STANDARDISATION OF GROWTH MEDIA AND ORGANIC NUTRIENT SCHEDULE FOR CONTAINER CULTIVATION OF SPINACH BEET (*Beta vulgaris* var. *bengalensis*)

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(2018-11-052)

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KERALA, INDIA

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by

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(2018-11-052)

THESIS

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DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

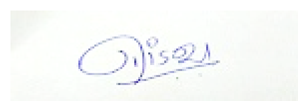
VELLAYANI, THIRUVANANTHAPURAM- 695522

KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"STANDARDISATION OF GROWTH MEDIA AND ORGANIC NUTRIENT SCHEDULE FOR CONTAINER CULTIVATION OF SPINACH BEET (*Beta vulgaris* var. *bengalensis*)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.



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CERTIFICATE

Certified that this thesis entitled **"STANDARDISATION OF GROWTH MEDIA AND ORGANIC NUTRIENT SCHEDULE FOR CONTAINER CULTIVATION OF SPINACH BEET** (***Beta vulgaris*** **var.** ***bengalensis*****)"** is a record of research work done independently by Ms. Aisha Majeed (2018-11-052) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Aisha Majeed

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BCR	Benefit cost ratio
CD	Critical Difference
Cm	Centimeter
cm^3	Cubic centimetre
CPE	Cumulative pan evaporation
DAS	Days after sowing
et al.	Co- workers
Fig.	Figure
FYM	Farm yard manure
G	Gram
Ha	Hectare
K	Potassium
K_2O	Potassium oxide
KAU	Kerala Agricultural University
Kg	Kilogram
kg ha^{-1}	Kilogram per hectare

LIST OF ABBREVIATIONS (CONTINUED)

L^{-1}	Per Litre
LAI	Leaf Area Index
MAI	Months after incubation
Max.	Maximum
Min.	Minimum
mL	Milli Litre
N	Nitrogen
No.	Number
NS	Not significant
OC	Organic carbon
P	Phosphorus
P_2O_5	Phosphorus pentoxide
SEm	Standard Error of mean
RH	Relative humidity
SE	Standard error

LIST OF ABBREVIATIONS (CONTINUED)

Sl.	Serial
t ha^{-1}	Tonnes per hectare
viz.	Namely

LIST OF SYMBOLS

₹	- rupees
@	- at the rate of
%	- per cent

Introduction

1. INTRODUCTION

As people move from villages to cities the conventional system of vegetable cultivation becomes very difficult because of declining farmland availability and labour shortage. Our state is depending too much on the neighbouring states for many of the vegetables which are flooded with several hazardous chemicals used right from planting to storage. This has created an awareness among urban population and led them to the habit of cultivating their own food within the home premises. Growing their own food within home means getting it fresh, unspoiled, perfectly ripened at fingertips, reduced transport and creating a bio-diversity into the garden. John *et al*. (2015) estimated that a model terrace garden of a three-cent house could produce an average of 250 kg pesticide free vegetables every year.

As gardening on house terraces or roof tops is gaining ample importance these days, leafy vegetables also got more prominence considering its nutritional value and ease of cultivation. Leafy vegetables occupy a very important place in the human diet. The recommended dietary allowance of leafy vegetable for an adult person is 125 g per day (Anon.,2013). Spinach beet commonly known as Indian Spinach or Palak (*Beta vulgaris* var. *bengalensis*) is a popular leafy vegetable of the world. It is cultivated throughout the plains of North India during winter season and is a new introduction to Kerala.

Spinach beet is particularly valued for its high ascorbic acid (40.9 mg), calcium (73 mg), iron (4.8 mg) and riboflavin (0.26 mg) content per 100 grams. It is regarded as the richest source of vitamin A amongst all the vegetables. The protein of spinach beet is rich in essential amino acids, especially lysine (Gairola *et al*., 2009).

Container gardening is a way to offer convenience and affordability of fresh and organic vegetables for family consumption. Growing vegetables in containers offers certain advantages too. With the right growing containers and growing media many fruits and vegetables can be produced irrespective of the space. However, majority of urban residents living in very small holdings or flats lack the basic requirement for farming *viz.*, quality growing media for filling the container or growbags. Spinach beet being a new crop to urban households under container gardening it is essential to formulate an ideal growth medium for its easy and successful cultivation.

Non-availability of sand and its high cost necessitate the introduction of alternate components for growth media preparation. Rockdust and compressed coirpith are suitable alternatives available in plenty and at a lower cost compared to sand. Rockdust may be co-utilised with compost in soil and horticultural growing media or alternatively may be a feedstock to a composting process (Szmidt *et al*.,1997). Coirpith improves soil conditions like drainage and stimulates growth of most of the crops when used as rooting media. Application of coirpith in soil helps in improving the structure and other physical and chemical properties of the soil (Bopaiah, 1991). High water holding capacity along with its air-filled porosity makes it an ideal growth medium. In this context, the possibility of utilising coirpith and rockdust which is available in plenty and cheap as a substitute for sand needs to be investigated for its suitability to spinach beet cultivation. 'Suchitha', is a patented eco-friendly product developed by Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani by thermochemical digestion of degradable waste. The suitability of using this product as a growth medium component is also envisaged in this study.

Spinach beet responds well to applied nutrients. At present, there is a lack of separate nutrient recommendation for spinach beet grown organically in containers. The NPK recommendation for spinach beet is 80: 40: 80 kg ha^{-1} (Alur, 2017). As people prefer organically grown vegetables over inorganic vegetables in home gardens it is necessary to standardize an organic nutrient schedule for container grown vegetables.

In this backdrop, the present investigation was undertaken with the following objectives.

- To identify an ideal growth medium for container grown spinach beet
- To standardise an organic nutrient schedule for container grown spinach beet.

Review of literature

2. REVIEW OF LITERATURE

Container gardening is generally for urban areas where having an actual garden is not possible. It is space efficient, mobile and can be arranged to fit wherever it is chosen to set up home garden. Growing plants in containers reduce risk of soil-borne diseases, lessen weed problems and mobile plants gives more control over moisture, sunlight and temperature. Leafy vegetables can be grown very easily both in kitchen gardens or in terraces. These can be maintained very well in areas which receive enough rainfall and sunlight.

The most preferred and consumed leafy vegetable in Kerala is Amaranthus. Among the leafy green vegetables, Spinach beet is considered as a powerhouse of nutrients and an invariable part of North Indians diets. Being short duration with nutritious rich leaves and easy cultivation practices, it is a suitable candidate for introduction and cultivation in the urban households of Kerala for food and nutritional security. The present study envisages to identify a suitable growth medium and organic nutrient schedule for container cultivation of spinach beet.

2.1 URBAN FARMING

Urban as well as peri urban agriculture can help in achieving nutritional security. Conventional agriculture needs to continue, but urban agriculture can supplement nutrients. Growing food plants in buildings and on terraces complement food security. Urban and peri-urban agriculture (UPA) provide about 10 per cent of the global food supply and have a significant potential to reduce poverty and increase food security in urban households (Graefe *et al*., 2008).

Urban agriculture is a global and growing pursuit that can contribute to economic development, job creation, food security and community building. It can, however, be limited by competition for space with other forms of urban development, a lack of formalized land use rights and health hazards related to food contamination (Whittinghill and Rowe, 2012). Planting on a rooftop is a way to insulate buildings, reduce stormwater flows, and potentially provide space for birds, bees and people to congregate (Whittinghill and Starry, 2016). Bisna (2018) reported an increase in the frequency of leafy vegetable consumption after starting farming on house terrace.

According to Padmanabhan and Swadija (2003), urban families can utilize their little space for cultivation by farming on house terrace which will provide fresh, hygienic vegetables that can be produced at low cost utilizing household bio waste and family labour. Sreedaya (2004) reported that for a model vegetable garden in terrace, 60-70 sacks have to be accommodated in an area of 1000 square feet. It was recommended to give 20 per cent each for leafy and tuberous vegetables and 60 per cent for fruit vegetables in order to attain the vegetable self-sufficiency from the terrace itself for a family having four members of which two are children below the age of 10 years.

2.2 CONTAINER CULTIVATION

Miles (2010) opined that growing vegetables in containers is a good approach to obtain healthy plants in case of poor soil conditions and space limits. According to Oki and Suzuki (2018), for the double cropping of cucumber in a greenhouse, alternating cultivation with soil and grow bags is more cost-effective than cultivation with only soil or grow bags. Therefore, to establish a cultivation method, coir grow bag cultivation was examined in the summer. As a result, stable growth and equal or high yield could be achieved, compared with those of soil cultivation, by placing a drainage pot that monitors drainage to optimize the supply of nutrient solution. No root-knot nematodes were found in grow bags placed on plastic mulch beds in a field markedly polluted with root-knot nematodes, with the larval density in the soil under the grow bags reduced to 1/17 during the cultivation.

Devaza and Holmer (2002) observed that there is a possibility to practice multi-storey cropping even in a very limited space through container cultivation as it can help the city green and reduce air pollution and container gardening can convert extra time into a leisurely productive one. Almost any vegetable that will grow in a typical backyard garden will also do well as a container-grown plant. Vegetables that are ideally suited for growing in containers include tomatoes, peppers, eggplant, green onions, beans, lettuce, squash, radishes and parsley. Pole beans and cucumbers also do well in this type of garden, but they do require considerably more space because of their vining growth habit (Joseph, 2008).

2.3 SPINACH BEET

Spinach beet (*Beta vulgaris* var *bengalensis*) commonly known as Indian spinach or Palak is a highly nutritious leafy vegetable in India preferred for its succulent leaves. It is a good source of vitamin C, vitamin A, iron and calcium (Aykroyd, 1956). Spinach beet belongs to Chenopodiaceae with its origin in Indo-China region (Purohit,1968). It is a widely grown leafy vegetable of short duration. In India it can be grown throughout the year but main crop was taken during winter mainly sown in October -November. The crop will become ready for harvest at 35 days after sowing (DAS) and subsequent cuttings can be taken in 15 days interval. As the plant matures from stage I (15 days) to stage II (30 days) the iron and magnesium content increased whereas the zinc and copper content decreased as the plant grew (Khader and Rama, 2003). It has some medicinal properties as the leaves are used for inflammation, paralysis, headache, earache and a remedy for diseases of spleen and liver. Spinach beet can also act as mild laxative besides these medicinal values. It neutralizes the acidity produced during digestion of fatty substances and helps to prevent constipation (Balasaheb,2005).

2.4 GROWTH MEDIUM FOR CONTAINER CULTIVATION OF SPINACH BEET

The functions of growth medium include the porous nature while providing physical support, and formulated to hold water in the small pores (micropores) between their particle. Most of the essential mineral nutrients that nursery plants need for rapid growth must be obtained through the roots from the growing medium and the gas exchange occurs in the large pores (macropores) or air spaces in the growing medium (Landis *et al*.,1990). Whitcomb (2003) emphasized that improper media mixing is one of the major causes of variation in container plant quality. The choice of the growing media can be made best by using detailed study of the physical and hydraulic characteristics of the growth media (Raviv, 2015).

Success of plants grown in pot culture can be summed up by the physical attributes of the growing media that influences its ability to provide sufficient water to the root systems without any oxygen shortage (Khayyat *et al*., 2007; Michel, 2010). The good physical environment means the physical makeup of the growing media *viz.* maximum water holding capacity (WHC), bulk density of the mixture, air-filled porosity (AFP), water retention characteristics at a particular matric potential and the mechanical support to the plant growth. (Kukal *et al*., 2012)

2.4.1 Farmyard manure (FYM) as a Component of Growth Medium in Container Cultivation

2.4.1.1. Effect of FYM on Soil Properties

Costa *et al*. (1991) reported that addition of FYM increased water holding capacity with reduced erosion thereby making more nutrients available to the soil. Gaur (1994) reported that the most common and readily available organic manure is FYM constituting urine, straw and dung. Water holding capacity, soil aeration, permeability and biological properties were improved on addition of organic matter (Banerjee ,1998). Soil bulk density values were found to lower from 1.55 to 1.38 g cc^{-1} with the application of FYM at 32 t ha^{-1} (Maheswarappa, 1999). Improvement in the soil structure due to FYM application leads to a better environment for root development (Prasad and Sinha,2000). An increase in total porosity from 42.6 to 44 per cent was observed when the rate of application of FYM was enhanced from 2.5 to 5 t ha^{-1}.

Udayasooriyan *et al.* (1988) observed a rise in soil organic carbon content from 0.91 to 1.58 per cent with continuous addition of manures especially FYM. Gupta *et al*. (1994) observed FYM as an excellent source of P and facilitated improved enzyme activities and microbial biomass. Farmyard manure release nutrients slowly and steadily and activates soil microbial biomass (Belay *et al*., 2001).

Organic carbon content of the soil was found to be enhanced with FYM application rather than poultry manure and neem cake as reported by Sreekala (2004). Farmyard manure has been used as a soil conditioner since ancient times and its benefit have not been fully harnessed as large quantities required in order to satisfy the nutritional needs of crops (Makinde *et al*., 2007).

Use of FYM significantly increased soil organic matter and available water holding capacity but decreased the soil bulk density, creating a good environment for growth and development of the crop (Tadesse *et al*., 2013).

2.4.1.1. Effect of FYM as Growth Media Component

Arunkumar (2000) reported that the best growth media and organic nutrient schedule for amaranth organically on terraces was of soil + sand + cow dung (1:1:1) + adhoc organic POP of KAU with respect to growth, yield, cooking quality and it is equally effective as the INM recommendation in the POP of KAU.

Yield, phosphorus, iron, manganese, zinc, copper uptake and ascorbic acid content increased with the application of both the inorganic N fertilizer and farmyard manure with a maximum at 90 kg N ha^{-1} with 20 t FYM ha^{-1} in spinach and increased shelf life of spinach leaves with application of 20 t FYM ha^{-1} (Kansal *et al*., 1981). The application of cattle dung mixed with saw dust to the soil resulted in better quality in spinach compared to application of chemical fertilizers (Yamazaki and Roppongi, 1998).

Farm yard manure and inorganic sources of nutrients @150:100:100 kg NPK ha^{-1} improved the growth and yield in spinach beet (Padmanabha *et al*., 2009). Uptake of N, P and K were highest in the treatment in which FYM at 10 t ha^{-1} + vermicompost at 2.5 t ha^{-1} + panchagavya 3 per cent as foliar spray was applied (Rajeswari and Shakila, 2010).

In a pot culture experiment with *Celosia argentia* the media that was fertilized with poultry manure and cow dung recorded higher moisture content compared to control and other treatments (Makinde *et al*., 2007).

The growing medium, soil + silt + FYM improved the total soluble solids (6.26 %) of the fruits with an additional improvement in total sugars (15.92 %) in strawberry fruits (Ayesha *et al*., 2011).

Row application of FYM reduced the quantity needed and the localised application of FYM enhanced P fertilizer use efficiency. Localizing organic materials increased profitability of cropping systems and maximizing P from FYM increased yields in low input systems (Otinga *et al*., 2013).

Cerna (1980) reported that NPK application in the absence of farmyard manure retarded the formation of vegetative organs and subsequently reproductive organs. Number of fruits per plant and total yield in brinjal was increased with increase in the quantity of farmyard manure applied upto 10 t ha^{-1} in brinjal (Asiegbu and Uzo,1984). Increase in plant height and number of branches per plant was observed in tomato with the application of FYM @10 t ha and 20 t ha over control (Sharma and Sharma, 2004).

An increased dry matter production was observed in bhindi when FYM was used as an organic amendment (Senthilkumar and Sekhar,1998). Yield attributing characters like length of the fruit, weight of the fruit and number of fruits per plant in snake gourd were highest in plots applied with FYM compared to vermicompost and poultry manure (Joseph,1998).

Dhanya (2011) reported higher starch content in tubers of sweet potato when 100 % of recommended dose of nutrients was substituted with FYM.

2.4.2 Coirpith as a Component of Growth Medium in Container Cultivation

India annually produces about 280,000 metric tons of coir fiber. By weight, coir fibers account for about one-third of the coconut pulp and the other two-thirds is the coirpith. The industries in turn leave elastic, cellular and cork like spongy non-fibrous tissue which is generally referred to as coirpith or coco-peat (Bhowmic and Debnath, 1985). In each nut, around 14-17g of coirpith is available (Kamaraj, 1994 and Reddy, 1996).

Coirpith was also known to increase the oxygen supply to the rooting medium (Nagarajan *et al*., 1985). Application of coirpith in soil helps in improving the structure and other physical and chemical properties of the soil (Bopaiah,1991). Coirpith improves the physical properties such as bulk density, pore space, infiltration rate and hydraulic conductivity of even the heaviest clay soils and allows free drainage when coirpith is incorporated as an ameliorant. Because of its sponge like structure coirpith helps to retain water and improve aeration in root zone (Savithri and Khan, 1994).

The size of coirpith particle range from 800 to 1112.5 μm (average 956.25 μm) and exhibited CEC above 140 meq / 100 g which were considered to be adequate (Miller and Jones, 1995). Coir-pith compost improved the growth of black gram by increasing the rate and activity of nodulation and increasing the availability of P and K (Jayakumar *et al*.,1997).

Coco peat finds use 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; Karon *et al*., 1999; Rao, 1999). Coco peat is the product from coir, can be substituted for soil in the potting mixture due to its low weight and high-water holding capacity. Bhatia *et al*., 2004 reported that growing medium containing soil + FYM + cocopeat (2:1:1) in combination with bio fertilizers and water-soluble fertilizers was found to be the best for the carnation flower production.

Coirpith can be used as an organic component of growth media attributing to its desirable properties like high water holding capacity, excellent drainage, absence of weeds, greater physical resiliency, renewability, slower decomposition, acceptable pH, CEC, EC and easier wettability than peat (Cresswell,1992). Coirpith can be used as an alternative to peat in growth medium attributing to its desirable physical and chemical properties (Bragg *et al*., 1993; Savithri and Khan, 1994). Alifar *et al.* (2010) reported that the best growth medium for recording higher fruit yield in cucumber was cocopeat alone and was superior than other treatments including perlite-cocopeat (50:50 v/v), perlite-cocopeat-peat moss (50-20-20 v/v and 50-30-20 v/v) and perlite-peatmoss. Kukal *et al*. (2012) reported that the air-filled porosity was highest (190.7 %) in soil+ FYM + coirpith media and lowest (25.3%) in sole soil media.

Magani *et al*. (2003) reported that lettuce grown with organic method using cocopeat presented an increase in growth rate, fresh weight, leaf number, leaf area, height and root shoot ratio compared to traditional one. Bhat *et al*. (2013) reported that substrate containing vermicompost, cocopeat, perlite and sphagnum moss produced significantly better growth, yield and quality in tomato, cucumber and capsicum than other substrate combinations and was better than other ready to use mixed and conventional soil based growing medium.

Negi (2016) reported that in alstroemeria cv. ‘Capri’ maximum number of rhizomes and rhizome portions with rhizome tip and tuberous roots along with maximum weight of rhizome cluster per plant was noticed in growing medium consisting of cocopeat + FYM (1:1; v/v).

Cuckoorani (2013) reported that the fruit yield, water use efficiency and BC ratio in bhindi were observed higher in the growth media combination with coirpith compost and FYM in the ratio 2:1 by weight.

2.4.3 Sand as a Component of Growth Medium in Container Cultivation

A reduction in aeration and drainage is observed when small sand particles are lodged in existing pore spaces. Sand is the inorganic component in a growth media which has very high bulk density, moderate porosity and low cation exchange capacity (Landis *et al.*,1990). Gordon (2004) reported that the most serious disadvantage of using sand as a component in growth media is its weight, since it causes problems with handling and increases the cost of shipping.

Sand is used to increase porosity, but small sand particles can lodge in existing pore spaces and reduce aeration and drainage. In general, sizes of 0.002 to 0.010 mm (0.05 to 0.25 mm) are too small and will block drainage holes and reduce aeration (Wilkerson, 2011).

2.4.4 Rockdust as a Component of Growth Medium in Container Cultivation

Rockdust is a generic term describing material from quarrying operations, typically of 90% particle size <200 mesh size. It may be co-utilised with compost in soil and horticultural growing media or alternatively may be a feedstock to a composting process (Szmidt *et al*.,1997). Experiment on co-utilization of rockdust and compost revealed that addition of rockdust to compost not only increased mineral content but also accelerated microbial activity, heat buildup and there by increased the rate of break down (Anon., 1998).

By the application of rockdust, the water holding capacity and cation exchange capacity of soil was improved (Fragstein and Vougtmann,1987). In lettuce, application of basalt and glacial dust increased plant growth (Barker *et al*., 1998). In tomatoes, the application of rockdust increased plant height and induced earliness in flowering (Yarrow,1998). Granite applied to highly weathered soil @ 300 t ha^{-1} increased soil cation exchange capacity from 9-14 c mol kg^{-1} after 9 months (Gillman, 1980).

Microorganisms increased the dissolution of ground rock fertilizers by release of organic ligands, H+ ions and organic acids into the soil (Richardson,2001). Szmidt (2004) reported that rockdust with other inert materials such as sand, could have effects on physical properties of plant growth media and the effects could occur on moisture holding capacity and air porosity. Soil treated with rockdust along with farmyard manure had shown better release of nutrients required for coleus (Rose, 2008).

One of the potential benefits of rockdust was possibility of multi elemental release of Potassium, Magnesium, Iron, Zinc, Manganese and Copper (Weerasuriya *et al*.,1993). Application of rock powder @ 1 t ha^{-1} along with FYM @ 12.5 t ha^{-1} resulted in the saving of 25 to 50 per cent of fertilizer in cassava (Shehana *et al*., 2006). Increasing the rate of application of rockdust resulted in an increase in the available nutrient contents of soil and reduced recommended dose of organic fertilizers to half for coleus when applied along with rockdust @ 10 t ha^{-1} (Rose,2008).

Anon (1997) reported that the application of rockdust could substitute 25 per cent of fertilizer in radish. In a pot experiment using rockdust in lettuce, cress and brassicas using perlite as medium, the initial growth rate, shoot length, root length and dry weight of rockdust applied lettuce was higher when compared to control. (Madeley, 1999).

Lowest bulk density of 1.10 Mg m^{-3}, highest water holding capacity of 57.33 per cent and maximum pore space of 54.67 per cent were observed when rockdust was supplied @ 1 t ha^{-1} along with lime in an incubation study (Shehana,2006). Egli *et al*. (2010) reported that rockdust helped in stablising soil organic matter and its paramagnetic behaviour aid plants in taking up water and nutrients. Lekshmi (2011) reported that 75 per cent of N as bio mineral compost (compost enriched with rockdust and *Trichoderma*) along with panchagavya application was superior to all other treatments in chilli in promoting soil health, yield and quality.

2.4.5 Suchitha as a Component of Growth Medium in Container Cultivation

The chemical composition of municipal solid waste (MSW) indicates high moisture content, low calorific value and high nutrient content making the dominant organic fraction of waste more suitable for recycling in the form of manure (Anon., 2001). Worldwide, MSW generation is estimated at 1.3 billion tonnes per year (Castaldi, 2014).

In Kerala, the estimate of MSW generation is 8338 tonnes per day (Varma, 2006). The Kerala Agricultural University has developed a new patented Rapid Conversion Technology (RCT) for quick thermo chemical conversion of degradable wastes to value added organic manure, popularized as ‘Suchitha’. This novel technology has the advantage of both waste disposal at source and production of value-added organic manure and it is fast, efficient, hygienic and completed within one day, utilizing the waste for production of value-added organic fertilizer. In this process, degradable waste, which is collected is segregated at source, and size is reduced by wet grinding and making it a uniform paste of uniform size. Fresh waste was ground to uniform consistency in the grinder unit of the KAU Suchitha waste processing machine and was added with chemical reagents like HCl (0.25 N, 50 ml kg^{-1} waste) for 30 min. followed by KOH (0.5 N,100 ml kg^{-1} waste) for 30 min and was boiled at 100 ^{0}C in the reactor unit. Within one hour the processing was completed and thermochemical organic fertilizer was produced. It was added with coirpith @ 40 g kg^{-1} waste and charcoal powder @ 30 g kg^{-1} waste and the moisture content was reduced by sun drying. The dried mass was then pulverized and fortified with calculated doses of essential plant nutrients and packed in convenient sized packing. (Sudharmaidevi *et al*.,2017).

Sudharmaidevi *et al*. (2017) reported thermochemical treatment of degradable solid wastes to rapidly producing organic fertilizer as an alternative to conventional composting practices. The method is scientific, efficient and capable of providing a rapid and sustainable solution for hygienic waste disposal and an organic fertilizer.

Substitution of FYM with rapid organic fertilizer imparted a better buffering action to soil, ensured a steady supply of major nutrients during the active growth stages of the crop and resulted in higher dry matter production in banana. (Leno *et al.*, 2017). Jacob (2018) reported that the plants treated with thermochemical organic fertilizer fortified with nutrients recorded the highest shoot mass, root mass and dry matter yield compared to aerobic compost, microbial compost and vermicompost.

Agele *et al.* (2015) reported that use of agricultural wastes either alone or in combination with N, P, K fertilizers is reported to enhance the growth and yield characters of maize. Jayakrishna *et al*. (2016) reported that plant height, number of primary branches, shoot weight and fruit yield were higher for the growth medium comprising of thermochemical digest of degradable waste with coirpith compost and soil.

Thermochemical organic fertilizer (Suchitha) mixed with cocopeat and soil in 1:1:1 proportion recorded the highest fruit yield, number of fruits and individual fruit weight in okra and in cow pea. The treatment combination of thermochemical organic fertilizer (Suchitha) mixed with cocopeat and soil in 1:1:1 proportion recorded the highest pod yield and which was 1.25 times more than that of common practice with soil, sand and FYM in 1:1:1 proportion (Jacob *et al.*, 2019). It was also reported that the same growth media combination gave better results for chilli, amaranthus and tomato.

FMRCT (fortified manure produced by Rapid Conversion Technology) @ 3.3 t ha^{-1} is found to be an ideal value added organic manure for oriental pickling melon and estimation of heavy metals in FMRCT revealed that the concentration of Zn, Cu, Pb, Cr, Ni were well below the toxic level and As and Cd below detectable limits, rendering the organic manure environmentally safe (Leno *et al*., 2017).

Leno *et al*. (2017) reported that FMRCT applied plants recorded a yield increase of 63 per cent over poultry manure applied plots and 125 per cent over FYM applied plots on a per plant basis in oriental pickling melon. As the micronutrient dynamics in the soil-plant system is concerned, the rapid organic fertilizer produced from degradable waste through thermochemical processing had proved to be a substitute for FYM (Leno and Sudharmaidevi, 2018).

Ramesha (2019) reported that the thermochemical organic fertilizer is an effective and efficient substitute for conventional organic manures and its fortification with nutrients helped in realising higher productivity and profitability in amaranthus. He also reported that the thermochemical organic fertilizer enhanced soil organic carbon and possessed comparable fertility value as conventional organic manures. He reported it as an environmentally safe option since heavy metal content is below detectable level and the fortification of thermochemical organic fertilizer facilitated efficient root phenomic characters coupled with proliferation of rhizospheric microorganisms, which favoured enhanced mineralisation of soil available nutrients and root nutrient acquisition.

2.5 NUTRIENT LEVELS

2.5.1 Effect of Nutrient Levels on Growth and Yield

Salaj and Jasa (1965) reported that N had significant effects on yield of spinach and the combination of 90 kg N, 27 kg P and 60 kg K ha^{-1} recorded highest yield. Tripathy *et al.* (1993) reported that NPK each at 30 kg ha^{-1} gave higher yield in spine gourd. Dixit (1997) reported that yield increased with increasing N rate and increasing FYM in cabbage.

Baburao (2006) reported higher leaf yield, leaf area and number of leaves in palak when 50% RDF and 50% N through poultry manure was applied. Kumar (2013) reported higher fresh weight and dry weight of spinach beet in 100 per cent RDF through inorganic fertilizers and 75 per cent RDF through inorganic fertilizers + 25 per cent RD of N through poultry manure along with bio fertilizers.

Cuckoorani (2013) observed a higher root length, root spread and root volume in the higher nutrient levels in container grown bhindi. She also observed that different levels of NPK had no influence on number of branches per plant. However, the application of 125 per cent of POP through organic sources when applied directly to the growth medium resulted in highest no. of flowers and fruits in okra.

Successive doses of fertilizer levels increased considerably the number of clusters per plant, number of fruits per cluster, size of fruits, weight of fruits and yield per plant in tomato (Sepat *et al*., 2012). Soumya (2015) reported that nutrient levels failed to influence number of branches in the soilless cultivation of tomato. Different levels of NPK influenced the growth and yield of tomato, where increased levels of NPK resulted in higher growth performance than recommended NPK level. But it did not reflect in yield of tomato (Jayasinghe *et al*., 2016).

In the soil less cultivation of tomato in containers, among the different nutrient levels tried, 125 per cent of POP (94:50:31 kg NPK ha^{-1}) recorded early flowering, early fruit set, maximum number of inflorescences per plant, fruits per plant, fruit length, fruit girth and yield per plant (Soumya,2015).

2.5.2 Effect of Nutrient Levels on Quality and Nutrient Uptake

Rathore and Manohar (1989) reported that N and phosphorus uptake increased significantly with 20 kg N and 75 kg P ha^{-1} recording highest values in fenugreek.

Cuckoorani (2013) reported higher nutrient uptake in bhindi with the highest nutrient level which was 125 per cent of POP as organic. Kumar (2013) reported that highest N uptake was recorded with 100 per cent recommended dose of fertilizers along with bio fertilizers. Soumya (2015) reported increased nutrient uptake in soilless cultivation of tomato with the highest nutrient level.

Kansal *et al*. (1989) studied the response of spinach to different levels of N (0, 30, 60 and 90 kg ha^{-1}) and FYM (0, 10 and 20 t ha^{-1}) in sandy loam soil and found that the yield, nutrient uptake and ascorbic acid content increased with the combined application of inorganic N fertilizer and farmyard manure with the maximum being at 90 kg N ha^{-1} + 20 t FYM ha^{-1}.

Increased nitrate contents with increased chemical fertilizer use were demonstrated in lettuce (Liu *et al.*, 2014). On the contrary, the vitamin C content found to be maximum (7.63 mg 100 g^{-1}) in the organically grown lettuce plants with FYM as source of N compared to conventionally grown chemical fertilised plants (Caliskan *et al.*, 2014).

Baburao (2006) reported that higher iron and fibre content in palak were observed when 50 per cent RDF and 50 per cent N were applied through poultry manure. Higher vitamin C content in palak was reported with higher rates of N application (Bhore *et al.*, 2000; Singh *et al.*,2015).

2.5.3 Effect of Nutrient Levels on Soil Properties

Arunkumar (2000) reported higher NPK content of medium after the experiment in the INM as per KAU POP in organically grown amaranthus. Cuckoorani (2013) reported higher NPK content of the medium after the experiment with the highest nutrient level in bhindi. Soumya (2015) reported that the highest N content after the experiment was observed when 100 per cent recommended dose applied organically whereas the better K status was observed in 125 per cent of recommended dose applied organically in soilless cultivation of tomato.

2.6 NUTRIENT SOURCES

2.6.1 Oil cakes as Nutrient Source in Container Gardening

After oil is extracted from oilseeds, the remaining solid portion is dried as cake and can be used as a manure. Joshi *et al*. (2016) reported that oil cakes can enhance soil structure, aeration and water holding capacity of soil.

Application of groundnut cake and FYM resulted in an enhanced growth in tomato plants (Chinnaswamy,1967). Groundnut cake when applied in a rice fallow rotation for ten years enhanced the water holding capacity of soil (Biswas *et al.*, 1969).

Mashkoor *et al*. (1980) reported that application of oilcake increased growth in chilli, tomato and eggplant seedlings.

Among the organic N sources, application of FYM + neem cake registered maximum population of bacteria (38.6 CFU g), fungi (15.2 CFU g) and actinomycetes (12.2 CFU g). Higher urease and dehydrogenase activities were observed with the application of FYM + neem cake (Krishnakumar *et al*., 2005).

Neem seed cake performs the dual function of both fertilizer and pesticide, acts as a soil enricher, reduces the growth of soil pest and bacteria, provides macro nutrients essential for plant growth, helps to increase the yield of plants in the long run, bio degradable, ecofriendly and excellent soil conditioner (Lokanadhan *et al*.,2012).

Soumya (2015) reported that incubated groundnut cake + PGPR Mix 1 was the best nutrient source in soilless cultivation of tomato in containers 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 g L^{-1}), net income (4.79 ₹ per bag) and BCR (1.69).

2.6.2 Poultry Manure as a Nutrient Source in Container Gardening

Yadav *et al*. (1989) reported that poultry manure contains 60 per cent of N as uric acid, 30 per cent as more stable organic form and 10 percent as mineral N and it contains growth promoting hormones that produced better root than chemical fertilizers. Poultry manure application registered over 53 per cent increase in N level in the soil from 0.09 to 0.14 per cent and increase in exchangeable cations with manure application (Boateng *et al.*, 2006). In agriculture, the main reasons for applying poultry manure is as organic amendment of the soil and for supply of nutrients to crops (Warren *et al*., 2006). It was also indicated that poultry manure more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008).

Adeleye *et al*. (2010) reported that poultry manure application improved soil physical properties; reduced soil bulk density, increased total porosity and soil moisture retention capacity. Its improved soil organic matter, total N, available P, exchangeable Mg, Ca, K and lowered exchange acidity.

A higher yield in lettuce was observed when poultry manure was applied (Anez and Tavira,1984) as nutrient source. It was reported that very little nitrate content was observed in two spinach varieties treated with poultry manure in controlled pot trials. Potassium nitrate application resulted in the highest N uptake levels and poultry manure application gave the lowest in spinach beet (Goh and Vityakon,1986). Gardini *et al.* (1992) reported a higher yield in spinach beet by the use of poultry manure compared to mineral fertilizers.

The application of 50 per cent RDF and 50 per cent N through poultry manure enhanced vegetative growth as well as yield and quality parameters in palak (Baburao,2006). However, Zhao *et al*. (2006) and Rambialkowska (2007) reported that leafy vegetables were rich in vitamin C when produced organically.

Aparna (2011) reported that amaranthus cultivated using poultry manure recorded higher plant height and maximum yield. She also reported that protein, starch, and iron content in amaranthus leaves were higher in the poultry manure treated plots.

Jyothi (2006) stated that poultry manure recorded highest green leaf yield in amaranthus and spinach beet compared to other organic nutrient sources like vermicompost and FYM. She also reported that poultry manure increased micronutrient content in the amaranthus and spinach beet. Asha (2012) reported that residual poultry manure accumulated higher P, K, S and Zn in amaranthus.

Application of a mixture of urea and poultry manure in amaranthus produced highest fresh leaf mass and highest fresh stem mass (Shiyam and Binang,2010). Single application of poultry manures to soil during the production cycle of *Amaranthus* *cruentus*, enhanced growth performance and leaf productivity (Adewole and Dedeke,2012).

A study conducted in brinjal with application of 100 kg N through different sources *viz*, urea, FYM, poultry manure,pig manure and sheep manure. The application of half N as poultry manure and remaining half through urea recorded maximum plant height, dry matter and NPK uptake (Jose *et al.*,1988). Growth characters in brinjal *viz*., plant height, number of leaves, branches and LAI were significantly increased by poultry manure application and poultry manure treated plots showed maximum number of flowers and fruits leading to maximum fruit set percentage (Rekha ,1999). Application of poultry manure increased the number of leaves in amaranthus (Ibeawuchi *et al*., 2006)

Integration of 50 per cent N through inorganic fertilizers and 50 per cent N through poultry manure were found to be the best in cauliflower with respect to number of leaves, plant spread, earliness in curd initiation and maturity, net weight of curd, yield and dry matter of the curd. Increase in shelf life was reported in 100 per cent N supplied through poultry manure alone (George,2004).

The literature apprised on various growth media components and nutrient sources for container cultivation of spinach beet revealed the significance of each in determining the growth, yield and quality of spinach beet. The present study aimed to investigate the effects of both for identifying the most suitable growth media combination and organic nutrient schedule.

Materials and methods

3. MATERIALS AND METHODS

The present study entitled "Standardization of growth media and organic nutrient schedule for container cultivation of spinach beet (*Beta vulgaris* var. *bengalensis*)" was undertaken to standardize a suitable growth medium for spinach beet cultivation in containers and also to standardize an organic nutrient schedule. The materials used and the methods adopted for the study are presented in this chapter.

3.1 EXPERIMENT DETAILS

3.1.1 Location

The field experiment was conducted at Instructional farm, College of Agriculture, Vellayani. The station is located at 8° 25' 45.977" N latitude and 76° 59' 22.123" E longitude.

3.1.2 Climate and Season

The field experiment was conducted during *rabi* 2019 extending from October 2019 to February 2020. The data on weekly mean maximum and minimum temperatures, maximum and minimum relative humidity and total rainfall during the study period obtained from the Department of Agricultural Meteorology, College of Agriculture, Vellayani during the cropping season is documented in Appendix 1 and presented in Fig. 1.

3.1.3 Cropping History of the Experimental Site

The experimental area was previously under banana cultivation.

3.2.MATERIALS

3.2.1 Crop and Variety

Spinach beet variety 'All Green' was used for the study. The variety was released from Indian Agricultural Research Institute, New Delhi. 'All Green' is an early variety

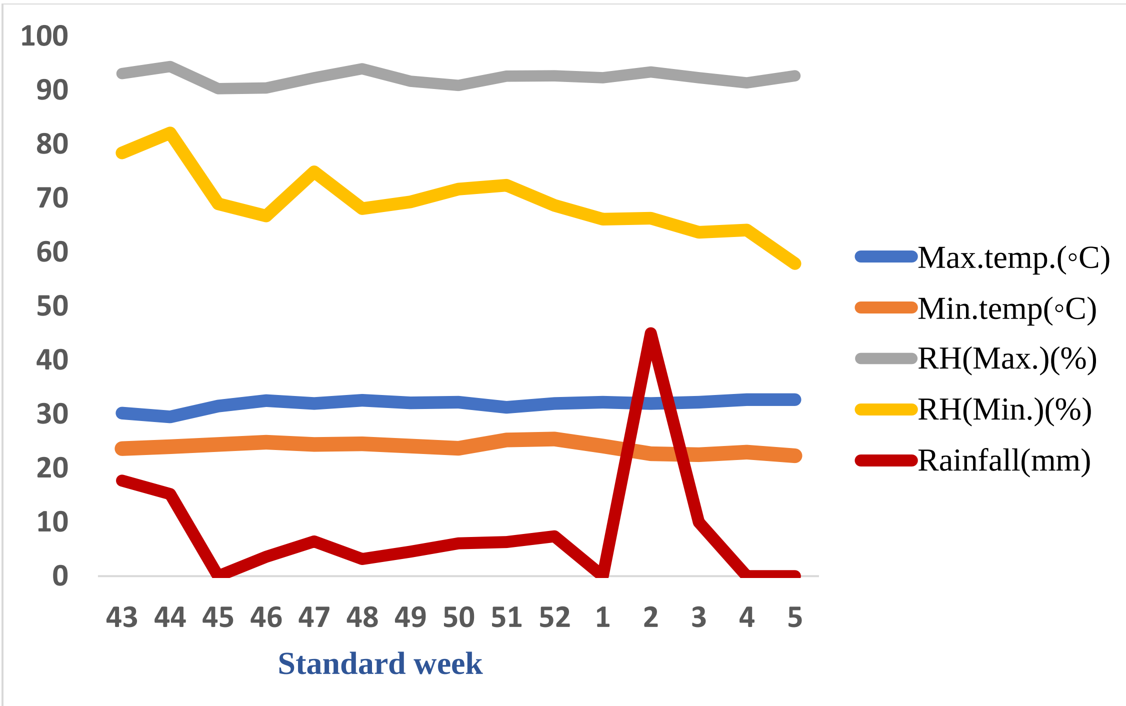

Fig 1. Weather data during the cropping period October 2019– February 2020

suitable for growing in *rabi* season. Leaves are lush green, uniform, tender with entire leaf margins and grows to a height of 15-20 cm. The seeds were collected from National Seeds Corporation, Palakkad

3.2.2 Containers

UV stabilized woven plastic sacks of thickness 1400 denier capable of holding 15 kg potting mixture were used as the containers.

3.2.3 Growth media

Five different growth media tested were combinations of soil, sand, coirpith, farm yard manure (FYM), rock dust and Suchitha in various proportions. Farm yard manure was purchased from a local farmer near Vellayani. Sand and rock dust were procured from local suppliers and coir pith blocks available in market as ‘neopeat’ were used as source of coir pith. Suchitha is an organic fertilizer produced by rapid thermochemical processing of organic waste (Sudharmaidevi *et al*., 2017) at College of Agriculture, Vellayani. The initial chemical characteristics of the growth media are presented in Table 1.

3.2.4 Manures

The organic manures used in the experiment were poultry manure (1.6% N, 0.983% P_2O_5 and 1.84% K_2O) and fermented groundnut cake (2 %N).

3.3 METHODS

3.3.1 Experiment 1

Standardization of growth media and organic nutrient schedule for container cultivation of spinach beet (*Beta vulgaris* var. *bengalensis*)

Table 1. Initial chemical characteristics of different growth media

Particulars	soil: sand: FYM in 1:1:1 (M_1)	soil: rockdust: FYM in 1:1:1(M_2)	soil: compressed coirpith: FYM in 1:1:1(M_3)	soil: rockdust: compressed coirpith: FYM in 1:0.5:0.5:1 (M_4)	soil: suchitha : FYM in 1:1:1(M_5)	**Method used**
Organic C (%)	1.66	1.2	1.32	1.98	2.3	Walkley and Black rapid titration method (Jackson, 1973)
Available N (%)	0.011	0.013	0.017	0.015	0.017	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P (%)	0.042	0.031	0.047	0.043	0.049	Bray's colorimetric method (Jackson, 1973)
Available K (%)	0.012	0.011	0.024	0.016	0.022	Ammonium acetate method (Jackson, 1973)
Soil reaction (pH)	6.75	7.00	6.79	6.94	6.53	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (EC)	0.60	1.01	1.52	1.36	1.02	Digital conductivity meter

3.3.1.1 Technical Programme

Design : CRD

Treatment combinations : 15(5 x 3)

Replications : 3

Variety : All Green

3.3.1.2 Details of Treatments

The treatments consisted of factorial combinations of 5 different of growth media and 3 nutrient levels

A. Growth media (M) - 5

M_1- soil: sand: FYM (1:1:1)

M_2 - soil: rockdust: FYM (1:1:1)

M_3 - soil: compressed coirpith: FYM (1:1:1)

M_4- soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)

M_5 - soil: suchitha : FYM (1:1:1)

B. Nutrient Levels (N) - 3

N_1 - 100% of 80:40:80 kg NPK ha^{-1}

N_2 - N_1 + 50% N topdressed in 3 splits

N_3 - N_1+ 100% N topdressed in 3 splits

Treatment combinations: 15

T_1 - m_1n_1	T_6 - m_2n_3	T_{11} – m_4n_2
T_2 - m_1n_2	T_7 – m_3n_1	T_{12} – m_4n_3
T_3 - m_1n_3	T_8 – m_3n_2	T_{13}- m_5n_1

T_{4} - m_2n_1 T_9 - m_3n_3 T_{14}-m_5n_2

T_5 - m_2n_2 T_{10} – m_4n_1 T_{15}-m_5n_3

The recommended dose of NPK@ 80:40:80 kg ha^{-1} was given as basal on N equivalent basis through poultry manure as nutrient source. In N_2 and N_3, N was topdressed as fermented groundnut cake at 50, 70 and 90 DAS.

Plants were irrigated uniformly on alternate days.

3.3.1.3 Details of Cultivation

3.3.1.3.1 Field Preparation

The experimental area was cleaned and weeds and stubbles were removed. The field was levelled and black polythene mulching sheet was spread on the site. UV stabilized woven plastic sacks of thickness 1400 denier capable of holding 15 kg potting mixture was used as the container which was filled with potting media prepared as per the treatments. In each growbag, 10 kg potting medium was taken. The growbags were placed at a distance of 20 cm between the rows and 20 cm between the plants. The layout plan of experiment 1 is given in Fig 2.

3.3.1.3.2 Application of Manures

The nutrient requirement for each plant was calculated on the basis of plant population. Accordingly, dried and powdered poultry manure was applied as basal dose to meet the NPK requirement and incorporated well into the media. For topdressing, groundnut cake was fermented in water for 3 days and was applied at 50 ,70 and 90 DAS as per the treatment schedule (4 g per plant for treatment N_2 and 8 g per plant for treatment N_3).

3.3.1.3.3 Planting

Protrays were filled with vermicompost and compressed coirpith in the ratio 1:1. The seeds were sown after soaking in water overnight so as to facilitate faster

m_1n_2	m_1n_2	m_4n_1	m_3n_1	m_4n_3	m_5n_1	m_3n_2	m_3n_3	m_4n_1
m_3n_1	m_1n_1	m_3n_2	m_2n_2	m_3n_3	m_1n_1	m_1n_1	m_4n_3	m_2n_2
m_4n_3	m_1n_2	m_4n_1	m_3n_1	m_4n_3	m_5n_1	m_1n_3	m_3n_2	m_4n_2
m_5n_1	m_1n_1	m_3n_2	m_2n_2	m_3n_3	m_1n_1	m_5n_2	m_3n_3	m_4n_1
m_1n_3	m_4n_2	m_4n_2	m_1n_2	m_1n_3	m_3n_1	m_4n_1	m_3n_1	m_4n_1
m_2n_1	m_3n_2	m_5n_3	m_2n_3	m_3n_2	m_4n_3	m_4n_2	m_2n_2	m_3n_2
m_3n_3	m_4n_3	m_4n_3	m_5n_1	m_5n_1	m_4n_1	m_5n_1	m_3n_1	m_3n_1
m_2n_2	m_5n_3	m_1n_3	m_4n_3	m_4n_2	m_2n_2	m_4n_3	m_4n_1	m_2n_2
m_3n_2	m_2n_3	m_1n_1	m_5n_2	m_4n_1	m_2n_1	m_3n_3	m_5n_1	m_1n_1
m_2n_3	m_3n_1	m_2n_2	m_4n_2	m_1n_1	m_4n_1	m_2n_2	m_4n_1	m_2n_1
m_4n_2	m_5n_2	m_3n_1	m_5n_3	m_2n_3	m_5n_2	m_2n_2	m_5n_3	m_3n_3
m_5n_2	m_3n_3	m_3n_3	m_3n_3	m_1n_2	m_1n_3	m_2n_3	m_5n_2	m_2n_1
m_4n_1	m_5n_1	m_5n_2	m_3n_2	m_2n_2	m_3n_2	m_4n_1	m_2n_1	m_5n_2
m_5n_3	m_4n_1	m_2n_2	m_1n_3	m_5n_2	m_2n_2	m_5n_1	m_4n_2	m_2n_3
m_1n_1	m_2n_1	m_3n_1	m_4n_1	m_5n_1	m_5n_2	m_3n_1	m_3n_1	m_4n_3

Fig 2. Layout of Experiment 1

Plate 1. General view of the experiment I

germination. The seedlings were transplanted into containers at 28 DAS and each growbag was planted with 2 seedlings.

3.3.1.3.4 After Cultivation

Weeds were removed from the growbags by hand weeding as and when they appeared and plants were irrigated uniformly on alternate days.

3.3.1.3.5 Plant protection

As a prophylactic measure, the growth media was drenched with *Pseudomonas fluorescens* @ 20 g L^{-1} at fortnightly interval. Mealy bug was an important pest observed in the field. It was managed by spraying azadiractin @ 2mL L^{-1} at fortnightly interval. Wilt incidence was noticed during early stages of crop.

3.3.1.3.6 Harvest

Leaves were harvested when they were fully formed and bright green in colour. First harvest was done at 60 DAS and thereafter, at 15 days interval. Mature leaves were picked up from the base leaving the smaller ones to develop and to be picked up later.

3.3.2 Experiment II

Studies on nutrient availability in different growth media (Incubation study)

A concurrent lab incubation study of the growth media was conducted in pots kept under room temperature in the laboratory. The growth media prepared as per treatments was uniformly supplied with the recommended dose of NPK (80:40:80 kg ha^{-1}) as poultry manure and fermented groundnut cake as in Experiment 1. Care was taken to keep the media under optimum moist condition by sprinkling water uniformly on alternate days. The growth media were analyzed at monthly intervals for pH, EC, available N, P and K estimation adopting standard procedures as given in Table 1.

3.3.2.1. Technical Programme

Design : CRD

Treatments : 15

Replication : 3

3.4 OBSERVATIONS

One representative plant each from three grow bags were selected and labeled to record the various observations. Average values of the observations noted from these three plants from each replication were used for statistical analysis.

3.4.1 Growth and Yield Attributes

3.4.1.1 Plant Height

Plant height was measured from the observation plants from the base to the top most growing tip at specified intervals and the mean height expressed in cm.

3.4.1.2 Leaf Area Index (LAI)

Leaf area was measured using graph paper and the land area was measured as the area occupied by the plant in the container using the formula $A = \pi r^2$. LAI was worked out using the formula developed by Watson (1947).

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

3.4.1.3 Number of Economic Harvests

The treatments which yielded more than 15 g fresh leaves in single harvest was taken as the base for calculating the number of economic harvests.

3.4.1.4 Number of Leaves Harvested Per Plant

The number of leaves harvested per plant was counted at each harvest and added together to get the total number of leaves harvested per plant and average was worked out.

3.4.1.5 Leaf Yield Per Plant

Leaf yield from each observation plant were measured at each harvest, summed up to get the total leaf yield per plant and expressed in g per plant.

3.4.1.6 Leaf yield per Harvest

Leaf yield from each observation plant was measured at each harvest and mean value expressed in g.

3.4.1.7 Dry Matter Production (DMP)

Observation plants were uprooted, dried under shade and then dried in oven at 70 ± 5^0C until a constant weight is attained and total DMP was worked out and expressed in g per plant.

3.4.2 Root Studies at Final Harvest

3.4.2.1 Root Weight

After the final harvest, the observation plants were uprooted, fresh weight of the roots were recorded and expressed in g per plant.

3.4.2.2 Root Volume

Root volume was measured by the volume displacement method as equivalent to the volume of water displaced in mL while immersing the roots in a measuring cylinder containing known volume of water (Novoselov, 1960).

3.4.2.3 Root Shoot Ratio

After the final harvest, the plants were uprooted, dry weight of roots and shoots recorded separately and expressed in ratio.

3.4.3 Plant Analysis for Quality Parameters

3.4.3.1 Vitamin A

Freshly harvested leaves at third harvests were used for the estimation of vitamin A content as total beta carotene using colorimetric method of carotene estimation given by Sadasivam and Manickam (1996). The values were expressed in mg $100g^{-1}$.

3.4.3.2 Protein

Dried leaf samples at final harvests were digested using concentrated H_2SO_4 followed by distillation adopting the micro kjeldahl method for analyzing N content (Jackson, 1973). The protein content of leaves was calculated by multiplying N content of plant samples in per cent with the factor 6.25 (Simpson *et al.,* 1965).

3.4.3.3 Vitamin C

Freshly harvested leaves at third harvests were used for the estimation of vitamin C content using the 2, 6 – dichlorophenol indophenol dye method (Anon., 1955). Expressed in mg per 100 g of fresh green leaves.

3.4.3.4 Iron

The iron content in leaves at third harvests was measured after diacid digestion using Atomic Absorption Spectrometer and expressed in mg per 100 g.

3.4.3.5 N P K Uptake by Crop

Fresh plant samples collected from each plot were air dried followed by oven drying at 70 ± 5^0C until a constant weight was attained. After drying the plant tissue was ground and digested for nutrient analysis. Nitrogen content was estimated by the modified micro kjeldahl method (Jackson, 1973), P content was read colorimetrically using vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and K by flame photometry method (Jackson, 1973). Nutrient contents were expressed as percentage. Nutrient uptake by the crop was calculated using the formula

Nutrient uptake = nutrient content x total dry matter production in g per plant and expressed in g $plant^{-1}$.

3.3.4 Growth Media Analysis

Growth media samples were collected after the experiment from individual grow bags of the experimental field. The samples were shade dried, cleaned and sieved using a 2 mm sieve for pH, EC, available N and K estimation and 0.5 mm sieve for organic carbon estimation. The analysis was done adopting the standard procedures ~~as~~ given in Table 1.

3.3.5 Economics of Cultivation

The economics of cultivation of spinach beet on growbags was worked out by computing the cost of cultivation for each treatment based on cost of inputs alone and price of organic produce. The labour component was accounted as family labour.

3.3.5 .1 Gross Income

Gross income was calculated by multiplying the leaf yield with unit price of organic spinach beet**.**

Gross income (₹) = Total yield (kg) x unit price (₹ kg^{-1})

3.3.5.2 Net Income

Net income was calculated by subtracting the total cost incurred for the cultivation from the gross income expressed in ₹ per bag).

Net income = Gross income - cost of cultivation

***3.3.5.3* Benefit: Cost Ratio (BCR)**

$$BCR = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.3.6 Growth Media Analysis of experiment I

Growth media samples were collected from individual pots on incubation. The samples were shade dried, cleaned and sieved using a 2 mm sieve for pH, EC, available N, P and K estimation and 0.5 mm sieve for organic carbon estimation. The analysis was done adopting the standard procedures ~~as~~ given in Table 1.

3.3.7 Statistical analysis

The experimental data generated were analyzed statistically by applying the technique of analysis of variance (ANOVA) for factorial CRD experiment (Panse and Sukhatme, 1985) and the significance was tested by F test (Cochran and Cox, 1965). Wherever F test was significant, the critical difference (CD) values were computed for comparison.

Results

4. RESULTS

A field experiment entitled 'Standardization of growth media and organic nutrient schedule for container cultivation of spinach beet (*Beta vulgaris* var. *bengalensis*)' was conducted at College of Agriculture Vellayani, Thiruvananthapuram during rabi 2019. The study aimed at assessing the suitability of different growth medium for container cultivation of spinach beet and also to standardize an organic nutrient schedule. The experimental data was analyzed statistically and the results are presented below.

4.1 GROWTH MEDIA EVALUATION AND ORGANIC NUTRIENT SCHEDULE FOR CONTAINER GROWN SPINACH BEET

4.1.1 Growth and Yield Attributes

4.1.1.1 Plant Height (30 DAS and at each harvest)

The data on height of spinach beet at 30 DAS and at each harvest as influenced by treatments are presented in Table 2a and 2b.

The different growth media and nutrient levels have significant influence on the height of spinach beet plants at various growth stages. Growth media showed significant influence on plant height at all stages except at 90 DAS. At 30 DAS, M_4 (soil: rockdust: compressed coirpith: FYM in 1:0.5:0.5:1) was significantly superior to all other growth media combinations recording a plant height of 29.96 cm. This was followed by M_2 which was on par with M_3. Growth media with suchitha as one of the growth media components (M_5) recorded shorter plants (21.52 cm) during initial stages.

At 60 DAS, M_4 (soil: rockdust: compressed coirpith: FYM in 1:0.5:0.5:1) produced taller plants (32.66 cm) which was on par with M_3 (31.99 cm) and M_5 (31.33 cm). In conventional growth media (M_1) shorter plants were observed (26.55cm).

Table 2a. Effect of growth media and nutrient levels on height of spinach beet at different growth stages, cm

Treatments	Plant height					
	30 DAS	60 DAS (I harvest)	75 DAS (II harvest)	90 DAS (III harvest)	105 DAS (IV harvest)	120 DAS (V harvest)
Growth media (M)						
M_1 (soil: sand: FYM in 1:1:1)	24.03	26.55	29.29	34.87	32.44	30.48
M_2 (soil: rockdust: FYM in 1:1:1)	27.63	30.67	33.24	33.27	35.99	33.29
M_3 (soil: compressed coirpith: FYM in 1:1:1)	26.07	31.99	30.83	35.11	34.74	32.99
M_4 (soil: rockdust: compressed coirpith: FYM in 1:0.5:0.5:1)	29.96	32.66	32.85	35.07	27.59	33.85
M_5 (soil: suchitha: FYM in 1:1:1)	21.52	31.33	32.94	33.59	38.26	33.89
SEm (±)	0.86	0.65	0.77	0.63	1.82	0.85
CD (0.05)	2.502	1.903	2.232	NS	5.276	2.46
Nutrient levels (N)						
N_1 (100% of 80:40:80 kg NPK ha^{-1})	25.77	30.76	31.76	34.34	30.82	32.29
N_2 (N1 + 50% N topdressed in 3splits)	24.46	30.22	30.24	33.59	34.93	32.56
N_3 (N1+ 100% N topdressed in 3splits)	27.29	31.06	33.48	34.85	35.66	33.87
SEm(±)	0.67	0.51	0.60	0.49	1.41	0.66

CD (0.05)	1.938	NS	1.729	NS	4.087	NS

NS- not significant

Table 2b. Interaction effect of growth media and nutrient levels on height of spinach beet at different growth stages, cm

Treatments	Plant height					
	30 DAS	60 DAS (I harvest)	75 DAS (II harvest)	90DAS (III harvest)	105 DAS (IV harvest)	120DAS (V harvest)
M x N						
m_1n_1	21.33	25.33	26.99	32.10	30	27.33
m_1n_2	24.77	26.77	27.10	34.11	33.77	31.88
m_1n_3	25.99	27.55	33.77	38.38	33.55	32.22
m_2n_1	26.99	30.38	33.44	34.16	37.77	35.10
m_2n_2	25.10	29.99	32.05	32.88	33.55	31
m_2n_3	30.77	32.22	34.22	32.77	36.66	33.77
m_3n_1	28.44	33.22	31.16	34.83	32.44	31.44
m_3n_2	25.55	31.55	31.16	36.49	35.77	33.22
m_3n_3	24.22	31.22	30.16	33.99	35.99	34.33
m_4n_1	29.88	32.44	31.16	31.99	32.88	32.33
m_4n_2	27.44	31.55	29.16	33.44	33.88	32.33
m_4n_3	32.55	33.99	38.22	39.77	35.22	36.87
m_5n_1	22.21	32.44	36.05	38.61	40.21	35.22
m_5n_2	19.44	31.22	31.72	32.83	37.66	34.33
m_5n_3	22.88	30.33	31.05	29.32	36.88	32.11
SEm(±)	1.49	1.14	1.33	1.09	3.15	1.47
CD (0.05)	NS	NS	3.866	3.179	9.139	4.267

At 75 DAS, the growth medium M_2 recorded taller plants (33.24 cm) which was on par with M_5 (32.94 cm) and M_4 (32.85 cm). A lower plant height of 29.29 cm was recorded in M_1 which was on par with M_3 (30.83 cm). No significant difference was observed among the growth media combinations at 90 DAS.

At 105 DAS, the growth medium M_5 with suchitha as growth media component recorded taller plants (38.26 cm) which was on par with M_2 (35.99 cm) and M_3 (34.74 cm). However, M_4 recorded lower plant height (27.59 cm) which was on par with M_1 (32.44 cm). At 120 DAS also, M_5 recorded taller plants (33.89 cm) and was on par with all growth media except M_1.

The various nutrient levels tested had significant influence on height of spinach beet plant at 30, 75 and 105 DAS. During these stages, N_3 recorded a higher plant height. At 30 and 75 DAS, N_3 was on par with N_1 while at 105 DAS, N_3 was on par with N_2.

The interaction effects were significant at 75, 90, 105 and 120 DAS. At 75 and 90 DAS, m_4n_3 recorded taller plants (38.22 cm and 39.77 cm). At 75 DAS, m_4n_3 was on par with m_5n_1 (36.05 cm) while at 90 DAS, m_4n_3 was on par with m_1n_3 (38.38) and m_5n_1 (38.61 cm). At 105 DAS, m_5n_1 recorded taller plants (40.21 cm) which was on par with all the interactions except m_1n_1. At 120 DAS, m_4n_3 recorded taller plants (36.87 cm) which was on par with m_2n_1(35.10 cm), m_2n_3(33.77 cm), m_3n_2 (33.22 cm), m_3n_3 (34.33 cm), m_5n_1(35.22 cm) and m_5n_2 (34.333 cm).

4.1.1.2 Leaf Area Index at Each Harvest

The variation in LAI of spinach beet at each harvest as influenced by growth media and nutrient levels are presented in Table 3a and 3b.

The study revealed that growth media combinations and nutrient levels exerted significant influence on LAI of the spinach beet plants at various growth stages. The influence of growth media on LAI was significant at all growth stages. LAI was

Table 3a. Effect of growth media and nutrient levels on Leaf Area Index (LAI) at each harvest

Treatments	LAI				
	60 DAS (I harvest)	75 DAS (II harvest)	90 DAS (III harvest)	105 DAS (IV harvest)	120DAS (V harvest)
Growth media(M)					
M_1(soil: sand: FYM (1:1:1)	0.70	0.80	0.74	0.71	0.7
M_2(soil: rockdust: FYM (1:1:1)	0.75	0.82	0.76	0.73	0.71
M_3(soil: compressed coirpith: FYM (1:1:1)	0.66	0.79	0.77	0.76	0.74
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	0.81	0.83	0.79	0.78	0.77
M_5 (soil: suchitha : FYM (1:1:1)	0.85	1.17	1.11	1.02	0.98
SEm (±)	0.008	0.006	0.007	0.007	0.009
CD(0.05)	0.024	0.018	0.02	0.021	0.025
Nutrient levels (N)					
N_1 (100% of 80:40:80 kg NPK ha^{-1})	0.77	0.92	0.88	0.83	0.81
N_2 (N1 + 50% N topdressed in 3splits)	0.78	0.87	0.81	0.79	0.77
N_3 (N1+ 100% N topdressed in 3splits)	0.71	0.85	0.81	0.78	0.76
SEm(±)	0.006	0.005	0.005	0.006	0.007
CD (0.05)	0.019	0.014	0.015	0.016	0.02

Table 3b. Interaction effect of growth media and nutrient levels on LAI at each harvest

LAI					
Treatments	60 DAS (I harvest)	75 DAS (II harvest)	90 DAS (III harvest)	105DAS (IV harvest)	120DAS (V harvest)
M x N					
m_1n_1	0.68	0.78	0.73	0.71	0.69
m_1n_2	0.79	0.85	0.79	0.77	0.76
m_1n_3	0.64	0.76	0.70	0.65	0.64
m_2n_1	0.82	0.87	0.82	0.77	0.75
m_2n_2	0.74	0.80	0.71	0.68	0.65
m_2n_3	0.68	0.8	0.75	0.73	0.72
m_3n_1	0.64	0.78	0.77	0.76	0.75
m_3n_2	0.68	0.84	0.80	0.79	0.79
m_3n_3	0.65	0.76	0.76	0.74	0.69
m_4n_1	0.81	0.82	0.77	0.76	0.75
m_4n_2	0.83	0.87	0.83	0.83	0.8
m_4n_3	0.8	0.79	0.78	0.75	0.75
m_5n_1	0.91	1.35	1.32	1.15	1.09
m_5n_2	0.85	0.99	0.92	0.87	0.84
m_5n_3	0.80	1.16	1.1	1.05	1.00
SEm(±)	0.014	0.011	0.012	0.012	0.015
CD (0.05)	0.042	0.032	0.034	0.036	0.044

superior in M_5 at all stages of growth (0.85, 1.17, 1.11, 1.02 and 0.98 respectively) and this was followed by M_4. At 60 and 75 DAS, M_3 recorded the lowest LAI (0.66 and 0.79 respectively). At 75 DAS, M_3 was on par with M_1.

The various nutrient levels tested had significant influence on LAI of spinach beet plants at all the growth stages. LAI was significantly superior in N_1 (0.92,0.88,0.83 and 0.81) except at 60 DAS. At 60 DAS, N_2 (0.78) recorded higher LAI which was on par with N_1(0.77). The LAI was lower in N_3 which was on par with N_2 except at 60 and 75 DAS.

The interaction effects were significant at all the growth stages and m_5n_1 recorded significantly superior LAI values at all stages of growth. The interaction m_1n_3 recorded the lowest LAI at all the stages except at 75 DAS. At 75 DAS, m_3n_3 and m_1n_3 recorded the lowest LAI. At 60 DAS, m_1n_3 was on par with m_1n_1, m_3n_1 and m_3n_3. At 90 DAS, m_1n_3 was on par with m_1n_1 and m_2n_2. .At 105 and 120 DAS, m_1n_3 was on par with m_2n_2.

4.1.1.3 No. of Economic Harvests

The effect of growth media, nutrient levels and their interaction effects on number of economic harvests presented in Table 4a and 4b.

All growth media except M_1 and M_3 recorded 5 economic harvests and rest of them with 4 economic harvests. All the nutrient levels recorded 5 economic harvests. Among the interactions, conventional growth medium with recommended dose of nutrients (m_1n_1) recorded the lowest number of economic harvests.

4.1.1.4 Leaf Yield per Harvest

The influence of growth media, nutrient levels and their interaction effects on leaf yield per harvest is presented in Table 4a and 4b.

Table 4a. Effect of growth media, and nutrient levels on leaf yield per harvest and number of economic harvests

	Leaf yield per harvest (g per plant)					
Treatments	60 DAS (I harvest)	75 DAS (II harvest)	90 DAS (III harvest)	105 DAS (IV harvest)	120 DAS (V harvest)	No. of economic harvests
Growth media (M)						
M_1(soil: sand: FYM (1:1:1)	13.84	22.64	19.20	16.10	15.17	4
M_2(soil: rockdust: FYM (1:1:1)	18.33	32.38	31.51	19.68	17.31	5
M_3(soil: compressed coirpith: FYM (1:1:1)	10.41	20.73	15.33	16.34	15.15	4
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	15.62	26.32	20.24	15.40	14.74	5
M_5 (soil: suchitha: FYM (1:1:1)	22.85	32.67	24.67	20.67	18.92	5
SEm (±)	0.80	1.48	10.15	0.95	0.84	-
CD (0.05)	2.328	4.321	NS	2.767	2.450	-
Nutrient levels (N)						
N_1 (100% of 80:40:80 kg NPK ha^{-1})	16.41	28.65	33.08	18.53	16.66	5
N_2 (N_1 + 50% N topdressed in 3splits)	15.96	25.68	20.28	16.99	16.26	5
N_3 (N_1+ 100% N topdressed in 3splits)	16.26	26.52	19.21	17.39	15.86	5
SEm(±)	0.62	1.15	7.86	0.73	0.65	-
CD (0.05)	NS	NS	NS	NS	NS	-

Table 4b. Interaction effects of growth media and nutrient levels on leaf yield per harvest and number of economic harvests

Treatments	Leaf yield per harvest (g per plant) 60 DAS (I harvest)	75 DAS (II harvest)	90 DAS (III harvest)	105DAS (IV harvest)	120DAS (V harvest)	No. of economic harvests
M x N						
m_1n_1	10.98	19.55	10.10	12.66	11.29	1
m_1n_2	16.39	25.11	24.22	15.88	16.95	5
m_1n_3	14.17	23.27	23.27	19.77	17.27	4
m_2n_1	19.16	38.22	47.33	24.11	21.66	5
m_2n_2	17.64	27.21	17.99	18.60	16.32	5
m_2n_3	18.21	31.72	19.21	16.33	13.95	5
m_3n_1	12.78	17.22	12.77	16.60	14.22	4
m_3n_2	11.39	23.00	15.00	14.88	15.07	4
m_3n_3	7.05	21.99	18.22	17.55	16.18	4
m_4n_1	12.15	26.21	18.86	11.00	12.33	3
m_4n_2	15.44	28.00	22.77	15.88	14.66	4
m_4n_3	19.27	24.77	19.10	19.33	17.23	4
m_5n_1	26.96	42.06	36.33	28.31	23.80	4
m_5n_2	18.96	25.11	21.44	19.70	18.30	4
m_5n_3	22.63	30.83	16.24	14.00	14.66	3
SEm(±)	1.39	2.57	17.58	1.65	1.46	-
CD (0.05)	4.033	7.485	NS	4.793	4.243	-

Perusal of data revealed that growth media alone had significant influence on leaf yield per harvest except at 90 DAS. Among the growth media combinations tested, M_5 (soil: suchitha: FYM (1:1:1) recorded a higher leaf yield per harvest during all the harvests which was on par with M_2 (soil: rockdust: FYM (1:1:1) except at 60 DAS. The growth medium M_3 recorded the lowest leaf yield per harvest at 60 DAS and 75 DAS and was on par with M_1 at 75 DAS. At 105 and 120 DAS, M_4 recorded lower leaf yield per harvest and was on par with M_1 and M_3. The different nutrient doses tested had no significant effect on leaf yield per harvest.

However, the interaction effects showed significant influence on leaf yield per harvest at all growth stages except at 90 DAS. At all stages of harvest, m_5n_1 recorded superior leaf yield per harvest and was on par with m_2n_1 except at 60 DAS. Growth medium with suchitha or rockdust in place of sand under recommended dose (m_5n_1 and m_2n_1) turned out to be the best growth media and nutrient level combination for higher leaf yield per harvest.

4.1.1.5 No. of Leaves Harvested per Plant

The variations in no. of leaves harvested per plant with respect to growth media, nutrient levels and their interaction effects are presented in Table 5a and 5b.

The results revealed that no. of leaves harvested per plant was significantly influenced by the growth media combinations. The growth media containing rock dust in place of sand (M_2) recorded higher no. of leaves per plant (24.54) and was equivalent to the media where sand is replaced with suchitha or M_5 (24.28) and M_1 (22.97). The growth media M_3 (19.98) recorded the lowest no. of leaves which was on par with M_4 (21.57).

The various nutrient levels tested had significant influence on the no. of leaves harvested per plant. The nutrient level N_3 (23.84) gave higher no. of leaves harvested per plant which was on par with N_1 (23.29).

Growth media and nutrient levels together exerted significant effect on no. of leaves harvested per plant. Higher leaf number (28.98) was recorded in m_5n_1 which was on par with m_2n_1, m_1n_2, m_1n_3, m_2n_3 and m_4n_3. Lower no. of leaves per plant was recorded in m_1n_1 which was on par with m_2n_2 m_3n_2, m_3n_1, m_4n_2 and m_5n_2

4.1.1.6 Leaf Yield per Plant

The influence of growth media, nutrient levels and their interaction effects on leaf yield per plant are presented in Table 5a and 5b.

Perusal of the data indicated the significant effect of growth media on leaf yield per plant. Growth media with suchitha (M_5) as a component recorded the maximum leaf yield of 118.08 g per plant and was significantly superior to the other growth media tested. The next best growth media turned out to be M_2 with leaf yield of 99.68 g and was on par with M_4(90.38 g per plant). The growth medium M_3 (77.98 g per plant) recorded lowest leaf yield per plant which was on par with M_1 (86.78 g per plant). However, the different nutrient levels tested had no significant effect on leaf yield per plant.

The interaction between growth media and nutrient levels were found to be significant with m_5n_1 showing significantly superior effect on leaf yield per plant (157.47 g per plant). The next best growth media nutrient level combination for higher leaf yield per plant was m_2n_1 (113.72 g per plant) which was on par with m_4n_2, m_4n_3, m_5n_3, m_2n_2 and m_1n_2.The lowest leaf yield per plant was recorded in m_1n_1 and was on par with m_3n_1, m_3n_2, m_3n_3 and m_4n_1.

4.1.2 Root Studies at Final Harvest

4.1.2.1 Root Weight

The growth medium has significant effect on root weight (Table 6a and 6b). Significantly superior root weight (14.77 g per plant) was recorded in M_5 which was

Table 5a. Effect of growth media and nutrient levels on Leaf yield per plant and no. of leaves harvested per plant

Treatments	No. of leaves harvested per plant	Leaf yield per plant (g)
Growth media(M)		
M_1(soil: sand: FYM (1:1:1)	22.97	86.78
M_2(soil: rockdust: FYM (1:1:1)	24.54	99.68
M_3(soil: compressed coirpith: FYM (1:1:1)	19.98	77.98
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	21.57	90.38
M_5 (soil: suchitha : FYM (1:1:1)	24.28	118.08
SEm (±)	0.94	3.62
CD (0.05)	2.739	10.512
Nutrient levels (N)		
N_1 (100% of 80:40:80 kg NPK ha^{-1})	23.29	97.88
N_2 (N_1 + 50% N topdressed in 3splits)	20.87	93.51
N_3 (N_1+ 100% N topdressed in 3splits)	23.84	91.58
SEm(±)	0.73	2.81
CD (0.05)	2.121	NS

Table 5b. Interaction effect of growth media and nutrient levels on Leaf yield per plant and no. of leaves harvested per plant

Treatments	No. of leaves harvested per plant	Leaf yield per plant (g)
M x N		
m_1n_1	17.08	70.61
m_1n_2	26.34	97.21
m_1n_3	25.49	92.54
m_2n_1	28.76	113.72
m_2n_2	19.64	97.70
m_2n_3	25.20	88.63
m_3n_1	20.98	73.60
m_3n_2	18.20	79.34
m_3n_3	20.76	81.00
m_4n_1	20.63	74.00
m_4n_2	19.20	98.77
m_4n_3	24.87	98.38
m_5n_1	28.98	157.47
m_5n_2	20.99	94.55
m_5n_3	22.87	98.37
SEm (±)	1.63	6.27
CD (0.05)	4.744	18.208

followed by M_2. The growth medium M_3 recorded lower root weight (8.14g per plant) which was on par with M_4 (9.3 g per plant).

The various nutrient levels tested found to have significant influence on root weight. Significantly superior root weight (12.66 g per plant) was recorded in N_1 while the N_3 recorded lower root weight (9.59 g per plant) which was on par with N_2 (10.09 per plant).

The interaction between growth media and nutrient levels registered significant effect on root weight. Higher root weight was recorded by m_5n_2 (19.56 g per plant) which was on par with m_2n_1(19.14g g per plant). The interaction m_3n_2 (5.80 g per plant) recorded lower root weight which was on par with m_1n_3 (8.58 g per plant), m_2n_2(8.18 g per plant), m_2n_3(7.44 g per plant), m_3n_1(6.69 g per plant), m_4n_2(6.92) and m_4n_3(7.77 g per plant).

4.1.2.2 Root Volume

Observations on root volume is presented in Table 6a and 6b. The main effects and interaction effects of different growth media and nutrient levels on root volume of spinach beet were found to be non-significant.

4.1.2.3 Root Shoot Ratio

The effect of growth media, nutrient levels and their interaction on root shoot ratio is presented in Table 6a and 6b.

The growth medium could exert a significant effect on root shoot ratio. The growth medium M_5 registered higher root shoot ratio (0.67) which was on par with M_1(0.58). Root shoot ratio was the least in M_3 which was on par with M_1 and M_2.

The various nutrient level tested had significant influence with N_1(0.56) recording a higher root shoot ratio and on par with N_2 (0.50).

Table 6a. Effect of growth media, and nutrient doses on root weight, root volume and root shoot ratio

Treatments	Root weight (g per plant)	Root volume (cm^3 per plant)	Root shoot ratio
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	10.10	7.11	0.58
M_2(soil: rockdust: FYM (1:1:1)	11.58	4.55	0.44
M_3(soil: compressed coirpith: FYM (1:1:1)	8.14	6.11	0.34
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	9.3	4.88	0.41
M_5 (soil: suchitha : FYM (1:1:1)	14.77	6.00	0.67
SEm (±)	0.64	0.72	0.05
CD (0.05)	1.855	NS	0.130
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	12.66	5.66	0.56
N_2 (N_1 + 50% N topdressed in 3splits)	10.09	6.00	0.50
N_3 (N_1+ 100% N topdressed in 3splits)	9.59	5.53	0.41
SEm(±)	0.49	0.55	0.04
CD (0.05)	1.437	NS	0.101

Table 6b. Interaction effect of growth media, and nutrient levels on root weight, root volume and root shoot ratio

Treatments	Root weight (g per plant)	Root volume (cm^3 per plant	Root shoot ratio
M x N			
m_1n_1	11.86	7.33	0.61
m_1n_2	9.88	8.66	0.67
m_1n_3	8.58	5.33	0.48
m_2n_1	19.14	4.66	0.80
m_2n_2	8.18	4.33	0.19
m_2n_3	7.44	4.66	0.33
m_3n_1	6.69	6.00	0.34
m_3n_2	5.80	5.66	0.21
m_3n_3	11.92	6.66	0.46
m_4n_1	13.19	4.66	0.48
m_4n_2	6.92	4.33	0.34
m_4n_3	7.77	5.66	0.42
m_5n_1	12.40	5.66	0.56
m_5n_2	19.56	7.00	1.09
m_5n_3	12.26	5.33	0.35
SEm(±)	1.11	1.24	0.08
CD (0.05)	3.214	NS	0.225

Among the interactions, m_5n_2 recorded significantly superior root shoot ratio (1.09). Root shoot ratio recorded was the least in m_2n_2 (0.19) which was on with m_2n_3, m_3n_1, m_3n_2, m_4n_2 and m_5n_3.

4.1.3 Quality Analysis

4.1.3.1 Vitamin C

The effect of growth media, nutrient levels and their interaction on vitamin C content of spinach beet is presented in Table 7a and 7b.

The growth medium with suchitha (M_5) registered significantly higher ascorbic acid content (38.02 mg 100 g^{-1}) at third harvest which was on par with growth medium containing rock dust M_2 (36.04 mg 100 g^{-1}). The lowest value was recorded for M_4(23.7 mg 100 g^{-1}).

The nutrient levels also have significant effect on the vitamin C content. Significantly superior vitamin C content (34.36 mg 100 g^{-1}) was registered with higher N dose as in N_3 (N_1+ 100% N top dressed in 3splits).

Interaction effects were also found significant with medium containing suchitha and highest N dose (m_5n_3) recording significantly superior vitamin C content (44.44 mg 100 g^{-1}). This was followed by m_2n_2 and on par with m_2n_2, m_2n_1, m_3n_1, m_5n_1 and m_5n_2.

4.1.3.2 Vitamin A

The variations in vitamin A content in spinach beet as influenced by growth media, nutrient levels and interactions are shown in Table 7a and 7b.

The growth medium had significant effect on vitamin A content. The growth medium with rock dust as one of the components (M_2) registered significantly superior vitamin A content (6.2 mg 100 g^{-1}). It was followed by M_3 (6.01 mg 100 g^{-1}). The least value is recorded for M_1 (2.51 mg 100 g^{-1}).

Regarding nutrient levels, significantly superior vitamin A content (5.56) was found recorded by higher N dose (N_3) and the lowest vitamin A content was recorded for N_2(3.18 mg 100 g^{-1}).

Interaction effects were also found to be significant. The interaction m_4n_3 (7.56) has registered higher vitamin A content which was on par with m_3n_3 (7.45) and m_3n_1 (7.14).

4.1.3.3 Iron

The differences with respect to iron content in spinach beet as influenced by growth media, nutrient levels and interactions are shown in Table 8a and 8b.

The growth medium had significant effect on iron content. Iron content (3.45 mg 100 g^{-1}) in conventional growth media (soil: sand: FYM (1:1:1) was significantly superior to rest of the combinations. This was followed by M_5 (2.28 mg 100 g^{-1}). The least value is recorded by M_2 (1.64 mg 100 g^{-1}).

The nutrient levels also have significant effect on the iron content with the recommended dose of nutrient level (N_1) registering superior iron content (2.5 mg 100 g^{-1}) and it was followed by N_1(2.26 mg 100 g^{-1}).

Among the interactions, m_1n_1 (5.41 mg 100 g^{-1}) has registered higher iron content and it was significantly superior over all other treatments. The interaction m_4n_1 recorded lowest iron content (1.41 mg 100 g^{-1}).

4.1.3.4 Protein

The variations in protein content in spinach beet as influenced by growth media, nutrient levels and interactions are shown in Table 7a and 7b.

Table 7a. Effect of growth media and nutrient levels on vitamin C, vitamin A, iron and protein content of leaves

Treatments	Vitamin C (mg 100 g^{-1})	Vitamin A (mg 100 g^{-1})	Iron (mg 100 g^{-1})	Protein (%)
Growth media(M)				
M_1	28.14	2.51	3.45	20.16
M_2	36.04	6.2	1.64	18.66
M_3	32.09	6.01	1.82	17.68
M_4	23.7	4.27	1.89	22.59
M_5	38.02	2.96	2.28	21.36
SEm (±)	1.10	0.06	0.05	0.06
CD(0.05)	3.204	0.18	0.141	0.172
Nutrient levels (N)				
N_1	29.32	4.44	2.50	17.32
N_2	31.1	3.18	2.26	22.91
N_3	34.36	5.56	1.9	20.04
SEm(±)	0.85	0.05	0.04	0.05
CD (0.05)	2.482	0.147	0.109	0.133

Table 7b. Interaction effect of growth media and nutrient levels on vitamin C, vitamin A, iron and protein content of leaves

Treatments	Vitamin C (mg 100 g^{-1})	Vitamin A (mg 100 g^{-1})	Iron (mg 100 g^{-1})	Protein (%)
M x N				
m_1n_1	20.73	2.45	5.41	19.79
m_1n_2	31.10	2.88	2.91	19.72
m_1n_3	32.59	2.20	2.05	20.95
m_2n_1	34.07	6.63	1.44	14.00
m_2n_2	38.51	5.59	1.87	22.14
m_2n_3	35.55	6.38	1.63	19.83
m_3n_1	34.07	7.14	1.91	18.45
m_3n_2	29.62	3.44	1.91	17.27
m_3n_3	32.59	7.45	1.65	17.31
m_4n_1	23.7	3.41	1.41	16.52
m_4n_2	20.73	1.83	1.75	31.43
m_4n_3	26.63	7.56	2.50	19.83
m_5n_1	34.07	2.55	2.34	17.83
m_5n_2	35.55	2.15	2.86	23.97
m_5n_3	44.44	4.19	1.65	22.29
SEm(±)	1.91	0.11	0.08	0.10
CD 0.05)	5.55	0.328	0.244	0.297

The growth medium has significant effect on protein content. The growth medium M_4 has registered significantly superior protein content (22.59 %) at last harvest. It was followed by M_5 (21.36%). The least value was recorded for M_3 (17.68 %).

The nutrient levels with higher N supply also have significant effect on the protein content. Significantly higher protein content (22.91%) was registered in higher N levels N_2 and it was followed by N_3 (20.04 %).

Interaction effects were also found to be significant. The interaction m_4n_2 (31.43%) recorded higher protein content and it was significantly superior over all other treatments followed by m_5n_2 (23.97%).

4.1.4 Dry Matter Production (DMP)

The influence of different growth media, nutrient levels and their interaction on dry matter production of spinach beet is shown in the Table 8a and 8b.

It is evident that the growth medium has significant effect on dry matter production. The growth medium M_5 recorded higher dry matter production (33.05) followed by M_2. The growth medium M_3 (22.07) recorded a lower dry matter production which was on par with M_1 (24.56). The various nutrient level tested had no significant influence on dry matter production.

Among the interactions, variation in dry matter production was significantly superior with m_5n_1 (44.56). The next best interaction was m_2n_1 and was on par with m_4n_2, m_4n_3, m_5n_3, m_1n_2 and m_2n_2.The interaction m_1n_1 (19.98) recorded lower dry matter production which was on par with m_2n_3 (24.79), m_3n_1(20.83 g plant^{-1}), m_3n_2 (22.45), m_3n_3 (22.96), m_4n_1 (20.94).

4.1.5 NPK Uptake

The data on growth media, nutrient levels and their interaction effects on uptake of NPK is presented in Table 8a and 8b.

Table 8a. Effect of growth media and nutrient levels on dry matter production and NPK uptake, g $plant^{-1}$

Treatments	DMP	N	P	K
Growth media(M)				
M_1(soil: sand: FYM (1:1:1)	24.56	0.78	0.16	1.23
M_2(soil: rockdust: FYM (1:1:1)	28.21	0.82	0.37	1.09
M_3(soil: compressed coirpith: FYM (1:1:1)	22.07	0.62	0.34	0.91
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	25.57	0.94	0.36	1.25
M_5 (soil: suchitha : FYM (1:1:1)	33.05	1.08	0.42	2.00
SEm (±)	1.02	0.04	0.01	0.05
CD (0.05)	2.975	0.105	0.038	0.145
Nutrient levels (N)				
N_1 (100% of 80:40:80 kg NPK ha^{-1})	27.70	0.75	0.32	1.30
N_2 (N_1 + 50% N topdressed in 3splits)	26.46	0.97	0.33	1.30
N_3 (N_1+ 100% N topdressed in 3splits)	25.91	0.82	0.33	1.28
SEm(±)	0.79	0.03	0.01	0.04
CD (0.05)	NS	0.081	NS	NS

Table 8b. Interaction effect of growth media, and nutrient levels on dry matter production and NPK uptake, g plant^{-1}

Treatments	DMP	N	P	K
M x N				
m_1n_1	19.98	0.62	0.07	0.86
m_1n_2	27.51	0.86	0.23	1.98
m_1n_3	26.18	0.87	0.19	0.84
m_2n_1	32.18	0.72	0.46	0.69
m_2n_2	27.65	0.98	0.18	0.89
m_2n_3	24.79	0.78	0.47	1.67
m_3n_1	20.83	0.61	0.31	0.84
m_3n_2	22.45	0.62	0.35	0.90
m_3n_3	22.96	0.63	0.35	1.00
m_4n_1	20.94	0.54	0.34	0.95
m_4n_2	27.95	1.4	0.54	1.26
m_4n_3	27.84	0.87	0.18	1.54
m_5n_1	44.56	1.25	0.44	3.18
m_5n_2	26.75	1.02	0.38	1.47
m_5n_3	27.84	0.98	0.43	1.35
SEm(±)	1.77	0.06	0.01	0.08
CD (0.05)	5.153	0.181	NS	0.250

The growth medium used and nutrient levels tested have significant effect on uptake of N. The growth medium containing suchitha as one of the components showed its superiority with higher uptake of N (1.08 g $plant^{-1}$) and it was significantly superior over all other growth media. The recommended nutrient level with 50 % more N (N_2) could register a higher N uptake (0.97). The interactions were also found significant with m_4n_2 (1.4 g $plant^{-1}$) recording higher uptake of N which was on par with m_5n_1 (1.25 g $plant^{-1}$).

Regarding P uptake, the growth medium with suchitha (M_5) recorded higher P uptake (0.42 g $plant^{-1}$) and it was significantly superior over all other treatments. The lowest P uptake was recorded in the conventional growth medium $M_{1.}$ The various nutrient levels tested and the interaction had no significant influence on P uptake.

The growth medium M_5 recorded significantly higher K uptake (2 g $plant^{-1}$). It was followed by M_4 which was on par with $M_{1.}$ The various nutrient levels tested had no significant influence on K uptake. The interaction m_5n_1 recorded higher K uptake (3.18 g $plant^{-1}$) and it was significantly superior over all other interaction.

4.1.6 Growth Media Analysis After the Experiment

The changes in chemical characteristics of the growth medium after the experiment are furnished below.

4.1.6.1 pH

The main and interaction effect of growth media and nutrient levels interactions on pH of the medium is presented in the Table 9a and 9b.

Both the type of growth medium used and nutrient levels tested exerted significant influence on the final pH values of the media. In general, the pH value ranged between 6.5 to 7 or neutral range. The pH values of conventional growth media (6.81) and that with coir pith replacing sand (6.82) were on par with each other. The

Table 9a. Effect of growth media and nutrient levels on pH and EC of the medium after experiment

Treatments	pH	EC (dSm^{-1})
Growth media(M)		
M_1(soil: sand: FYM (1:1:1)	6.81	1.01
M_2(soil: rockdust: FYM (1:1:1)	7.01	1.02
M_3(soil: compressed coirpith: FYM (1:1:1)	6.82	1.54
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	6.94	1.37
M_5 (soil: suchitha : FYM (1:1:1)	6.55	1.03
SEm (±)	0.01	0.01
CD (0.05)	0.044	0.039
Nutrient levels (N)		
N_1 (100% of 80:40:80 kg NPK ha-1)	6.77	1.05
N_2 (N_1 + 50% N topdressed in 3splits)	6.86	1.08
N_3 (N_1+ 100% N topdressed in 3splits)	6.84	1.20
SEm(±)	0.01	0.01
CD(0.05)	0.034	0.030

Table 9b. Interaction effect of growth media and nutrient levels on pH and EC of the medium after experiment

Treatments	pH	EC (dSm^{-1})
M x N		
m_1n_1	6.59	0.74
m_1n_2	7.10	0.55
m_1n_3	6.74	0.56
m_2n_1	6.87	0.72
m_2n_2	6.94	1.40
m_2n_3	7.24	0.94
m_3n_1	6.91	1.52
m_3n_2	6.83	1.24
m_3n_3	6.70	1.88
m_4n_1	6.84	1.35
m_4n_2	7.08	1.24
m_4n_3	6.91	1.53
m_5n_1	6.66	0.96
m_5n_2	6.38	1.00
m_5n_3	6.63	1.12
SEm(±)	0.02	0.03
CD (0.05)	0.076	0.067

recommended nutrient practice recorded a pH value of 6.77. Among the interactions, all the combinations recorded pH values in neutral range except m_1n_2, m_2n_3 and m_4n_2.

4.1.6.2 Electrical Conductivity (EC)

The results of the main and interaction effect of growth media and nutrient levels on final EC status of the medium is presented in the Table 9a and 9b.

Both the type of growth medium used and nutrient levels tested exerted significant influence on the final EC values of the media. In general, the EC values were found to have increased from the initial value. The final values were found to be above 1 in all growth media with conventional growth media and rock dust combination recording near to optimum range (1.01and 1.02 units). Growth media with compressed coir pith substitution recorded the maximum spike (1.54) which was significantly different from rest of the combinations.

Growth medium and nutrient levels together had significant effect on the final EC of the media showing a general increase from initial value (1.01 to 1.54 unit) which can be made safe for crop production with suitable management.

4.1.6.3 Organic Carbon

The results revealed the significant of growth media, nutrient levels and their interaction on final organic carbon content of the medium as presented in Table 10a and 10b.

There was a general enhancement irrespective of the growth medium. The growth medium with suchitha (M_5) registered significantly superior organic carbon content (2.61%) followed by M_4 (2.09%). The lowest organic carbon content was in M_2.

The various nutrient levels tested had significant influence on final organic carbon content with extra N fertilized bags (N_3) and recommended dose registering on par organic carbon content (1.93 and 1.87 % respectively) .

Among the interactions, growth medium with suchitha fertilized at recommended dose (m_5n_1) registered higher organic carbon content (2.74%) which was on par with m_4n_1 (2.67%). This was followed by m_5n_2 (2.56%) which was on par with m_5n_3 (2.52%).

4.1.6.4 Available N

The changes in available N content after experiment as influenced by treatments are shown in Table 10a and 10b.The results revealed that different growth media, nutrient levels and their interaction had significant influence on available N content after the experiment. There was general increase in available N status of the media after the crop growth with M_3 (0.022%) registering higher available N content which was on par with M_5 (0.020%). The conventional growth medium M_1 recorded the least available N content.

The various nutrient levels tested showed significant influence on available N with recommended dose (N_1) recording significantly superior available N content (0.019%). The final available N was the same in both N_2 and N_3.

Interaction of growth media and nutrient levels showed significant variation on available N content. Growth medium substituted with suchitha under recommended dose of nutrients (m_5n_1) recorded significantly superior available N content (0.028 %) after the experiment and it was followed by m_2n_3, m_3n_1 and m_3n_2.

4.1.6.5 Available K

The data on available K content after experiment as influenced by treatments are shown in Table 10a and 10b. The results revealed that growth medium alone had significant effect on final available K content.

Table 10a. Effect of growth media and nutrient levels on available NK and organic carbon content after experiment, %

Treatments	OC content	Available N	Available K
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	1.73	0.014	0.014
M_2(soil: rockdust: FYM (1:1:1)	1.31	0.016	0.016
M_3(soil: compressed coirpith: FYM (1:1:1)	1.51	0.022	0.029
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	2.09	0.016	0.020
M_5 (soil: suchitha : FYM (1:1:1)	2.61	0.020	0.024
SEm (±)	0.04	0.001	0.003
CD(0.05)	0.116	0.002	0.001
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	1.87	0.019	0.018
N_2 (N_1 + 50% N topdressed in 3splits)	1.76	0.017	0.023
N_3 (N_1+ 100% N topdressed in 3splits)	1.93	0.017	0.02
SEm(±)	0.030	0.00	0.00
CD (0.05)	0.090	0.001	NS

Table 10b. Interaction effect of growth media and nutrient levels on available NK and organic carbon content after experiment, %

Treatments	OC content	Available N	Available K
M x N			
m_1n_1	1.44	0.015	0.012
m_1n_2	1.67	0.011	0.015
m_1n_3	2.10	0.016	0.016
m_2n_1	1.39	0.014	0.010
m_2n_2	0.74	0.012	0.027
m_2n_3	1.82	0.022	0.011
m_3n_1	1.09	0.022	0.027
m_3n_2	2.07	0.022	0.026
m_3n_3	1.36	0.022	0.033
m_4n_1	2.67	0.017	0.016
m_4n_2	1.76	0.019	0.021
m_4n_3	1.84	0.011	0.024
m_5n_1	2.74	0.028	0.026
m_5n_2	2.56	0.020	0.027
m_5n_3	2.52	0.011	0.018
SEm(±)	0.06	0.00	0.000
CD (0.05)	0.201	0.003	NS

The growth medium substituted with compressed coir pith (M_3) resulted in significantly higher final available K content (0.029%) compared to conventional growth media (0.014%). Perusal of the data showed that the various nutrient levels tested and their interactions didn't record any significant variation on final available K content of the media.

4.1.7 Pest and Disease Incidence

The common pest observed in spinach beet was leaf eating caterpillar and mealy bugs. Wilt incidence was noticed in the early stages.

4.1.8 Economic Analysis

The results of the economic analysis on effect of growth media, nutrient levels and their interaction on spinach beet cultivation are presented in Table 11a and 11b.

On scrutinizing the data on economics of spinach beet cultivation in containers, it was revealed that the treatments can significantly influence BC ratio alone. The net income received didn't record any significant variation with respect to main or interaction effects. Spinach beet cultivation in a growth medium substituted with rock dust instead of sand (M_2) recorded a significantly superior BC ratio (1.30). The next best economic growth medium was conventional one with 50 per cent additional N supplementation registering a BC ratio of 1.20. However, the growth medium with suchitha (M_5) which recorded higher yield had the lowest BC ratio (0.67).

The nutrient levels could significantly influence BC with recommended dose recording significantly superior BCR values (1.05). The most economic combination was turned out to be with growth media where rockdust is substituted for sand (m_2n_1) and recommended level of nutrient with a significantly superior BC ratio of 1.67. The next best economic combination was traditional growth media with recommended dose of nutrients (1.01). The combination m_5n_3 recorded a lower net income and BC ratio (-16.89 and 0.53).

Table 11a. Effect of growth media and nutrient levels on net income and BCR

Treatments	Net income (₹ per bag)	BCR
Growth media(M)		
M_1(soil: sand: FYM (1:1:1)	4.35	1.10
M_2(soil: rockdust: FYM (1:1:1)	6.49	1.30
M_3(soil: compressed coirpith: FYM (1:1:1)	1.63	0.82
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	-0.63	0.93
M_5 (soil: suchitha : FYM (1:1:1)	-9.93	0.67
SEm (±)	-	0.008
CD (0.05)	-	0.002
Nutrient levels (N)		
N_1 (100% of 80:40:80 kg NPK ha^{-1})	19.57	1.05
N_2 (N_1 + 50% N topdressed in 3splits)	16.64	0.97
N_3 (N_1+ 100% N topdressed in 3splits)	15.25	0.87
SEm(±)	-	0.00
CD (0.05)	-	0.017

Table 11b. Interaction effects of growth media and nutrient levels net income and BCR

Treatments	Net income (₹ per bag)	BCR
M x N		
m_1n_1	2.1	1.01
m_1n_2	3.3	1.2
m_1n_3	2	1.07
m_2n_1	4.8	1.67
m_2n_2	4.0	1.23
m_2n_3	1.2	1.01
m_3n_1	-2.5	0.85
m_3n_2	-3.6	0.81
m_3n_3	-4.0	0.81
m_4n_1	-2.6	0.82
m_4n_2	0.25	1.04
m_4n_3	-0.8	0.94
m_5n_1	-2.01	0.94
m_5n_2	-16.6	0.55
m_5n_3	-16.8	0.53
SEm(±)	-	0.01
CD (0.05)	-	0.038

4.2. EXPT II. STUDIES ON NUTRIENT AVAILABILITY IN DIFFERENT GROWTH MEDIA (INCUBATION STUDY)

4.2.1. Growth Media Analysis

4.2.1.1 pH

The data on effect of growth media, nutrient levels and their interaction effects on pH of growth media incubated under laboratory condition is presented in Table 12a and 12b

All the growth medium except with suchitha recorded a pH value in neutral range (6.6 to 7.3) initially. However, M_5 had an initial pH in the slightly acid range (6.41). The pH of all the growth media showed an increasing trend over the periods of incubation and the pH values of different growth media ranged between 6.5 to7.5. Among all the growth media tested, the growth medium M_2 which has rock dust as one of the components showed a progressive increase in pH in neutral range over the periods of incubation. However, the growth medium containing suchitha showed a lower hike in pH value over the entire period of incubation. The trend in pH changes observed with different nutrient levels were in line with the growth media. Among the growth media nutrient level combinations, there was progressive decrease in acidity reaching neutrality during incubation.

4.2.1.2 EC

The variations in EC values as influenced by growth media, nutrient levels and their interaction on incubation is presented in Table 13a and 13b.

The different growth media components had significant influence on deciding the EC value of the media. The growth medium M_3 with compressed coir pith as one of the components recorded a significantly higher initial EC of 1.41 unit which showed a progressing trend over the months. However, the traditional growth media recorded a safe

Table 12a. Effect of growth media and nutrient levels pH on incubation

	pH		
Treatments	I MAI*	2 MAI	3MAI
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	6.65	6.81	6.94
M_2(soil: rockdust: FYM (1:1:1)	6.85	6.99	7.09
M_3(soil: compressed coirpith: FYM (1:1:1)	6.63	6.83	6.94
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	6.81	6.95	7.01
M_5 (soil: suchitha : FYM (1:1:1)	6.41	6.52	6.64
SEm (±)	0.01	0.01	0.01
CD(0.05)	0.038	0.031	0.039
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	6.60	6.75	6.87
N_2 (N_1 + 50% N topdressed in 3splits)	6.72	6.86	6.93
N_3 (N_1+ 100% N topdressed in 3splits)	6.69	6.85	6.96
SEm(±)	0.01	0.00	0.01
CD(0.05)	0.029	0.024	0.03

*MAI-Months after incubation

Table 12b. Interaction effect of growth media and nutrient levels on pH on incubation

Treatments	pH		
M x N	1 MAI	2 MAI	3 MAI
m_1n_1	6.40	6.57	6.70
m_1n_2	7.02	7.11	7.17
m_1n_3	6.54	6.74	6.94
m_2n_1	6.70	6.83	6.93
m_2n_2	6.73	6.93	7.04
m_2n_3	7.10	7.20	7.30
m_3n_1	6.71	6.88	7.02
m_3n_2	6.66	6.86	6.96
m_3n_3	6.53	6.75	6.85
m_4n_1	6.70	6.83	6.88
m_4n_2	6.99	7.08	7.14
m_4n_3	6.74	6.95	7.01
m_5n_1	6.47	6.64	6.84
m_5n_2	6.23	6.30	6.36
m_5n_3	6.54	6.61	6.73
SEm(±)	0.02	0.01	0.02
CD(0.05)	0.065	0.054	0.067

*MAI-Months after incubation

limit of EC value (<1) during the entire period. All growth media showed an increasing trend in EC over the periods of incubation.

The different levels of nutrients applied to the media were found to enhance the EC of the media during incubation. Though the recommended dose recorded a safer value (0.98) initially, it was found to increase during incubation.

Among the interactions, traditional growth media with any of the nutrient levels tested were found to have a safe EC limit during incubation. However, growth media combinations with M_3 and M_4 where presence of coir pith was realized, the EC values were found to be above 1.

4.2.1.3 Organic carbon

The variations in organic carbon status as influenced by growth media, nutrient levels and their interaction effects are presented in Table 14a and 14 b.

The growth media had significant effect on organic carbon status. There was a progressive increase in organic carbon status during incubation. During the first month, the growth media with coir pith recorded a significantly higher organic carbon content compared to other growth medium. During second and third month, growth medium with rock dust (M_2) registered a higher organic carbon content. During the entire period of incubation, the growth medium M_5 recorded the lowest organic carbon content.

The various nutrient levels tested had significant influence on organic carbon status at all the stages. The nutrient level N_3 recorded higher organic carbon (1.59) at first month. However, during second month both N_2 and N_1 recorded on par with higher organic carbon. The nutrient level N_2 recorded higher organic carbon during the third month. During the second and third month N_3 recorded the lowest organic carbon.

Table 13a. Effect of growth media and nutrient levels on EC on incubation, dSm^{-1}

	EC		
Treatments	1 MAI	2 MAI	3 MAI
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	0.55	0.62	0.74
M_2(soil: rockdust: FYM (1:1:1)	0.92	1.06	1.12
M_3(soil: compressed coirpith: FYM (1:1:1)	1.43	1.59	1.65
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	1.29	1.38	1.46
M_5 (soil: suchitha: FYM (1:1:1)	0.97	1.04	1.10
SEm (±)	0.01	0.00	0.00
CD (0.05)	0.029	0.006	0.025
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	0.98	1.09	1.19
N_2 (N_1 + 50% N top dressed in 3splits)	1.01	1.12	1.17
N_3 (N_1+ 100% N top dressed in 3splits)	1.11	1.20	1.29
SEm(±)	0.00	0.00	0.00
CD(0.05)	0.022	0.005	0.02

*MAI-Months after incubation

Table 13b. Interaction effect of growth media and nutrient levels on EC on incubation, dSm^{-1}

Treatments	EC		
	1 MAI	2 MAI	3 MAI
M x N			
m_1n_1	0.60	0.74	0.86
m_1n_2	0.51	0.55	0.61
m_1n_3	0.55	0.57	0.77
m_2n_1	0.66	0.78	0.87
m_2n_2	1.25	1.40	1.52
m_2n_3	0.86	0.92	0.97
m_3n_1	1.45	1.59	1.66
m_3n_2	1.13	1.29	1.36
m_3n_3	1.73	1.89	1.92
m_4n_1	1.21	1.36	1.47
m_4n_2	1.25	1.28	1.32
m_4n_3	1.41	1.51	1.60
m_5n_1	0.97	1.00	1.09
m_5n_2	0.92	1.01	1.04
m_5n_3	1.01	1.10	1.1.17
SEm(±)	0.01	0.00	0.01
CD(0.05)	0.050	0.011	0.044

*MAI-Months after incubation

Table 14a. Effect of growth media and nutrient levels on organic carbon on incubation, %

	Organic carbon		
Treatments	1 MAI	2 MAI	3MAI
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	1.40	2.20	2.44
M_2(soil: rockdust: FYM (1:1:1)	1.37	2.43	2.59
M_3(soil: compressed coirpith: FYM (1:1:1)	1.87	2.38	2.46
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	1.35	2.31	2.45
M_5 (soil: suchitha: FYM (1:1:1)	1.33	1.96	2.16
SEm (±)	0.02	0.02	0.03
CD (0.05)	0.082	0.084	0.09
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	1.31	2.25	2.43
N_2 (N_1 + 50% N topdressed in 3splits)	1.49	2.32	2.53
N_3 (N_1+ 100% N topdressed in 3splits)	1.59	2.20	2.29
SEm(±)	0.02	0.02	0.02
CD(0.05)	0.063	0.065	0.069

*MAI-Months after incubation

Table 14b. Interaction effect of growth media and nutrient levels organic carbon content on incubation, %

Treatments	Organic carbon		
M x N	1 MAI	2 MAI	3MAI
m_1n_1	0.67	1.45	1.90
m_1n_2	2.08	3.05	3.18
m_1n_3	1.45	2.10	2.25
m_2n_1	2.02	3.52	3.73
m_2n_2	0.96	1.81	2.00
m_2n_3	1.14	1.97	2.05
m_3n_1	1.56	2.04	2.11
m_3n_2	1.62	2.08	2.19
m_3n_3	2.44	3.02	3.08
m_4n_1	0.85	1.94	2.02
m_4n_2	2.13	3.12	3.27
m_4n_3	1.08	1.88	2.06
m_5n_1	1.47	2.30	2.41
m_5n_2	0.67	1.57	2.03
m_5n_3	1.85	2.01	2.04
SEm(±)	0.04	0.05	0.05
CD(0.05)	0.141	0.145	0.155

*MAI-Months after incubation

The interaction effects were also significant on organic carbon status during all the three months. The growth media containing coir pith at highest nutrient levels recorded higher organic carbon content at first month (2.44%) and it was followed by m_4n_2 (2.13%) which was on par with m_1n_2 and m_2n_1. During second and third month m_2n_1 recorded significantly superior organic carbon status.

4.2.1.4 Available N

The data on effect of growth media, nutrient levels and their interaction effects on final available N status of the media is presented in Table 15a and 15b.

The growth media showed significant effect on final available N status except at second month after incubation. During the first month, the growth medium with compressed coir pith (M_3) recorded higher available N (0.017%) which was on par with M_4 and M_5. After 3 months of incubation also M_3 recorded significantly higher available N (0.028%) status.

The different levels of nutrients supplied to the medium exerted significant influence on available N status throughout the period of incubation with the highest nutrient level (N_3) registering higher available N status. Naturally, the lowest available N status was recorded in recommended dose (N_1) during all the growth stages.

The interaction effects were significant on available N at all the three months. During the first month growth media containing compressed coir pith and higher N levels top dressed recorded higher final available N status. During the second month m_4n_2 recorded higher available N which was on par with m_2n_3, m_3n_3, m_4n_3 and m_5n_3. During the third month m_2n_3 recorded higher available N and it was followed by m_3n_2 and m_3n_3 which was on par with m_3n_1, m_4n_2, m_4n_3 and m_5n_3.

4.2.1.5 Available P

The final available P status of the media as influenced by growth media, nutrient levels and their interaction effects is presented in Table 16a and 16b.

Table 15a. Effect of growth media and nutrient levels on available N on incubation, %

Treatments	Available N		
	1 MAI	2 MAI	3 MAI
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	0.014	0.017	0.020
M_2(soil: rockdust: FYM (1:1:1)	0.015	0.017	0.024
M_3(soil: compressed coirpith: FYM (1:1:1)	0.017	0.018	0.028
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	0.016	0.017	0.021
M_5 (soil: suchitha: FYM (1:1:1)	0.016	0.016	0.023
SEm (±)	0.00	0.00	0.00
CD (0.05)	0.001	NS	0.003
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	0.014	0.016	0.019
N_2 (N_1 + 50% N topdressed in 3splits)	0.016	0.017	0.023
N_3 (N_1+ 100% N topdressed in 3splits)	0.017	0.018	0.028
SEm(±)	0.00	0.00	0.00
CD(0.05)	0.000	0.001	0.002

*MAI-Months after incubation

Table 15b. Interaction effect of growth media and nutrient levels available N on incubation, %

Treatments	Available N		
M x N	1 MAI	2 MAI	3MAI
m_1n_1	0.014	0.017	0.020
m_1n_2	0.014	0.017	0.021
m_1n_3	0.015	0.017	0.019
m_2n_1	0.015	0.016	0.016
m_2n_2	0.016	0.017	0.017
m_2n_3	0.015	0.018	0.038
m_3n_1	0.015	0.017	0.025
m_3n_2	0.017	0.018	0.029
m_3n_3	0.018	0.018	0.029
m_4n_1	0.014	0.014	0.014
m_4n_2	0.017	0.02	0.025
m_4n_3	0.018	0.018	0.025
m_5n_1	0.014	0.016	0.019
m_5n_2	0.015	0.016	0.023
m_5n_3	0.017	0.018	0.028
SEm(±)	0.00	0.00	0.00
CD (0.05)	0.001	0.002	0.005

*MAI-Months after incubation

The growth media had significant effect on available P during all the months. At all stages of incubation, growth media containing both rock dust and compressed coir pith (M_4) recorded significantly superior available P status. A significantly lower P status was recorded by M_1 (4.32 ppm).

The various nutrient levels tested had significant influence on available P at all the months and the nutrient level N_3 recorded higher available P during all the three months and the nutrient level N_1 recorded lowest available P during the first two months and N_2 recorded lowest available N during the third month.

The interaction effects were significant on available P status all throughout incubation. The growth medium containing rock dust and coir pith with higher nutrient levels (m_4n_3) resulted in significantly higher available P status during all the stages of incubation. The lowest available P was recorded for m_2n_1 during all the three months.

4.2.1.6 Available K

The main effect and interaction effects of growth media and nutrient levels on final available K status of the media is presented in Table 17a and 17b.

The growth media has significant effect on available K during all the months. The conventional growth medium of soil: sand: FYM in 1:1:1 (M_1) recorded higher available K status during all stages of incubation.

The various nutrient level tested had significant influence on available K with the recommended dose of nutrient (N_1) recording higher available K during all the three months. N_2 recorded lowest available K during all the three months which was on par with $N_{3.}$ The interaction effects were significant on available K at all the three months. The combination m_3n_1 and m_1n_3 recorded higher available K during all stages of incubation.

Table 16a. Effect of growth media and nutrient levels on available P on incubation, ppm

	Available P		
Treatments	1 MAI	2 MAI	3 MAI
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	4.32	4.50	4.71
M_2(soil: rockdust: FYM (1:1:1)	4.52	4.64	4.79
M_3(soil: compressed coirpith: FYM (1:1:1)	5.57	5.77	5.97
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	6.48	6.66	6.73
M_5 (soil: suchitha: FYM (1:1:1)	5.57	5.97	6.18
SEm (±)	0.02	0.03	0.01
CD (0.05)	0.077	0.087	0.048
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	5.07	5.36	5.61
N_2 (N_1 + 50% N topdressed in 3splits)	5.21	5.41	5.58
N_3 (N_1+ 100% N topdressed in 3splits)	5.60	5.75	5.83
SEm(±)	0.02	0.02	0.01
CD (0.05)	0.059	0.067	0.037

*MAI-Months after incubation

Table 16b. Interaction effect of growth media and nutrient levels on available P on incubation, ppm

Treatments	Available P		
M x N	1 MAI	2 MAI	3 MAI
m_1n_1	4.07	4.41	4.74
m_1n_2	4.73	4.8	4.96
m_1n_3	4.16	4.29	4.44
m_2n_1	3.76	3.77	3.93
m_2n_2	4.63	4.88	5.03
m_2n_3	5.18	5.28	5.41
m_3n_1	6.14	6.36	6.56
m_3n_2	5.09	5.26	5.46
m_3n_3	5.48	5.68	5.88
m_4n_1	6.47	6.63	6.92
m_4n_2	5.29	5.60	5.77
m_4n_3	7.69	7.74	7.49
m_5n_1	4.94	5.64	5.89
m_5n_2	6.3	6.5	6.89
m_5n_3	5.49	5.78	5.95
SEm(±)	0.04	0.05	0.02
CD(0.05)	0.133	0.15	0.082

*MAI-Months after incubation

Table 17a. Effect of growth media and nutrient levels on available K on incubation, %

	Available K		
Treatments	1 MAI	2 MAI	3 MAI
Growth media(M)			
M_1(soil: sand: FYM (1:1:1)	0.038	0.041	0.044
M_2(soil: rockdust: FYM (1:1:1)	0.016	0.018	0.022
M_3(soil: compressed coirpith: FYM (1:1:1)	0.033	0.035	0.039
M_4 (soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1)	0.026	0.028	0.034
M_5 (soil: suchitha: FYM (1:1:1)	0.035	0.038	0.040
SEm (±)	0.00	0.00	0.00
CD (0.05)	0.002	0.002	0.003
Nutrient levels (N)			
N_1 (100% of 80:40:80 kg NPK ha^{-1})	0.033	0.036	0.040
N_2 (N_1 + 50% N topdressed in 3splits)	0.027	0.029	0.033
N_3 (N_1+ 100% N topdressed in 3splits)	0.029	0.031	0.035
SEm(±)	0.00	0.00	0.00
CD (0.05)	0.002	0.002	0.002

*MAI-Months after incubation

Table 17b. Interaction effect of growth media and nutrient levels on available K on incubation, %

Treatments	Available K		
M x N	1 MAI	2 MAI	3 MAI
m_1n_1	0.045	0.048	0.051
m_1n_2	0.023	0.025	0.028
m_1n_3	0.047	0.049	0.054
m_2n_1	0.013	0.015	0.018
m_2n_2	0.019	0.021	0.024
m_2n_3	0.015	0.018	0.024
m_3n_1	0.047	0.049	0.053
m_3n_2	0.028	0.030	0.034
m_3n_3	0.025	0.027	0.029
m_4n_1	0.024	0.026	0.034
m_4n_2	0.025	0.027	0.035
m_4n_3	0.028	0.030	0.033
m_5n_1	0.035	0.040	0.043
m_5n_2	0.038	0.040	0.042
m_5n_3	0.031	0.033	0.036
SEm(±)	0.00	0.00	0.00
CD (0.05)	0.004	0.004	0.005

*MAI-Months after incubation

Discussion

5. DISCUSSION

Spinach beet commonly known as ‘Indian Palak’ is a highly nutritious leafy vegetable suited for container cultivation in urban households. For widespread organic cultivation of spinach beet in containers, identifying an ideal growth medium and nutrient schedule is a prerequisite. The results of the experiments conducted with these objectives are discussed briefly in this chapter.

5.1 EFFECT OF GROWTH MEDIUM ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN SPINACH BEET

Container gardening has become a lifestyle for self-sufficiency in urban areas due to space constraints. With the right growing containers and growth medium, vegetables can be cultivated anywhere and used fresh especially, leafy vegetables like spinach beet. Type of growth medium used is the key to successful container gardening. The ideal growth medium combination is sand, soil and FYM in 1:1:1 ratio. However, the high cost and paucity of sand as a growth medium component urged the need for identifying a suitable substitute for container gardening.

The results of the study to identify a suitable growth medium for container grown spinach beet indicated that the various growth medium combinations tested had a significant influence on growth, yield and quality parameters of spinach beet. The growth medium M_5 with soil, suchitha and FYM in the ratio 1:1:1 recorded higher values for growth and yield attributes. Growth characters like plant height (at 75 and 90 DAS), LAI, yield characters like leaf yield per harvest, leaf yield per plant, number of leaves harvested per plant and dry matter production were superior in this growth medium combination. The next best growth medium identified was M_2 where rockdust substituted sand. These results indicated that suchitha, a product formed out of thermochemical digestion of degradable waste could be effectively used for substituting sand. This is in conformity with the findings of Jayakrishna *et al*. (2016) where she observed taller plants, more primary branches, higher shoot weight and yield in chilli when sand and FYM were replaced by suchitha and coirpith compost respectively.

Results of the study revealed that the growth medium tested had significant influence on plant height at all stages except at 90 DAS. Upto 60 DAS, growth medium with sand replaced by rockdust and compressed coirpith (CCP) together in equal proportion recorded taller plants. However, from 105 DAS onwards, growth medium with suchitha as substitute for sand recorded taller plants. The growth medium with compressed coirpith gave a better initial response because CCP had proved to be a good substrate for seedling establishment and a widely preferred growth medium for high value crops in protected cultivation. Also, CCP is produced after washing coirpith several times with good water and compressed into blocks after removing tannins and phenols. Hale and Orcutt (1987) reported increase in plant height in the medium containing compressed coirpith which he attributed to the presence of nitrogen at higher quantities leading to increase in vegetative growth of plants mainly by cell elongation and partly by cell division. Along with coirpith, rockdust might have also contributed as a medium component by way of remineralisation. Fragstein and Vogtmann (1987) reported that rockdust contains most of the nutrients required for plant growth except N and P. Finely ground rock powder serves as a fast food for microbes and a population explosion of bacteria was observed in soils after rockdust application as reported by Garcia *et al*. (2002). The favourable effects of these two medium components together might have contributed to production of taller plants during initial stage. The effect of suchitha was visible during later period of crop growth and it may be due to the availability of nutrients at later stages of crop growth. It was reported that the application of rapid organic fertilizer (suchitha) has resulted in an increase in the availability of micronutrients at the later stages of banana crop (Leno and Sudharmaidevi, 2018).

Leaf area shows the photosynthetic efficiency of plants and so does the leaf area index (LAI). The different growth medium tested had significant influence on the LAI of spinach beet. LAI was higher for the growth medium M_5 at all the growth stages and it was significantly superior over all other treatments. This could be ascribed to the higher initial NPK status of the growth medium M_5 compared to others. Gairola *et.al* (2009) reported higher LAI in spinach beet in treatments where K was applied along with N and P than treatments where no K was applied. The higher LAI automatically augment solar energy harvesting ability and as a result there is enhancement in the production of photosynthates and their subsequent translocation and hence total dry matter production (Blanchet *et al*., 1962; Linser and Herwig, 1968; Beringer, 1982; Saxena, 1985).

Though the initial NPK status of the growth media M_3 and M_5 was comparable, the growth medium combination could not support a better crop growth. Coirpith possess a high-water retention capacity of 600- 800 per cent and a maximum of 1100 per cent (Anon., 2016). However, the high-water holding capacity of cocopeat causes poor air-water relationship which will lead to low aeration within the medium thus affecting the oxygen diffusion to the roots. This might have caused reduction in the yield of spinach beet in the growth medium M_3 even though it had high initial K and N status.

Spinach beet is grown for its tender succulent leaf and petiole. The major yield attributes studied were leaf yield per harvest, number of leaves harvested per plant and leaf yield per plant. Most of the yield determining factors studied were found superior in the growth medium M_5. Though the number of leaves harvested per plant was higher for the growth medium M_2, it was on par with M_5 (Fig.4). This might be due to the higher availability of nutrients and growth substances throughout the growth period in the latter. Jayakrishna *et al.* (2016) reported that the yield of chilli was higher for the growth medium with soil, coirpith compost and suchitha in the ratio 1:2:1. Yield enhancement by rockdust application had been illustrated by Rose (2008) in coleus where the highest number of tubers per plant and total dry matter production was recorded with rockdust @ 10 t ha^1 along with equal quantity of FYM and 50 percent of chemical fertilizers.

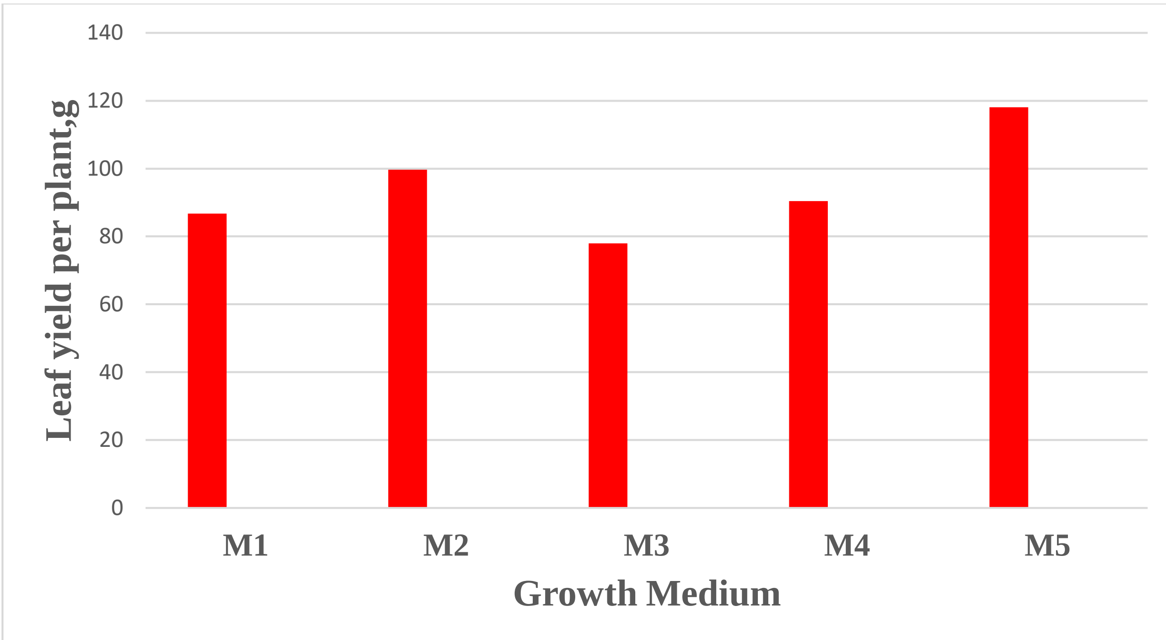

Fig 3. Effect of growth medium on leaf yield per plant in spinach beet

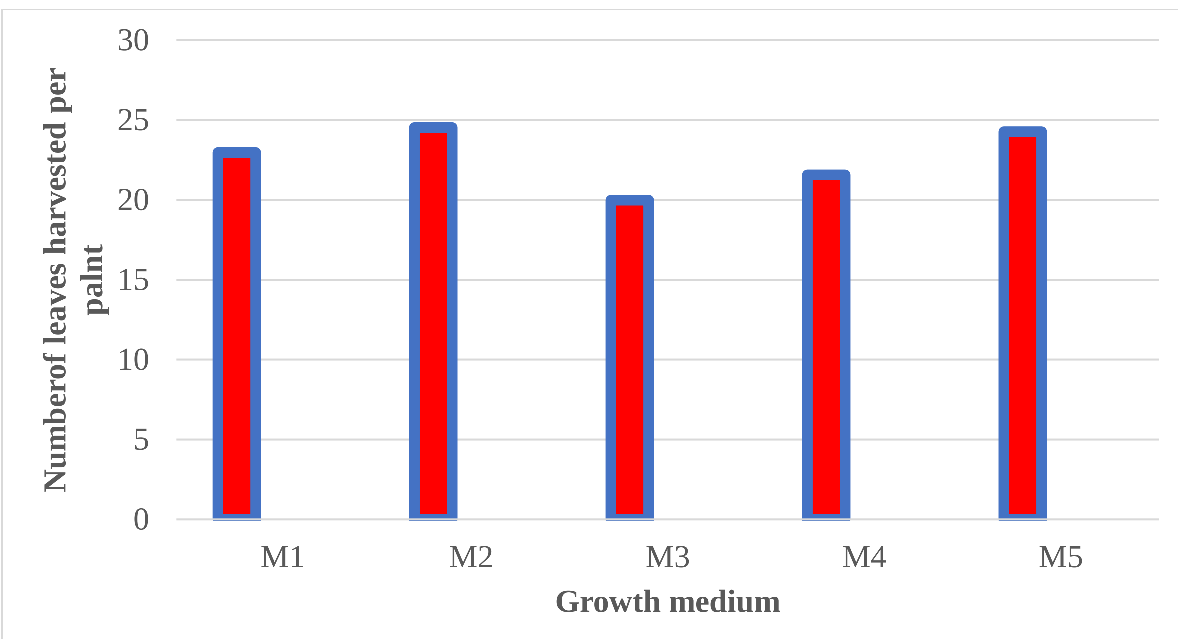

Fig 4. Effect of growth medium on number of leaves harvested per plant in spinach beet

Even though number of leaves per plant was higher and on a par for the growth medium M_2, M_5 and M_1, the leaf yield per plant was significantly superior for growth medium M_5 (Fig.3). This might be due to the large thick leaves produced in the medium comprising of suchitha. Taller plants and higher LAI also contributed to a higher leaf weight. This pointed to the fact that there might not be any positive correlation between number of leaves harvested and the leaf yield per plant in spinach beet. This is in consonance with the findings of Raghunath (2001) where no positive correlation between yield and number of leaves was reported. The leaves harvested from plants in M_5 were larger sized which could be due to the higher nutrient availability with the presence of suchitha. Since suchitha is made from organic wastes, its rich nutritional status for both micro and macro nutrients would be the probable reason for higher nutrient availability in M_5. Jayakrishna *et al*. (2016) reported nutritional status of suchitha as 3.6 % N, 0.4% P, 1.5% K and micronutrients as Fe (3518 mg kg^{-1}) , Mn (172 mg kg^{-1}), Cu (52mg kg^{-1}), Zn (197 mg kg^{-1}) and B(1.2 mg kg^{-1}).Yawalker (1963) reported that with increased NPK, yield of spinach beet also increased when compared to control. This is suggestive of the fact that the crop demands a higher availability of nutrients especially N. Nitrogen, being a component of protoplasm had a favourable effect on chlorophyll content of leaves and resulted in increased synthesis of carbohydrates. Several studies authenticate the role of nitrogen in line with findings of Ramakrishna (2005), Phadnis *et al*. (2007) and Madhavi *et al*. (2009).

Regarding total dry matter production in different growth medium, the highest total dry matter production was recorded with the growth medium M_5 (Fig.5). Higher dry matter production might be due to increased leaf area, higher leaf yield and increased number of leaves. The increased leaf area leads to increased photosynthetic efficiency and increased carbohydrate assimilation (Rao, 2003). As nutrient

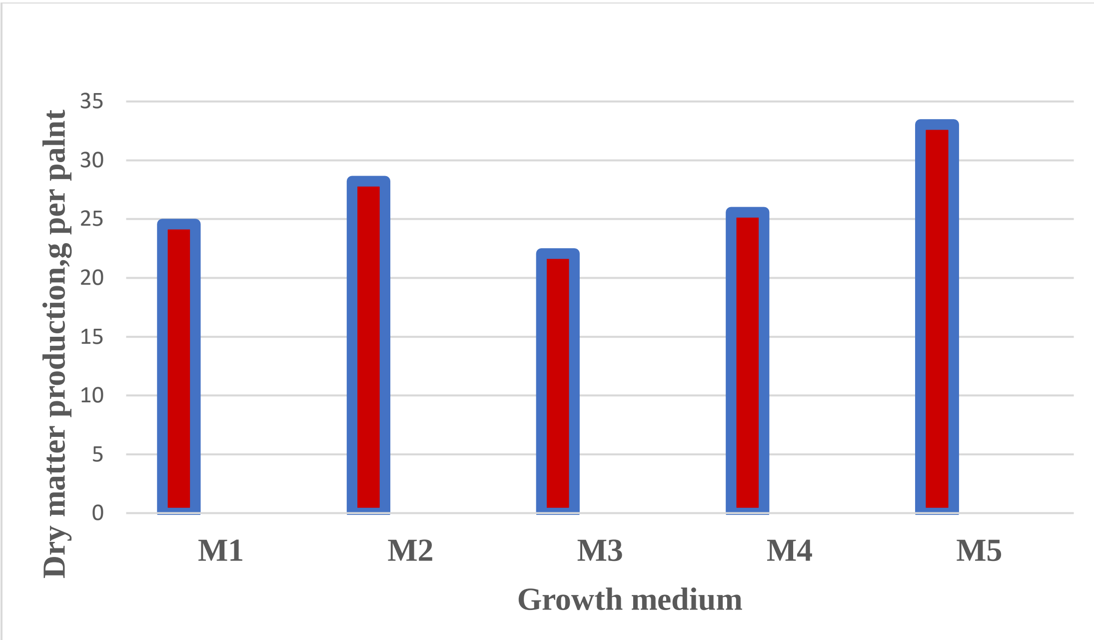

Fig 5. Effect of growth medium dry matter production, g per plant

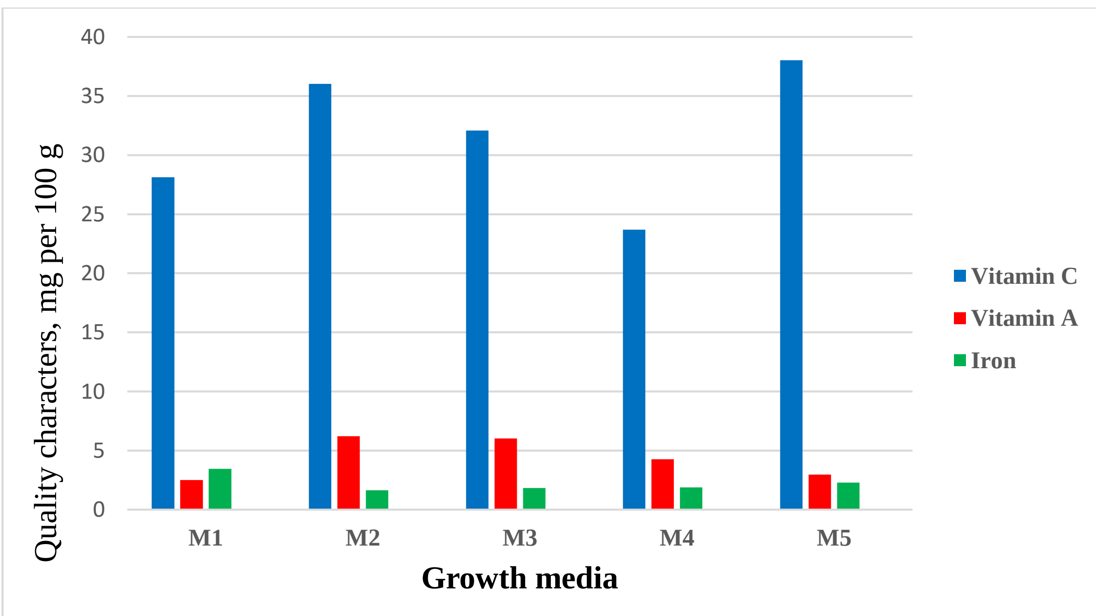

Fig 6. Effect of growth medium on quality characters of spinach beet

uptake is a positive function of dry matter production (Ramakkal *et al.*1988), M_5 registered the highest NPK uptake due to increased drymatter production. This is in consonance with findings of Mallangouda *et al*. (1995) in onion and Prabhakaran (2003) in tomato.

When root characters were analysed, root weight and root shoot ratio were also found higher in M_5. Root growth is important in determining the nutrient supply to the shoot which in turn, affects crop yield (Barber and Silberbush,1984). Increasing nutrient supplies in the soil may decrease root length but increase root weight in a quadratic fashion (Fageria and Moreira, 2011). A higher nutritional status of suchitha automatically augment a higher nutrient availability in M_5 which could lead to a higher root weight. Better physical and chemical properties of the growth medium also might have contributed to improved root growth. The average root weight of spinach beet in M_5 was 14.77 g whereas the root weight recorded in M_3 was only 8.14g. This clearly illustrated the superiority of suchitha as a rooting medium. There was no significant effect of growth medium on root volume because root volume which normally may not vary much in containers of uniform size was unaffected by any of the growth medium tested. Similar result was reported by Nesmith and Duval (1998).

Leafy vegetables play a vital role in daily diet of humans with high nutritional values. However, the nutritional quality of a crop depends on soil factors such as pH, available nutrients, texture, organic matter content, fertilizer applications, cultural practices, soil-water relationships and weather and climatic factors (Hornick,1992). Regarding the different quality attributes, the growth medium with suchitha recorded higher vitamin C at third harvest. The increase in ascorbic acid content in the leaves of spinach beet grown in the medium containing suchitha might be due to its better nutritional status enabling better uptake of major and micronutrients leading to increased carbohydrate synthesis and corresponding biosynthesis of vitamin C. Ultimately the carbohydrates synthesised might get converted into ascorbic acid which is a monosaccharide derivative.

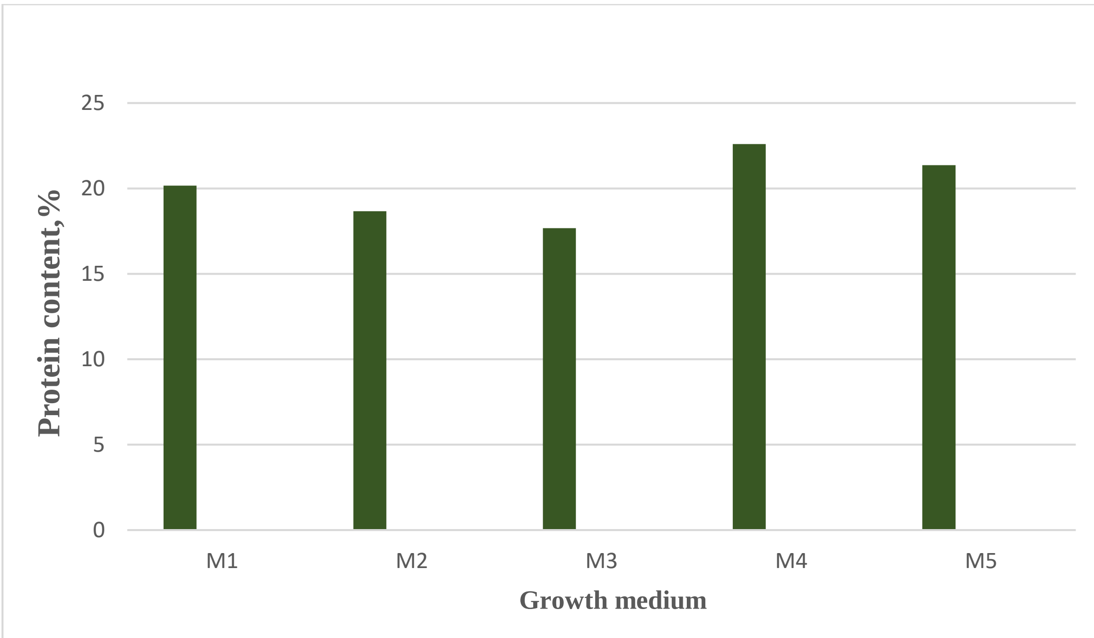

Fig 7. Effect of growth medium on protein content of spinach beet

The growth medium with rockdust recorded higher vitamin A content which could be attributed to its faster solubility rate both in water and organic acids, promptly releasing nutrients and increasing the pH of solution (Keller,1948). However, the iron content in conventional growth medium was superior to rest of the combinations. This can be ascribed to the ideal textural composition and favourable EC of conventional growth medium which favoured better root growth as evident from the higher root shoot ratio and root volume. Higher root growth might have helped in better iron uptake. Though no consistent results could be obtained in general with respect to protein content of leaves, higher leaf nitrogen during third harvest augmented higher protein content in M_4.

Availability, accessibility and economic feasibility are the facts that decide the widespread acceptance of a growth medium. The economic analysis favoured spinach beet cultivation in the growth medium where sand was substituted with rockdust. Though the growth medium M_5 registered a higher yield, higher net income and BC ratio were recorded in growth medium M_2 since the component that replaced sand in M_5 was suchitha which is a costly material. But the component in the growth medium M_2 was rockdust which is cheap and easily available. In coleus cultivation, rockdust application @ 10 t ha^{-1} along with equal quantities of FYM resulted in a higher BC ratio of 2.08 compared to POP recommendation (Rose,2008).

5.2 EFFECT OF NUTRIENT LEVELS ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN SPINACH BEET

Nutrient management especially nitrogen has a significant importance in spinach beet as leaves are the economically important plant part. Rajeswari and Shakila (2010) reported organic nutrition to be the best for spinach beet. However, there is a lack of an organic nutrient schedule for container grown spinach beet at present. The present recommended dose (RD) of NPK for the crop is 80:40:80 kg per ha (Alur, 2017). As organic manures serve as slow release source of N, P and K for plant nutrition and microbial growth, higher doses of nitrogen (150 and 200 per cent) in addition to the RD of NPK were tested for formulating an organic nutrient schedule.

The results of the study disclosed the superiority of existing RD of NPK supplied entirely as basal for most of the yield parameters. Plants fertilised with RD of NPK through organic sources recorded superior values with respect to height, LAI and number of leaves harvested per plant. This implied the fact that higher dose of nitrogen via organic sources could not bring about any substantial increase in plant height or number of leaves per plant. Correspondingly, nutrient levels could not produce any significant influence on leaf yield per harvest and leaf yield per plant. Manure application at RD might have provided the required NPK for plant growth. In spinach, Magen (2008) and Alur (2017) reported balanced NPK nutrition for increased yield.

Amongst the root parameters, root weight and root shoot ratio varied significantly with nutrient levels. Root characters were higher at RD of NPK (80:40:80) implying the significance of balanced nutrition. This indicated that excess nutrient supply by organic means had not enhanced root growth. This is contradictory to findings of Cuckoorani (2013) in organic bhindi raised in growbags where higher dose of nutrients helped in better proliferation of root system. Because of higher root weight, higher root shoot ratio was also recorded in N_1. It has been reported that mineral nutrient supply has a significant influence on both the size and morphology of the root system and this effect of mineral nutrition depends mainly on the nutrient, the concentration range considered, the means of application, and on environmental conditions (Jager, 1986).

Standardising the manurial dose for quality leaf production is of utmost importance in spinach beet being a nutritious leafy vegetable particularly rich in vitamins (A and C), iron and protein. Many studies revealed the unfavourable effect of nitrogenous fertilisers on leaf quality (Audonin and Kochubei,1979). However, in the present study 200 per cent nitrogen topdressed along with RD of NPK through organic sources recorded significantly superior vitamin A and vitamin C content in spinach beet. Increase in quality attributes like vitamin C in N_3 may be attributed to the enhanced production of growth promoting substances which accelerates physiological processes like synthesis of carbohydrates or monosaccharides. Ascorbic acid, which is a monosaccharide derivative is produced from carbohydrates in presence of enzymes. This is in conformity with the reports of Balakrishnan (1988) in chillies, Kalyani *et al*. (1996) in cauliflower and Karuthamani *et al*. (1995) in pumpkin. Higher vitamin A levels could be due to the balanced and reliable supply of nutrients, both major and micro from organic sources resulting in favourable carbohydrate metabolism in plants. Organic crops contain a significantly higher number of antioxidants (vitamin C, polyphenols and flavonoids) as well as minerals than conventionally raised crops (Gyorene *et al*., 2006). The iron content in the leaves were found higher in RD of NPK and there was a decrease in iron content with progressive increase in nitrogen. Bawa and Yadav (1986) reported that the iron content of spinach beet leaves varied in amounts according to the stage of maturity, conditions of growth, fertilizers used and nature of soil. It is in contrast to findings of Bhatt (1998) where application of NPK fertilizer has a greater impact on the enhancement of iron content of spinach. The study indicated a significantly high protein content with 150 per cent nitrogen top dressed along with RD of NPK. This could be due to the high nitrogen content (0.037% in the leaves. The higher nitrogen content may be diverted for conversion into protein. Worthington (1998) reported improved protein quality in organic crops over conventionally grown crops.

The nutrient levels showed no significant influence on the dry matter production. This is in total disagreement with the findings of Vivek (2005) where he reported that dry mater production increased with increase in the application of fertilizer levels in spinach beet. Application of 150 per cent nitrogen along with RD of NPK recorded higher nitrogen uptake at final harvest and this increased uptake could be attributed to prolonged availability of nitrogen to the plants. The nutrient provided by fermented ground nut cake was sufficient enough to produce an enhanced nitrogen uptake. This is in consonance with the findings of Anjana (2017) where she observed higher N uptake in 100 per cent recommended dose which is supplied through fermented ground nut cake. However, P and K uptake were found unaffected by nutrient levels This accords with the reports of

Vijaylekshmi(1990) where P uptake in garden pea was not influenced by different levels of N and Santoki (1991) where different levels of N couldn't produce any significant influence on P and K content of rice.

Available N, organic carbon, pH and EC of the medium after the experiment were found to be influenced by nutrient levels. Available N and OC were superior in RD of NPK indicating the supremacy of balanced fertilisation by in organic nutrition. The results find ample support from the findings of Manna *et al*., (2013) where balanced application of nutrients had positive effect on soil carbon and Soumya (2015) where 100 per cent recommended dose resulted in higher available N after the experiment than 125 per cent of recommended dose.

Benefit cost ratio shows the economic feasibility of cultivation. Application of 100 per cent RD of NPK recorded higher net income and BCR. Application of recommended dose showed positive impact on benefits rather than higher doses leading to lower cost of production with higher net income and subsequently higher BCR.

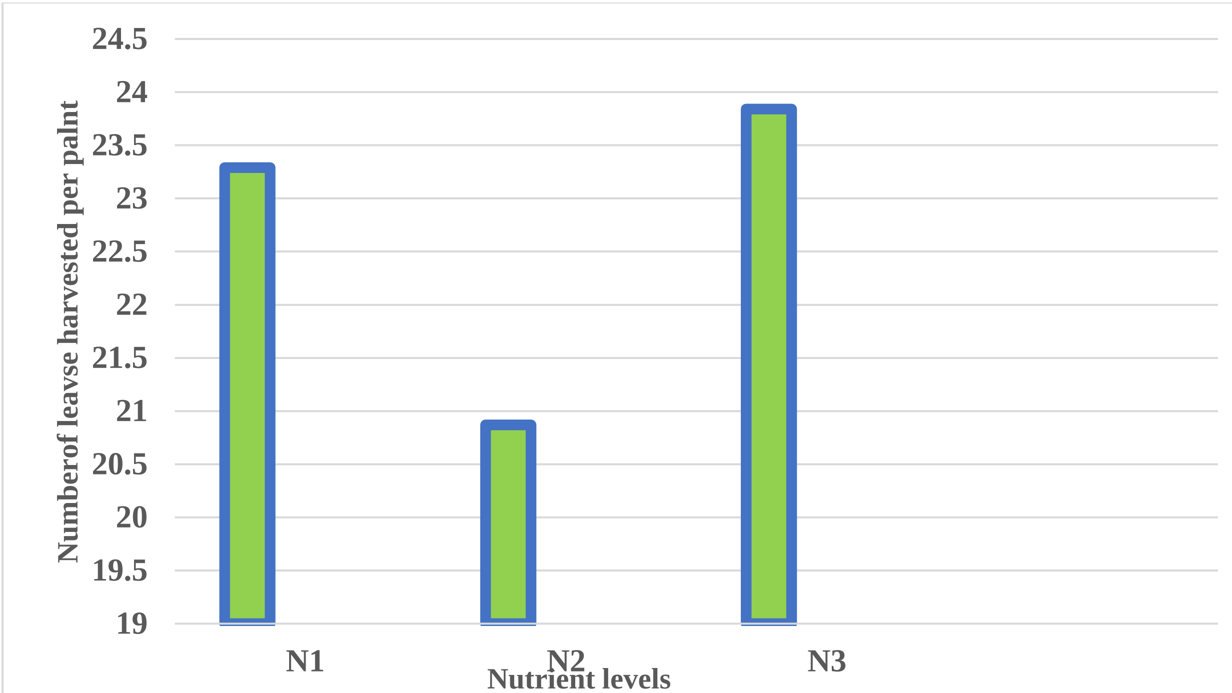

Fig 8. Effect of nutrient levels on number of leaves harvested per plant in spinach beet

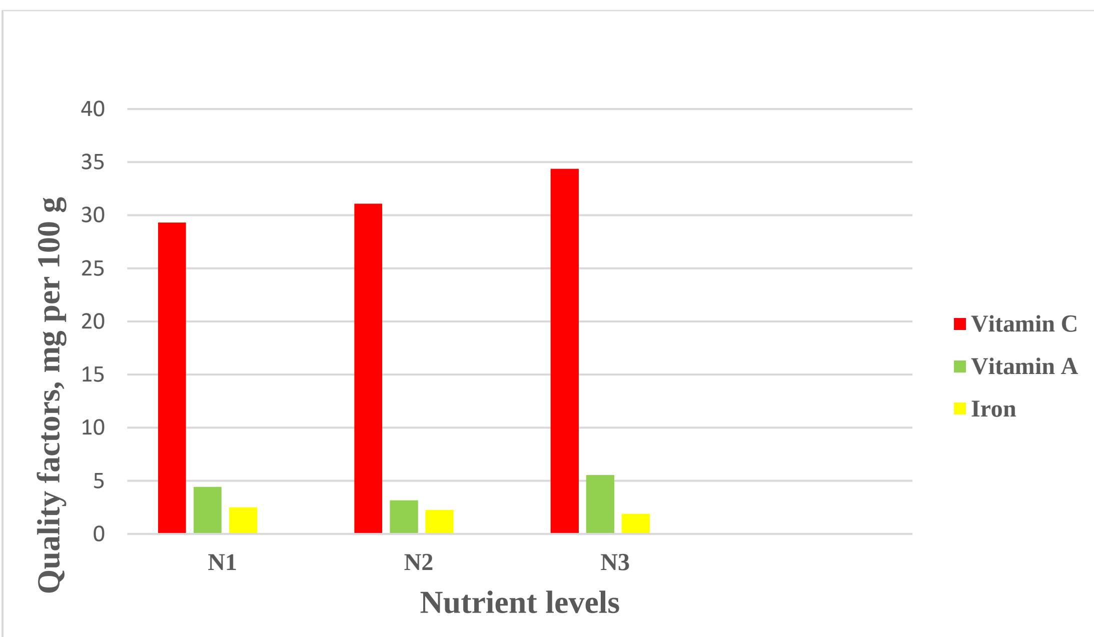

Fig 9. Effect nutrient levels on quality characters of spinach beet

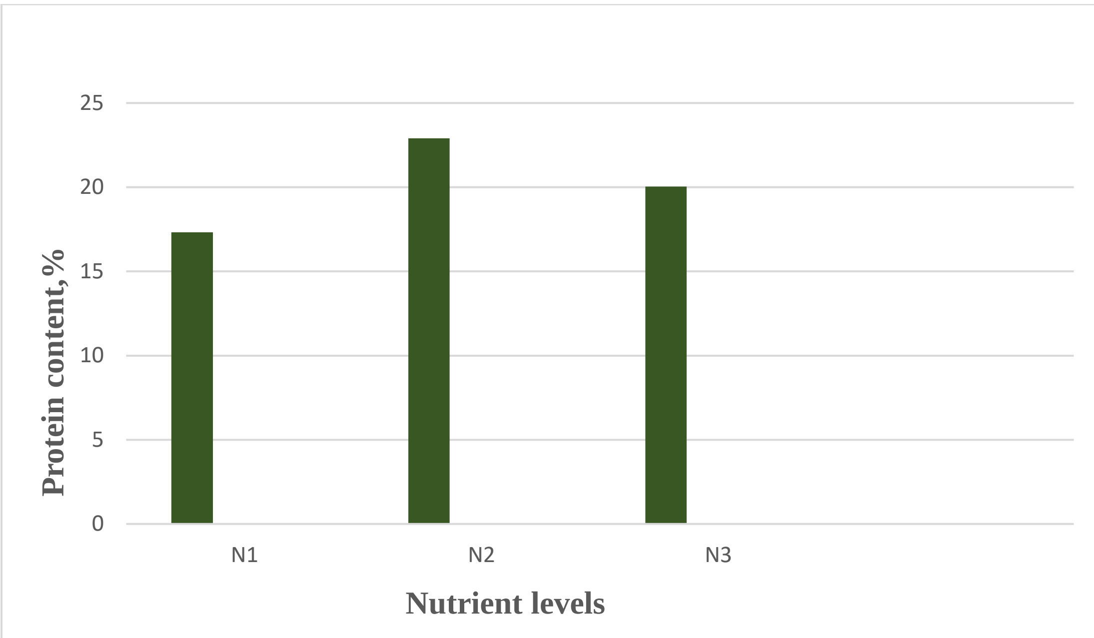

Fig 10. Effect nutrient levels on protein content of spinach beet

5.3 INTERACTION EFFECT OF GROWTH MEDIUM AND NUTRIENT LEVELS ON GROWTH AND YIELD CHARACTERS OF CONTAINER GROWN SPINACH BEET

The interaction between growth medium and nutrient levels had significant influence on the growth, yield and quality parameters of container grown spinach beet. Among the interactions, m_5n_1 had significant effect on leaf area index, leaf yield per plant, leaf yield per harvest and dry matter production. This might be due to the cumulative effect of individual treatments. Anjana (2017) reported significance of interaction between growth media combinations and nutrient levels in registering higher number of primary branches per plant in container grown yardlong bean.

The quality attributes were influenced by different combinations of growth medium and nutrient levels. The interaction m_5n_3 recorded higher vitamin C content, m_4n_3 recorded higher vitamin A content, m_1n_1 recorded higher iron content and m_4n_2 recorded higher protein content. Better nutritional status of suchitha enabling better uptake of major and micronutrients coupled with higher nitrogen levels supplied through organic sources led to increased carbohydrate synthesis and corresponding biosynthesis of vitamin C. Asami *et al.* (2003) reported superiority of organic produce with respect to vitamins and minerals over conventionally grown plants. Growth media with rockdust and compressed coirpith with additional nitrogen supplementation via organic sources resulted in higher levels of vitamin A and protein. Reddy *et al*. (2014) stated that the combination of organic manures along with biofertilizers resulted in highest carotenoid content in spinach.

Even though m_5n_1 recorded higher leaf yield, the net income and BC ratio were lower and m_2n_1 had the highest net income and BC ratio. Rockdust being a cheap and easily available material, the cost incurred for preparation of growth media had been reduced. The growth medium with soil: rockdust and FYM in 1:1:1 proportion raised

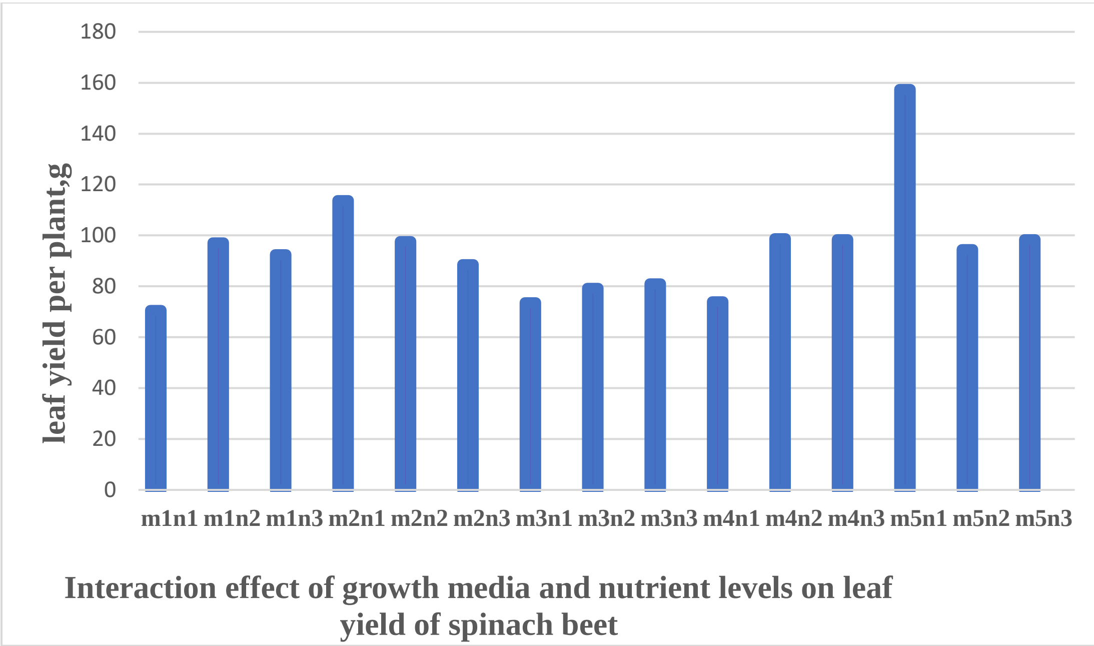

Fig 11. Interaction effect of growth medium and nutrient levels on leaf yield per plant in spinach beet

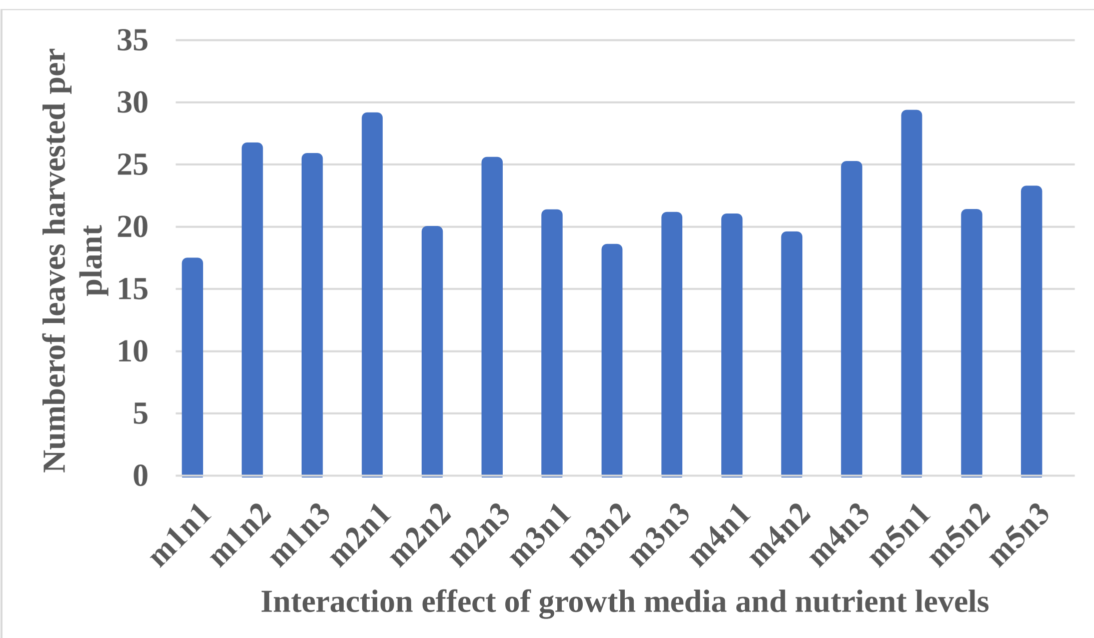

Fig 12. Interaction effect of growth medium and nutrient levels on number of leaves harvested per plant in spinach beet

Plate 2. Best treatment in terms of economics (m_2n_1)

Plate 3. Best treatment in terms of yield (m_5n_1)

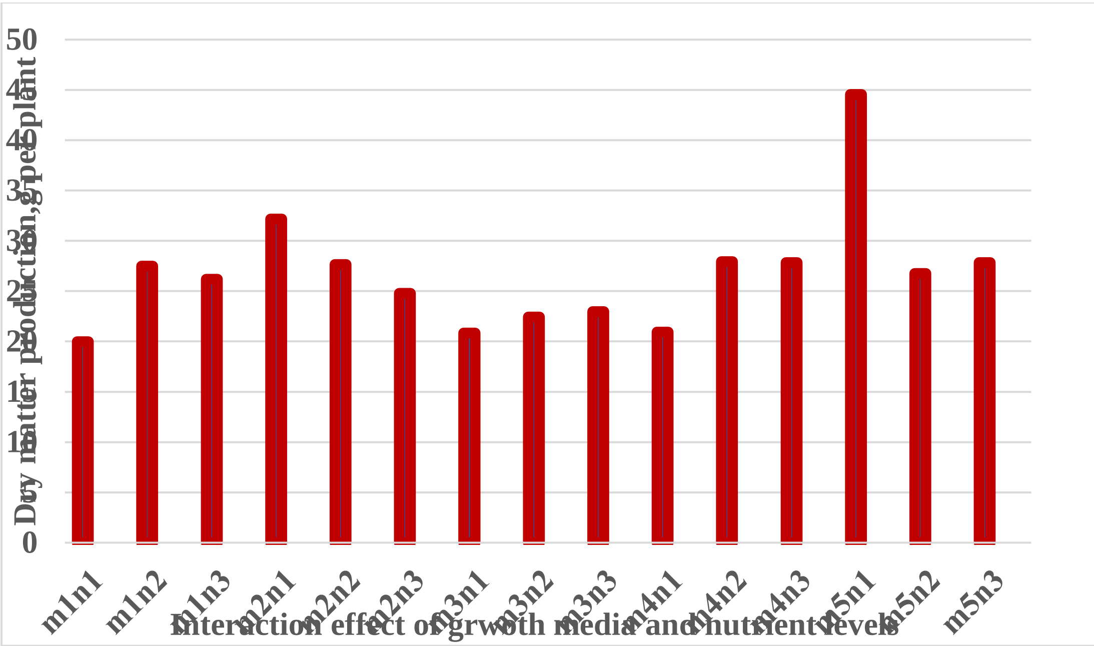

Fig 13. Interaction effect of growth medium and nutrient levels on dry matter production of spinach beet

under recommended level of nutrients (80:40:80 kg ha^{-1}) recorded a significantly superior B:C ratio of 1.67. This is suggestive that rockdust can successfully replace sand and could be recommended for areas where rockdust is locally available. As an alternate option, the next best combination of conventional medium with 50 per cent more N topdressed in 3 splits along with recommended dose could also be suggested. The growth medium containing suchitha under recommended level of nutrients though registered a higher yield, the higher unit price of the input hadn't favoured its economics.

5.4 STUDIES ON NUTRIENT AVAILABILITY IN DIFFERENT GROWTH MEDIUM (INCUBATION STUDY)

To meet crop nutrient requirement, a knowledge of soil chemical characteristics following manure application in soil is needed. It is pertinent to observe the chemical changes over time as the growth medium components vary in nutritional status. The concurrent incubation study conducted under laboratory conditions aimed to observe the changes in pH, EC, organic carbon, available N, P and K in the growth medium over a period of 3 months.

Initially, pH values of all the growth medium except with suchitha indicated a neutral range (6.6 to 7.3). Jayakrishna *et al*. (2016) also recorded a pH of 7.4 for suchitha used as growth medium. M_5 had an initial pH in the slightly acid range (6.41). On incubation, the pH of all the growth medium showed an increasing trend and it ranged between 6.5 to 7.5. Amongst all the growth medium tested, the growth medium M_2 which had rockdust as one of the components showed a progressive increase in pH in neutral range over the periods of incubation. It was reported that rockdust has fast solubility rate both in water and weak acids promptly releasing nutrients within minutes and increasing the pH of the solution (Keller,1948). However, the growth medium containing suchitha showed a lesser hike in pH value during the entire period of incubation. The trend in pH changes observed with different nutrient levels were in line with the growth medium. Application of poultry manure as basal dose hadn't changed pH irrespective of the growth medium. Amongst the growth medium nutrient level combinations, there was progressive decrease in acidity reaching neutrality during incubation.

Electrical conductivity is an important parameter used to estimate the level of dissolved salts in water and soil. The different growth medium components exerted a strong influence on deciding the EC value of the medium with an increasing trend displayed over the periods of incubation. The growth medium M_3 with compressed coirpith as one of the components recorded a significantly higher initial EC of 1.41 unit which showed a progressing trend over the months. As there is no leaching loss of nutrients happening in incubation study unlike field conditions, the concentration effect of soluble salts from coirpith might have enhanced EC values in M_3. This is in consonance with the findings of Limisha and Swadija (2019) where higher EC value due to the release of more soluble salts by the decomposition of coirpith on growth medium incubation had been reported. However, the traditional growth medium recorded a safe limit of EC value (<1) during the entire period.

The different nutrient levels applied to the medium were found to enhance the EC of the medium during incubation. Though the recommended dose recorded a safer value (0.98) initially, it was found to increase during incubation. This could be because of the addition of poultry manure as nitrogen source. Azeez and Van Averbeke (2012) found that electrical conductivity of soil significantly increases with the application of poultry, cattle and goat manures and the potential of manure induced soil salinization was very high in poultry manure and goat manure compared with cattle manure. Dikinya and Mufwanzala (2010) revealed increased electrical conductivity with increasing rates of chicken manures. Among the interactions, traditional growth medium with any of the nutrient levels tested were found to have a safe EC limit during incubation. However, growth medium combinations with M_3 and M_4 where presence of coirpith was realized, the EC values were found to be above 1.

The growth medium had significant effect on organic carbon status with a progressive increase during incubation. During the initial month, the growth medium with coirpith recorded a significantly higher organic carbon content compared to other growth medium. The higher organic carbon status at the beginning of incubation is indicative of a larger pool of resistant fractions that were available to be broken down. Limisha and swadija(2019) also observed a higher initial organic carbon status in growth medium containing coirpith which followed a declining trend upto 4 months after incubation. During second and third month, growth medium with rockdust (M_2) registered a higher organic carbon content. Vipitha (2011) reported that the mixture containing poultry manure, ground nut cake and Rockdust recorded the higher organic carbon content and the least was recorded in the mixture without rockdust. During the entire period of incubation, the growth medium M_5 recorded the lowest organic carbon content. Ramesha (2019) reported that the organic carbon content was higher for thermochemical organic fertilizer which is fortified with other mineral nutrients compared to thermochemical organic fertilizer without fortification. The various nutrient levels tested had significant influence on organic carbon status at all the stages with N_3 recording the lowest organic carbon during second and third month. From several studies it has been found that addition of manures increases the soil organic carbon initially. In the present study, topdressing with a highly soluble manure like fermented ground nut cake might have led to its breaking down at a faster pace within a short period resulting in lower content at the end.

Mineralization is a process of conversion of unavailable organic forms of nutrient to the plant available inorganic form (Tisdale *et al*., 1997). The growth medium showed significant effect on final available N status with a progressive increase. Vipitha (2011) observed a higher available N content upto 3 MAI which decreased afterwards when different organic manure mixtures were incubated for 6 months. The growth medium with compressed coirpith (M_3) recorded higher available N till the end of incubation. The optimum C: N ratio of a good manure has been suggested as $< 20:1$ (Manna, 2004). In the present study, except compressed coirpith, all other organic amendments had fairly narrow C:N ratio which indicated the dominance of N mineralization upon their incorporation in the soil. A wider C:N ratio in compressed coirpith indicated a slower mineralization activity during decomposition. The different levels of nutrients supplied to the medium exerted significant influence on available N status throughout the period of incubation with the highest nutrient level (N_3) registering higher available N status. Obviously, the lowest available N status was recorded in recommended dose (N_1) during all the growth stages.

The growth medium had significant effect on available P during all the months. On an average, there was a consistent increase in P release from organic growth medium components throughout the incubation period. At all stages of incubation, growth medium containing both rockdust and compressed coirpith (M_4) recorded significantly superior available P status. The higher initial available P status might be contributed from coirpith on decomposition over time and presence of rockdust might have solubilised more P and made available in the medium. Limisha and Swadija (2019) also reported higher P availability during second and third month of incubation from compressed coirpith. Initial increase of available P on incubation was observed by many researchers *viz.*, Sheeba (2004), Rose (2008), Vipitha (2011) and Limisha and Swadija (2019). Moharna *et al*. (2015) observed that the soil containing rock phosphate enriched compost on incubation showed an increasing trend in available P over the period of incubation.

The various nutrient levels tested had significant influence on available P at all the stages with N_3 recording higher available P. The growth medium containing rockdust and coirpith with higher nutrient levels (m_4n_3) resulted in significantly higher available P status during all the stages of incubation. The possible reason for this higher P status might be the contribution of soluble P both from rockdust and fermented ground nut cake as raw ground nut oil cake contains 1.5% Phosphorus. This accords for the reports of Rose (2008) where high rate of application of rockdust @ 10 t ha $^{-1}$ resulted in increase in the available nutrient content of soil and reduced the recommended dose of organic fertilizers to half in coleus.

With regard to the K content on incubation, a progressive increase during the period was observed. The conventional growth medium of soil: sand: FYM in 1:1:1 (M_1)

recorded higher available K status during all stages of incubation. This could be probably because of higher release of K from FYM under ideal textural composition. Based on the released amount of nutrients from different organic amendments, the best source seemed to be farmyard manure for K (Dey *et al*., 2019). The various nutrient level tested had significant influence on available K with the recommended dose of nutrient recording higher available K during all the three months. This is in total disagreement with the results of Limisha and swadija(2019) where the growth medium comprising compressed coirpith recorded higher K content throughout the period of incubation and the conventional potting medium recorded the lowest available K.

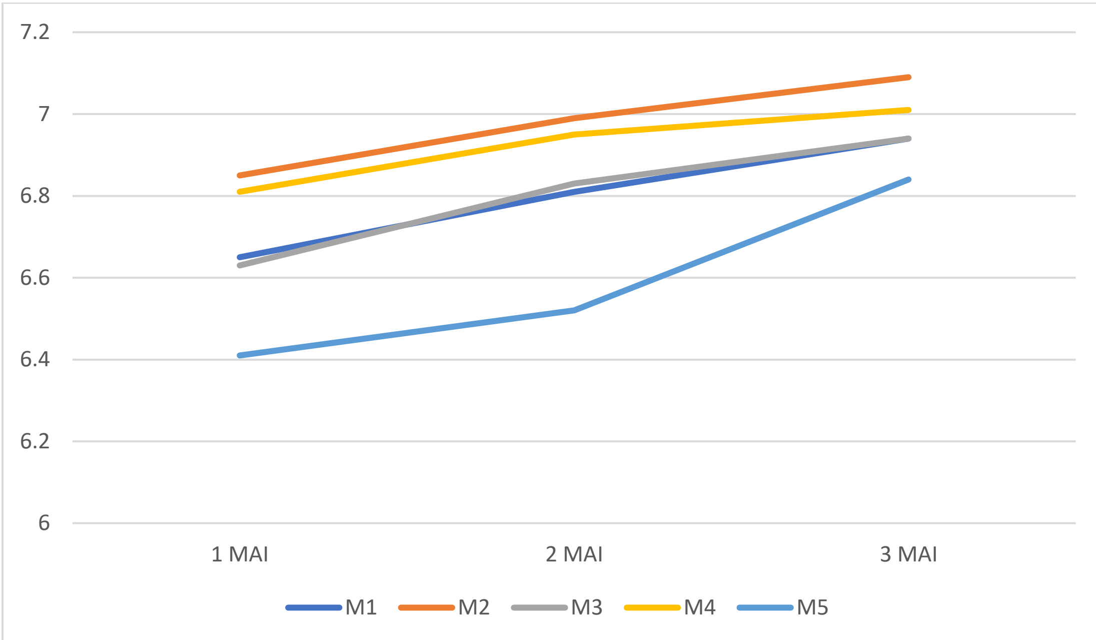

Fig 14. Change in pH of growth medium on incubation

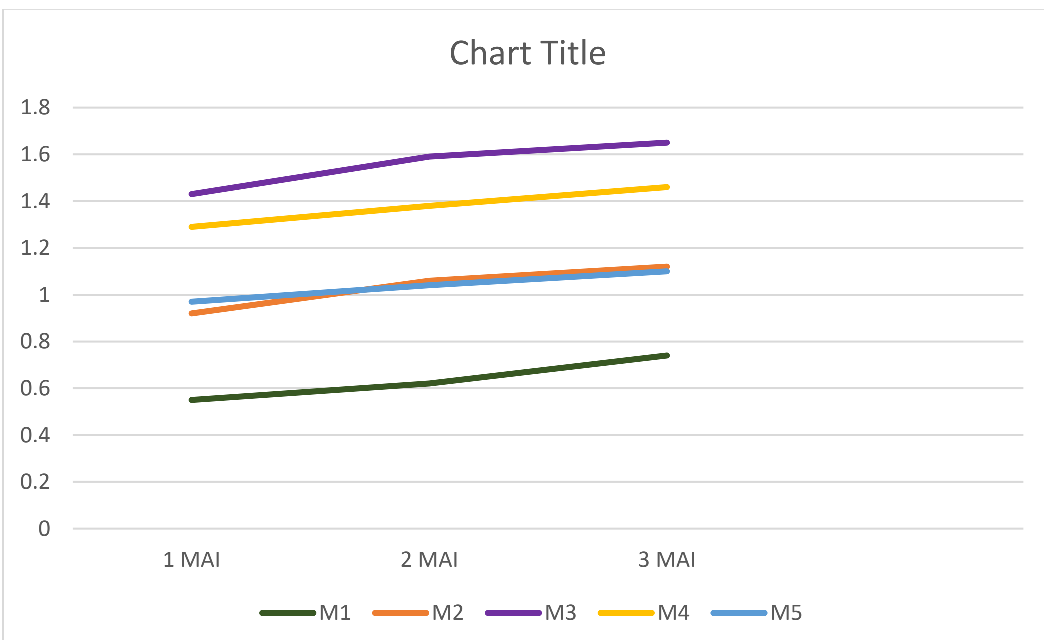

Fig 15. Change in EC of growth medium on incubation

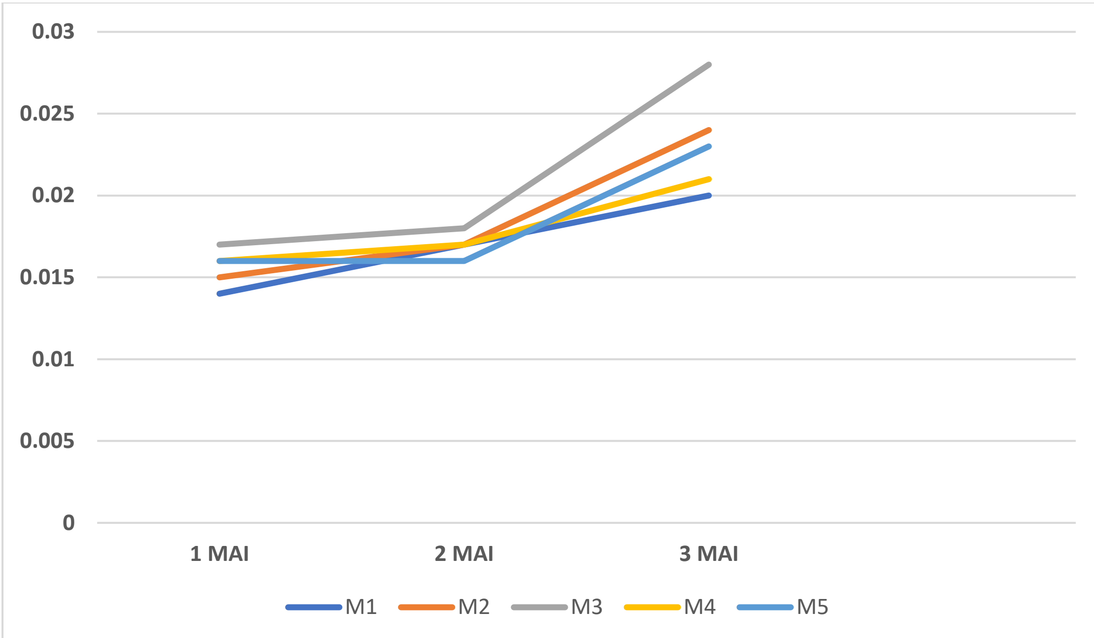

Fig 16. Change in available N in growth medium on incubation

The study investigated two factors related to container grown spinach beet cultivation *viz.*, growth media combinations and nutrient levels. From the results of the experiments conducted, the ideal growth media combination and organic nutrient schedule for container grown spinach beet could be summarised as

- Growth medium : soil: suchitha : FYM in 1: 1: 1 ratio on volume basis with respect to yield and soil: rockdust: FYM in 1: 1: 1 ratio on volume basis with respect to economics
- Organic nutrient schedule: 100 per cent recommended dose of 80:40:80 kg NPK ha^{-1} suppled as poultry manure (10g per plant) with entire dose as basal application.
- Ideal growth medium-organic nutrient schedule combination with respect to yield for container grown spinach beet could be soil: suchitha : FYM in 1: 1: 1 ratio on volume basis with 100 per cent recommended dose of 80:40:80 kg NPK ha^{-1} as basal application
- Ideal growth medium- organic nutrient schedule combination with respect to economics for container grown spinach beet could be soil: rockdust: FYM in 1: 1: 1 ratio on volume basis with 100 per cent recommended dose of 80:40:80 kg NPK ha^{-1} as basal application.

Summary

6. SUMMARY

The investigation entitled "Standardisation of growth media and organic nutrient schedule for container cultivation of spinach beet (*Beta vulgaris* var. *bengalensis*)" was undertaken at College of Agriculture, Vellayani during the period 2019-2020. The primary objectives of the study were to identify an ideal growth medium and to standardise an organic nutrient schedule for container grown spinach beet.

The first experiment on 'Standardisation of growth media and organic nutrient schedule for container cultivation of spinach beet (*Beta vulgaris* var. *bengalensis*)' was undertaken during the *rabi* season of 2019 at the Instructional Farm, College of Agriculture, Vellayani. The treatments consisted of five growth media {M_1: soil : sand : FYM (1:1:1), M_2 : soil : rockdust : FYM (1: 1: 1), M_3: soil: compressed coirpith: FYM(1:1:1),M_4: soil: compressed coirpith: rockdust: FYM (1:0.5:0.5:1), M_5: soil: suchitha: FYM (1:1:1)} and three nutrient levels (N_1: 100% of 80:40:80 kg NPK ha^{-1} , N_2: N_1 + 50% N topdressed in three splits, N_3: N_1 + 100% N topdressed in three splits). The experiment was laid out in completely randomized design with three replications. The crop was raised uniformly in UV stabilized woven plastic sacks of thickness 1400 denier capable of holding 15 kg potting mixture with 15 treatment combinations. The major nutrients N, P and K were applied by organic means as poultry manure and fermented groundnut cake as per the treatments. The results of the experiment are summarized hereunder.

- At 30 and 60 DAS, the growth medium M_4 recorded higher plant height and was on par with M_3 and M_5 at 60 DAS.
- At 75 DAS, M_2 recorded higher plant height which was on par with M_4 and M_5 while at 105 and 120 DAS, M_5 recorded higher plant height which was on was on par with all growth media except M_1 at 120 DAS.

- At 30 ,75 and 105 DAS nutrient level N_3 recorded higher plant height and was on par with N_1 while at 105 DAS N_3 was on par with N_2.
- Among the interactions at 75 and 90 DAS, m_4n_3 recorded higher plant height which was on par with m_5n_1. At 105 DAS m_5n_1 recorded higher plant height which was on par with all the interactions except m_1n_1. At 120 DAS, m_4n_3 recorded higher plant height which was on par with m_2n_1, m_2n_3, m_3n_2, m_3n_3, m_5n_1 and m_5n_2.
- LAI was significantly superior in M_5 at all stages of growth and the nutrient level N_1 registered higher LAI except at 60 DAS and at 60 DAS. N_2 recorded higher LAI which was on par with N_1. The interaction m_5n_1 recorded significantly superior LAI at all stages of growth.
- The growth media M_5 recorded higher leaf yield per harvest which was on par with M_2 except at 60 DAS. The nutrient levels tested didn't exert any significant influence on leaf yield per harvest. Among the interactions, m_5n_1 recorded superior leaf yield per harvest and was on par with m_2n_1 except at 60 DAS.
- The growth media M_2 recorded higher number of leaves harvested per plant which was on par with M_5 and M_1. The nutrient level N_3 gave higher number of leaves harvested per plant which was on par with N_1. m_5n_1 recorded higher number of leaves which was on par with m_2n_1, m_1n_2, m_1n_3, m_2n_3 and m_4n_3.
- Growth media M_5 which has suchitha as one of the growth media components recorded the maximum leaf yield per plant and was significantly superior over all other treatments. Different nutrient levels tested didn't exert any significant influence on leaf yield per plant. m_5n_1 have significantly superior effect on leaf yield per plant.
- The growth medium M_5 recorded higher dry matter production and the nutrient levels tested didn't exert significant influence on dry matter production. m_5n_1 recorded higher dry matter production among the interactions and was significantly superior to all other interactions.
- The growth media M_5 recorded significantly superior root weight and nutrient level N_1 recorded higher root weight which was significantly superior over all other

treatments. Among the interactions, m_5n_2 recorded higher root weight which was on par with m_2n_1.

- The growth medium M_5 registered higher root shoot ratio which was on par with M_1. The different nutrient levels tested had significant influence on root shoot ratio and N_1 recorded higher root shoot ratio which was on par with N_2.
- Among the quality parameters, the growth medium M_5 registered higher vitamin C content which was on par with M_2 and the nutrient level N_3 registered higher vitamin C content. Among interactions, m_5n_3 recorded higher vitamin C content.
- Vitamin A content was higher for the growth medium M_2 and the nutrient level N_3 registered higher vitamin A content. The interaction m_4n_3 had registered higher vitamin A content which was on par with m_3n_3 and $m_3n_{1.}$
- M_1 and N_1 registered higher iron content and among the interactions, m_1n_1 was significantly superior over all other treatments.
- The growth medium M_4 and the nutrient level N_2 registered higher protein content. Among the interactions, m_4n_2 registered higher protein content.
- The growth medium M_5 recorded higher uptake of N and it was significantly superior over all other treatments. The nutrient level N_1 and the interaction m_4n_2 recorded higher uptake of N which was on par with $m_5n_{1.}$
- The growth medium M_5 recorded higher P uptake and it was significantly superior over all other treatment and the various nutrient level tested and the interaction didn't exert any significant influence on P uptake.
- The growth medium M_5 recorded significantly higher K uptake. The various nutrient levels tested had no significant influence on K uptake. The interaction m_5n_1 recorded higher K uptake and it was significantly superior over all other interactions.
- The growth medium M_5 registered higher organic carbon content after the experiment. The nutrient level N_3 registered higher organic carbon content which was on par with N_1.

- The growth medium M_3 and nutrient level N_1 registered higher available N content. Among the interactions, m_5n_1 recorded higher available N content after the experiment.
- The growth media M_3 registered higher available K content and the nutrient levels and interaction didn't exert any significant influence on available K content after the experiment.
- Among the growth medium M_2 and among the nutrient levels N_1 recorded higher BC ratio and net income. Among the interactions, m_2n_1 recorded higher BC ratio and net income

The concurrent lab incubation study on nutrient availability in different growth media was conducted in Completely Randomised Design with 15 treatments replicated thrice. The five-growth media combinations were uniformly supplied with the recommended dose of NPK (80:40:80 kg ha $^{-1}$) as poultry manure and groundnut cake at respective intervals.

- The pH values of different growth media ranged between 6.5 to 7.5 and the growth medium M_3 which has compressed coirpith as one of the components had higher EC over the period of incubation.
- Organic carbon status of all the growth medium showed an increasing trend over the period of incubation.
- During the first month, organic carbon content in the growth media M_4 was higher and during second and third month M_2 recorded higher organic carbon.
- The nutrient level N_3 recorded higher organic carbon at first month. During the second and third month N_2 recorded higher organic carbon
- m_3n_3 recorded higher organic carbon content at first month and during the second and third month m_2n_1 recorded higher organic carbon content.
- During the first month, the growth medium M_3 recorded higher available N which was on par with all the growth medium. The growth medium had no significant effect on available N during the second month.

- During the third month the growth medium M_3 recorded higher available N. The nutrient level N_3 recorded higher available N during all the three months
- During the first month, m_3n_3 and m_4n_3 recorded higher available N which was on par with m_3n_2, m_4n_2, m_5n_3. During the second month m_4n_2 recorded higher available N which was on par with m_2n_3, m_3n_3, m_4n_3 and m_5n_3. During the third month m_2n_3 recorded higher available N.
- The growth media M_4 recorded higher available P during the entire period. The nutrient level N_3 recorded higher available P during all the three months and among the interactions m_4n_3 recorded higher available P during all the three months.
- The conventional growth medium of soil: sand: FYM in 1:1:1 (M_1) recorded higher available K status during all stages of incubation.
- The various nutrient levels tested had significant influence on available K with the recommended dose of nutrient (N_1) recording higher available K during all the three months.
- The combination m_3n_1 and m_1n_3 recorded higher available K during all stages of incubation.

From the results of the experiments conducted, the best growth medium and nutrient schedule for container grown spinach beet can be summarised as

- Growth media: soil: suchitha: FYM in 1: 1: 1 ratio on volume basis with respect to yield and soil: rockdust: FYM in 1: 1: 1 ratio on volume basis with respect to quality and economics
- Organic nutrient schedule: 100% recommended dose of 80:40:80 kg NPK ha^{-1} with entire dose as basal application

Future line of work

- Formulation of growth media with suchitha at various levels of substitution

- Effect of PGPR mix I and biofertilizers for yield and quality in container grown spinach beet
- Use liquid organic manures for nutrition in container grown spinach beet.
- Irrigation scheduling for container grown spinach beet

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Appendices

Appendix I

Weather data for the cropping period (Oct– Feb, 2019-2020)

Period	Standard week	Temperature (^{0}C)		Rainfall (mm) weekly Total	Relative humidity (%)	
		Max.	Min.		Max.	Min.
2019-2020	43	30.2	23.6	17.7	93.1	78.4
	44	29.5	24	15.2	94.4	82.1
	45	31.5	24.4	0	90.3	69
	46	32.5	24.8	3.6	90.4	66.7
	47	32	24.4	6.44	92.3	74.9
	48	32.6	24.5	3.2	94	68.1
	49	32.1	24.1	4.55	91.7	69.3
	50	32.2	23.7	6.07	90.9	71.7
	51	31.3	25.2	6.3	92.6	72.4
	52	31.97	25.4	7.4	92.7	68.7
	1	32.2	24.1	0	92.3	66.1
	2	32.01	22.67	45	93.4	66.3
	3	32.2	22.5	10	92.3	63.7
	4	32.7	23	0	91.4	64.1
	5	32.7	22.3	0	92.7	57.9

Appendix II

Cost of inputs

Sl No.	Inputs	Cost (₹)
1	Growbag	15 per bag
2	Seed	70 kg^{-1}
3	Coirpith	144 per block
4	Sand	3 kg^{-1}
5	Farm yard manure	5 kg^{-1}
6	Groundnut cake	70 kg^{-1}
7	Suchitha	55 kg^{-1}
8	Neem cake	23 kg^{-1}
9	Poultry manure	3 kg^{-1}

STANDARDISATION OF GROWTH MEDIA AND ORGANIC NUTRIENT SCHEDULE FOR CONTAINER CULTIVATION OF SPINACH BEET

(*Beta vulgaris* var. *bengalensis*)

by

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ABSTRACT

An investigation entitled 'Standardization of growth media and organic nutrient schedule for container cultivation of spinach beet (*Beta vulgaris* var.*benghalensis*)' was conducted at College of Agriculture Vellayani, Thiruvananthapuram during 2019-20. The objective of the study was to identify an ideal growth medium and to standardise an organic nutrient schedule for container cultivation of spinach beet. The study was conducted as two separate experiments with a field study and a concurrent lab incubation study on nutrient availability in different growth media.

The first experiment was conducted during the *rabi* season of 2019 at College of Agriculture, Vellayani. The treatments consisted of five growth media {M_1: soil : sand : FYM (1: 1 : 1), M_2 - soil: rockdust: FYM (1:1:1), M_3 - soil: compressed coirpith: FYM (1:1:1), M_4- soil: rockdust: compressed coirpith: FYM (1:0.5:0.5:1), M_5 - soil: suchitha : FYM (1:1:1) and three nutrient levels (N_1 - 100% of 80:40:80 kg NPK ha^{-1} , N_2 - N_1 + 50% N topdressed in 3splits , N_3 - N_1+ 100% N topdressed in 3splits). The recommended dose of NPK@ 80:40:80 kg ha^{-1} was given as basal through the nutrient source poultry manure. In N_2 and N_3, nitrogen was topdressed as fermented groundnut cake at 20, 40 and 60 DAT. The experiment was laid out in completely randomized design with three replications. The crop was raised in UV stabilized woven plastic sacks of thickness 1400 denier capable of holding 15 kg potting mixture with 15 treatment combinations.

Results of the study indicated that among the growth media, M_5 registered superior values for growth parameters, *viz.*, leaf yield per plant (118.08 g), leaf area index (2.07 at 75 DAS), dry matter production (33.05 g plant $^{-1}$) and leaf yield per harvest (32.67 g per plant at second harvest) and was on par with M_2. The major yield determining parameter *viz.*, number of leaves harvested per plant was superior in M_2 and was on par with M_5 and M_1. Root parameters including root weight and root shoot ratio were also found higher in M_5. The quality parameters including vitamin A and C were

found higher in M_2 and the iron content was found higher in M_1. M_5 recorded higher uptake of N, P and K and it was significantly superior over all other growth media.

The different nutrient levels did not exert any significant influence on leaf yield per harvest, leaf yield per plant and dry matter production. Between the nutrient levels, N_1 recorded the highest number of leaves harvested per plant (23.29), Leaf Area Index (1.63 at 75 DAS) root weight (12.66 g) and iron content (2.5). However, the vitamin C and A content were significantly higher in N_3. N_2 recorded higher N uptake and nutrient levels didn't exert significant influence on P and K uptake.

Among the interactions, m_5n_1 was found significantly superior with respect to leaf yield per plant, LAI and dry matter production. Maximum leaf yield per harvest was also recorded in $m_5n_1$which was on par with m_2n_1. The root weight and root shoot ratio were found higher in m_5n_2. The treatment combination m_5n_3 registered the highest vitamin C and vitamin A content was higher in m_4n_3, m_3n_3 and m_3n_1.The treatment combination m_1n_1 recorded higher iron content. The interactions m_4n_2 recorded higher uptake of N which was on par with m_5n_1. The interaction m_5n_1 recorded higher K uptake and it was significantly superior over all other interactions. Even though m_5n_1 recorded higher leaf yield, the net income and BC ratio were lower due to higher unit cost of suchitha. The individual effects of M_2, N_1 and their combination m_2n_1 recorded the highest net income (4.85 ₹ bag^{-1}) and benefit cost ratio (1.67).

The concurrent lab incubation study on nutrient availability in different growth media was conducted in Completely Randomised Design with 15 treatments replicated thrice. The five-growth media combinations were uniformly supplied with the recommended dose of NPK (80:40:80 kg ha^{-1}) as poultry manure and groundnut cake at respective intervals. The growth media samples analysed at monthly intervals indicated an increased release of nutrients in available form over the period. Prior to the experiment all the growth media recorded a pH range of 6.5 to 7 which showed an increasing trend. The growth combination with coirpith (M_3) recorded slightly higher EC values (1.52) compared to other combinations. Initial content of organic carbon, available N and P in the media were higher in M_5 and it gradually increased during the period of incubation with M_2 recording a higher organic carbon content at second and third month. The available nitrogen status showed an increasing trend among the growth media combinations during incubation with M_2 and M_3 recording higher values. Though M_5 recorded a higher initial available P status, M_4 with rockdust and coirpith as media components recorded a significantly higher available P status after second and third month of incubation. Though higher initial available K was observed in M_3, M_1 recorded higher available K after incubation. Among the nutrient levels, N_3 recorded higher available N, P and K during the period of incubation. Among the interactions, m_2n_2, m_4n_3 and m_3n_1 recorded higher available N, P and K status during incubation.

From the results of the experiments conducted, the best growth medium and nutrient schedule for container grown spinach beet can be summarised as

- Growth media: soil: suchitha: FYM in 1: 1: 1 ratio on volume basis with respect to yield and soil: rockdust: FYM in 1: 1: 1 ratio on volume basis with respect to quality and economics
- Organic nutrient schedule: 100% recommended dose of 80:40:80 kg NPK ha^{-1} with entire dose as basal application

സംഗ്രഹം

'പാലക് ചീരയുടെ ഗ്രോബാഗ് കൃഷി രീതിയിൽ വളർച്ച മാധ്യമങ്ങളുടെയും ജൈവ പോഷക പരിപാലന മുറകളുടെയും രൂപപ്പെടുത്തൽ' എന്ന ഗവേഷണ പഠനം 2018-2020 കാലഘട്ടത്തിൽ വെള്ളായണി കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. പാലക്കിന്റെ ഗ്രോബാഗ് കൃഷിക്ക് ഒരു മികച്ച വളർച്ച മാധ്യമം കണ്ടെത്തുകയും ജൈവ പോഷക പരിപാലന ക്രമം രൂപപ്പെടുത്തുകയും ചെയ്യുക എന്നിവയായിരുന്നു ഗവേഷണത്തിന്റെ ലക്ഷ്യം. പഠനം രണ്ടു പരീക്ഷണങ്ങളായി ഫീൽഡിലും ലാബിലുമായിട്ടാണ് നടത്തിയത്.

ആദ്യ പരീക്ഷണം കംപ്ലീറ്റലി റാണ്ടംയ്സ്ഡ് ഡിസൈൻ രീതിയിൽ 15 ട്രീട്മെന്റ്സ് മൂന്നു തവണ അവർത്തിച്ചാണ് നടത്തിയത്. വളർച്ച മാധ്യമങ്ങളായി ഉപയോഗിച്ച ട്രീട്മെന്റ്സ് ഇവയാണ്: M_1- മണ്ണ് : മണൽ : കാലിവളം (1:1:1), M_2- മണ്ണ് : പാറപ്പൊടി: കാലിവളം (1:1:1) , M_3- മണ്ണ് : കമ്പ്രെസ്സ് ചെയ്ത കയർപിത്ത്: കാലിവളം (1:1:1), M_4- മണ്ണ് : കമ്പ്രെസ്സ് ചെയ്ത കയർപിത്ത്: പാറപ്പൊടി: കാലിവളം (1:0.5:0.5:1) , M_5- മണ്ണ്: ശുചിത: കാലിവളം (1:1:1). ജൈവ പോഷകങ്ങളുടെ അളവുകൾ ഇവയാണ്. N_1: 80:40:80 കിലോഗ്രാം NPK ഹെക്ടർ ഒന്നിന് ശുപാർശ ചെയ്തിരിക്കുന്ന 100 ശതമാനം വളവും അടിവളമായി, N_2: N_1+ 50 ശതമാനം നൈട്രജൻ മൂന്നു തവണകളായി മേൽവളമായി, N_3: N_1 + 100 ശതമാനം നൈട്രജൻ മൂന്നു തവണകളായി മേൽവളമായി.

വിവിധ വളർച്ച മാധ്യമങ്ങൾ പരീക്ഷിച്ചതിൽ മണലിന് പകരം ശുചിത ചേർത്തു തയ്യാറാക്കിയ വളർച്ച മാധ്യമമാണ് ഇലകളുടെ ഉത്പാദനം, ലീഫ് ഏരിയ സൂചിക, ഡ്രൈ മാറ്റർ ഉത്പാദനം എന്നിവയിൽ മികച്ചതായി കണ്ടെത്തിയത്. ജൈവ പോഷക പരിപാലന ക്രമങ്ങൾ പരീക്ഷിച്ചതിൽ ശുപാർശ ചെയ്തിരിക്കുന്ന അളവിലുള്ള പോഷക ക്രമമാണ് (80:40:80 കിലോഗ്രാം NPK ഹെക്ടർ ഒന്നിന്) ഇലകളുടെ എണ്ണം, ലീഫ് ഏരിയ സൂചിക എന്നിവ കൂടുതലായി രേഖപ്പെടുത്തിയത്. എന്നാൽ ഇലകളുടെ ഗുണമേന്മ ഏറ്റവും മികച്ചതായി രേഖപ്പെടുത്തിയത് പാറപ്പൊടി മണലിന് പകരമായി ഉപയോഗിച്ച വളർച്ച മാധ്യമവും ശുപാർശ ചെയ്തിരിക്കുന്ന പോഷക ക്രമത്തിനേക്കാൾ 100 ശതമാനം അധികം നൈട്രജൻ ഉപയോഗിച്ച ജൈവ പോഷക ക്രമത്തിലുമാണ്.

ഫീൽഡ് പരീക്ഷണത്തോടൊപ്പം തന്നെ ഇതേ മാതൃകയിൽ ലാബ് പരീക്ഷണവും നടത്തുകയുണ്ടായി. വളർച്ച മാധ്യമങ്ങൾ എല്ലാ മാസവും കെമിക്കൽ അനാലിസിസിനു വിധേയമാക്കി . pH, EC ,N, P,K എന്നിവ എല്ലാ വളർച്ച മാധ്യമങ്ങളിലും മൂന്നു മാസത്തെ ഇൻക്യൂബേഷൻ പീരിയഡിൽ കൂടുന്നതായി നിരീക്ഷിച്ചു.

ഈ പരീക്ഷണത്തിൽ നിന്നും പാലക്കിന്റെ ഗ്രോബാഗ് കൃഷിരീതിക്ക് മണ്ണ്: ശുചിത: കാലിവളം 1:1:1 എന്ന അനുപാതത്തിൽ തയ്യാറാക്കിയ വളർച്ച മാധ്യമം ഇലകളുടെ വിളവ് നൽകുന്നതിൽ മികച്ചതായി കണ്ടെത്തി. മണ്ണ്: പാറപ്പൊടി: കാലിവളം 1:1:1 എന്ന അനുപാതത്തിൽ തയ്യാറാക്കിയ വളർച്ച മാധ്യമം ഇലകളുടെ

ഗുണമേന്മയിലും ആദായത്തിലും മികച്ചതായി രേഖപ്പെടുത്തി. ശുപാർശ ചെയ്തിരിക്കുന്ന പോഷകങ്ങൾ (80:40:80 കിലോഗ്രാം NPK ഹെക്ടർ ഒന്നിന്) അടിവളമായി (ചെടി ഒന്നിന് 10 ഗ്രാം) കോഴിവളത്തിലൂടെയാണ് നൽകിയത്.