STANDARDISATION OF OPERATIONAL PROCEDURES FOR PRO-TRAY SEEDLING PRODUCTION OF VEGETABLES

By
ARYA S.

(2019-12-045)

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE VELLANIKKARA,
THRISSUR- 680656
KERALA, INDIA
2021

STANDARDISATION OF OPERATIONAL PROCEDURES FOR PRO-TRAY SEEDLING PRODUCTION OF VEGETABLES

By

ARYA S.

(2019-12-045)

THESIS

Submitted in partial fulfilment of therequirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

(VEGETABLE SCIENCE)

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

VELLANIKKARA, THRISSUR- 680 656
KERALA, INDIA

2021

DECLARATION

I, hereby declare that this thesis entitled **"Standardisation of operational procedures for pro-tray seedling production of vegetables"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

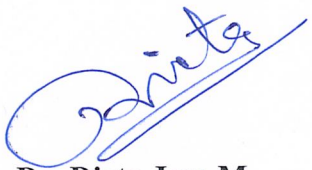
Date: 29.01.2022

Arya S.

(2019-12-045)

CERTIFICATE

Certified that this thesis entitled **"Standardisation of operational procedures for pro-tray seedling production of vegetables"** is a bonafide record of research work done independently by **Ms. Arya S. (2019-12-045)** 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.



Vellanikkara

Date: 29.01.2022

Dr. Dicto Jose M.

(Chairman, Advisory Committee)

Assistant Professor

Agricultural Research Station

Kerala Agricultural University

Mannuthy

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Arya S. (2019-12-045)**, a candidate for the degree of **Master of Science in Horticulture** with major field in **Vegetable Science**, agree that this thesis entitled **"Standardisation of operational procedures for pro-tray seedling production of vegetables"** may be submitted by **Ms. Arya S.** in partial fulfilment of the requirement for the degree.

Dr. Dicto Jose M
(Chairman, Advisory Committee)
Assistant Professor
Agricultural Research Station
Kerala Agricultural University, Mannuthy

Dr. T. Pradeepkumar
(Member, Advisory Committee)
Professor and Head
Department Vegetable Science
College of Agriculture, Vellanikkara

29/01/2022

Dr. P. Anitha
(Member, Advisory Committee)
Associate Professor & P.I.
AICVIP, Department of Vegetable Science
College of Agriculture, Vellanikkara

Gopal
29/1/2022

Dr. K. Surendra Gopal
(Member, Advisory Committee)
Professor and Head
Department of Agricultural Microbiology
College of Agriculture, Vellanikkara

ACKNOWLEDGEMENT

*First and foremost, I owe my heartfelt gratitude towards the **Almighty God** for all the blessing showered upon me which enabled me to complete the thesis work in time.*

*I would primarily like to express sincere gratitude whole-heartedly to my esteemed guide **Dr. Dicto Jose M.,** Assistant Professor, Agricultural Research Station, Mannuthy, chairman of my advisory committee. With great respect and devotion, I wish to place my heartfelt thanks to him for the inspiring guidance, untiring interest, esteemed advice, constructive criticism, valuable suggestions and immense help rendered by him throughout study and the period of the investigation and preparation of the thesis. I am genuinely indebted to him for the constant encouragement, unwavering support and intellectual freedom that have led me in the right direction in all ways.*

*I would like to express my extreme indebtedness and obligation to **Dr. T. Pradeepkumar,** Professor and Head, Department of Vegetable Science, College of Agriculture, Vellanikkara, member of my advisory committee for his meticulous help, scientific advice, timely support and critical evaluation.*

*It is with my heartfelt feelings, I wish to express my deep sagacity of gratitude and sincere thanks to **Dr. Anitha P.,** Associate Professor, Department of Vegetable Science, College of Agriculture, Vellanikkara for her valuable help and guidance, care, love and concern towards me during the past two years.*

*I express my heartiest gratitude to **Dr. K. Surendra Gopal,** Professor and Head, Department of Agricultural Microbiology, College of Agriculture, Vellanikkara, member of my advisory committee for his relentless support and valuable suggestions throughout the course of study.*

*I wish to express my sincere thanks to **Dr. Jayasree Sankar S.,** Department of Soil Science, College of Agriculture, Vellanikkara, for providing me with all the necessary facilities for the research.*

*I am also grateful to **Dr. Pratheesh P. Gopinath,** Department of Agricultural Statistics, College of Agriculture, Vellayani for the valuable guidance extended to me.*

I wish to extend my heartfelt thanks to my beloved teachers, ***Dr. Sangeeta Kutty M., Dr. Ashwini A., Dr. Rashmi C. R., Rekha C. R. and Dr. Flemine Xavier*** *for their encouragement, valuable help, and friendly suggestions rendered during the course of study.*

I am thankful to the research associates of the Department of Vegetable Science especially ***Veni chechi*** *and* ***Varun chettan*** *for their whole-hearted cooperation and timely assistance.*

I owe a great deal of appreciation and gratitude to ***Mohan sir, Sunitha chechi, Lohithakshan chettan*** *and* ***Shanta chechi*** *for providing their assistance during my research work.*

With pleasure, I express my heartfelt gratitude to ***Vineetha chechi*** *(Soil Science),* ***Divya chechi*** *(Forestry) and* ***Nisha Chechi*** *(Agricultural Microbiology) for their valuable help during the research work.*

I duly acknowledge the heartfelt support, encouragement, timely persuasions and precious suggestions and innumerable help by my dear friends ***Arya*** *and* ***Anu Latha****. I thank my dear friends* ***Nihla, Parvathy, Anila, Nanda, Reshma, Keerthana, Swathy, Anjitha, Shafreena, Athira, Sisira, Deena*** *and* ***Anjana*** *for their affection and support.*

I have the infinite pleasure to express wholehearted thanks to my dear seniors ***Alphy chechi****,* ***Nidhin chettan****,* ***Divya chechi, Remzeena chechi, Athulya chechi,*** *and* ***Anju chechi,*** *for their encouragement, moral support and timely assistance.*

A special word of thanks to my juniors ***Mintu, Jayalakshmi, Kousthubha and Aparna*** *for their prompt help and co-operation during the entire period of study.*

I express my heartiest gratitude to the ***Dean****, College of Agriculture, Vellanikkara for providing me with all the necessary facilities for the research.*

I express my great pleasure to extend indebtedness to ***Dr. Sharon C. L.,*** *P.G. Academic Officer, College of Agriculture for her whole-hearted co-operation and gracious help rendered during the last two years.*

I take this opportunity to extend my gratitude to ***Dr. A. T. Francis,*** *Librarian of the KAU central library.*

I acknowledge the whole-hearted co-operation, gracious help and mental support rendered by my dearest friends ***Jahnavi*** *and* ***Nikhil*** *during the period of study.*

I am in dearth of words to express my love towards my beloved father ***Mr. Sudhakaran,*** *mother* ***Mrs. Sindhu*** *and brother* ***Arun*** *for their boundless affection, moral support, deep concern, prayers and personal sacrifices, without which this endeavour would never have become a reality.*

For the whole journey, my head bows to Kerala Agricultural University for letting my dreams come true...

Arya S.

CONTENTS

LIST OF TABLES

LIST OF TABLES (Contd.)

LIST OF FIGURES

LIST OF FIGURES (Contd.)

LIST OF PLATES

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Vegetables are essential in human nutrition and its requirement is increasing around the world. It constitutes a treasure of vitamins, minerals and other nutrients of medicinal and therapeutic value. India occupies second largest position in vegetable production after China since nature has bestowed diverse agro-climatic conditions to our country. But the productivity is low due to inferior planting materials, improper nursery management practices and traditional cultivation practices. The first and foremost requirement for achieving full yield potential of any vegetable crop is healthy seeds and seedlings. Sowing the seeds in nursery beds and digging up the seedlings when they were large enough to be successfully transplanted was the standard method of producing vegetable seedlings during former times. The seedlings produced through this method exhibit root damage during transplanting which leads to poor establishment in field. Here comes the use of plug trays or pro-trays for growing vegetable seedlings, which was popularised from 1970 onwards.

Raising of seedlings in pro-trays under green house or shade net is an upcoming technology which provides individual space for each seedling. It leads to lesser competition among seedlings, which results in plants with good vigour. Such seedlings have better germination, uniform growth, healthy vegetative growth and vigour. Seedlings in pro-trays have well developed roots. Since seedlings can be transplanted along with the soft media, the damage to roots while transplanting can be avoided. Hence, the seedlings are free from transplanting shock. Since the seedlings have intact root system they can be transplanted at any time during the day and there is no need of providing individual shade during transplanting. It is easier to do gap filling with these seedlings and uniform crop stand can be obtained even after gap filling. Pro-tray seedlings reduce the crop duration in turn provide early yield and all plants exhibit synchronized maturity (Yadav and Bajpay, 2019). It helps to reduce the cost of seeds, especially hybrid seeds, by minimizing seed wastage. The use of soil-less or sterilised growing media can prevent seedling mortality due to damping off and other nursery diseases. Due to these evident advantages the practice of large-scale seedling production has become a viable commercial venture and has come out as a way of enhancing income.

Nursery raising system largely depends on type of growing media. Growing media for filling the pro-trays can be either soil-less or media containing soil. Commonly used substrates for filling pro-trays are cocopeat, dried cow dung, vermicompost, neem cake, vermiculite, perlite *etc*. Its chemical and physical properties determine the success of nursery production, since it is more important for optimum root and shoot growth (Pandiyaraj *et al*., 2017). Many of the substrates are not accessible to the farmers and are costly. Since an ideal medium for successful pro-tray vegetable seedling production is not yet standardised, there is a need to identify ideal high-quality soilless media for commercial production and soil containing low-cost media for seedling production by farmers.

Seeds saved are equivalent to seeds produced. Pre- sowing seed invigoration treatments have a prime role in improving seed germination and enhancing seedling vigour in vegetables. In seeds which show problems in seed germination like chilli, okra, bitter gourd, snake gourd *etc*. the effect of dormancy and variable viability can be overcome by treatment with chemicals like potassium nitrate and bio-agents like *Pseudomonas.* Moreover, this accomplishes uniform emergence and give better crop stand, earlier crop maturity, and allow escape from adverse environmental conditions in many horticultural crops. Seed treatment can be done either with chemical compounds or bio-control agents. Among chemicals KNO_3 is the most commonly used one. Apart from providing potassium and nitrogen to the plants, it triggers the germination processes and improve the germination percentage and increases the vigour of the seedlings. Majority of the vegetable seeds are affected by several internal or external seed borne pathogens. Seed treatment with suitable biocontrol agents like *Pseudomonas* and *Trichoderma* can prevent the growth of theses pathogens. *Pseudomonas* when treated with the seeds can enter into the plant cell and cause induced systemic resistance, which imparts resistance to pathogens (Prasad *et al*., 2016). Moreover, it enhances plant growth and vigour. It can be used as an organic method to control nursery diseases and hence can be used as a prophylactic measure and as an alternative to chemical control. Studies on the effect of seed treatment with a combination of chemicals and bio-control agents are scanty. It is because of the presumption that chemicals should not be mixed with biocontrol

agents. But bacteria survive better in isotonic rather than hypotonic or hypertonic solutions. A combination of seed invigoration using potassium nitrate and biocontrol agents like *Pseudomonas* would provide dual advantage of enhanced germination per cent and reduced incidence of nursery diseases.

Healthy, vigorously growing seedlings can also be produced through microbial inoculation of the substrate in pro-trays. Introducing beneficial microorganisms like Arbuscular Mycorrhizal Fungi (AMF), nitrogen fixers, phosphate solubilizers, potash mobilisers and Plant Growth Promoting Rhizobacteria (PGPR) can improve the plant growth by facilitating the uptake of nutrients, regulating the production of phytohormones and prevent the deleterious effect of phytopathogenic organisms by producing siderophores, antibiotics, lytic enzymes, HCN and ammonia (Desai *et al*., 2020). Roots of most cultivated plant species can be colonized by arbuscular mycorrhizal fungi (AMF) which are obligate symbionts belonging to the phylum Glomeromycota. It has been found that growth and yield of vegetables like tomato, chilli and capsicum *etc.* can be enhanced by application of AMF. AMF were found to be effective in acquiring mineral nutrients and water from soil, improving drought tolerance and aiding plant establishment. *Trichoderma viride* is a fungus which exhibits mycoparasitism. When treated with seeds it can prevent fungal diseases and can enhance plant growth. Consortia of Plant Growth-Promoting Rhizobacteria (PGPR) such as *Azospirillum brasilense*, *Pseudomonas* and *Bacillus* are effective in assisting the establishment of plants, avoiding stress conditions and providing plant nutrients. Inoculation of PGPR in the growing media is a strategy which can not only improve the growth and vigour of seedlings but also ensure nutrient supply in main field by organic means and increase the yield.

In Kerala, scope for vegetable seedling nursery is increasing now-a-days. Tomato (*Lycopersicon esculentum* L.) and chilli (*Capsicum annum*) are the major crops which are generally grown by means of seedlings. It suffers a problem of bacterial wilt when raised under traditional nursery raising method. So, pro-tray seedling production is the best alternative for the production of healthy pest and disease-free seedlings.

Okra (*Abelmoschus esculentus* L.), is a popular vegetable crop cultivated in Kerala. One of the reasons for the relatively low yield of okra is erratic and delayed germination. Moreover, seed germination per cent is low due to the presence of hard seed coat. These problems can be overcome to some extent by the adoption of pro-tray nursery technique.

Salad cucumber (*Cucumis sativus*) is well known for poly house cultivation since it is having high economic value. Cultivation of parthenocarpic gynoecious varieties of salad cucumber is increasing day by day and its seed cost is exorbitantly high. So, it is essential to conserve each and every seed by improving germination percentage and to reduce the seed wastage. Traditionally, seedling production in soil bed nursery is not common in cucumber. Pro-tray seedling nursery can ensure uniform crop stand and enhance early maturity.

In the above circumstances, the present study entitled‘Standardisation of operational procedures for pro-tray seedling production of vegetables’ was envisaged with the following objective:

Standardisation of media, pre-sowing seed invigoration, biopriming and biofertilizers for pro-tray seedling production of vegetables.

Review of literature

2. REVIEW OF LITERATURE

Seedling production using seedling trays is already a commercial venture which provides healthy vigorous seedlings of vegetables like tomato, chilli, brinjal, cabbage, cauliflower *etc*. Improved germination, uniform growth and vigour can be seen in pro-tray seedlings since the cells are equidistant and each seedling gets independent space for growth. The seedlings grown in pro-trays exhibit well developed root system and root damage to such seedlings is minimum while transplanting. The seedlings will be free from pests and diseases and have good field establishment. Moreover, it can lead to efficient utilization of seeds which is an expensive input especially, hybrid seeds. The available literature regarding the research topic 'Standardisation of operational procedures for pro-tray seedling production of vegetables' is presented under the following headings:

2.1. Effect of different growing media:

2.1.1. Effect of physical properties of growing media on seedlings:

2.1.2. Effect of peat on seedlings:

2.1.3. Effect of vermicompost on seedlings:

2.1.4. Effect of animal manures on seedlings:

2.1.5. Cost analysis

2.2. Influence of pre sowing seed invigouration techniques:

2.2.1. Seed treatment with chemicals:

2.2.2. Seed treatment with bioagents:

2.3. Effect of biofertilizers on seedlings:

2.1. Use of different growing media:

Growing media plays an important role in the germination and vigour of seeds. Because of environmental, technical, and economical concerns, choosing a growing medium is not an easy task.

2.1.1. Effect of physical properties on seedling production:

In order to meet the growth requirements of plants, the growing media must possess a variety of parameters, including physical, chemical, hydrological, and biological qualities.

According to Noguera *et al.* (2000) the essential physical characteristics of the material used as a substrate are: high water holding capacity (20 - 30%), low bulk density (≤ 0.4 g/cm^3), high porosity (≥ 85% v/v), fine texture and stable structure.

According to Gruda and Schnitzler (2004), peat is the most common material used for vegetable seedling production. However, continuous irrigation may cause deterioration of the physical characteristics such as porosity, water and air volume of peat. In order to increase the water holding capacity and to avoid fluctuations in water content volume, commercial nurseries often mix peat with perlite or vermiculite (Baillu *et al.*, 2017).

A study conducted by Paramanandham *et al.* (2013) showed that EC was high in unwashed and low in washed cocopeat extract. So, washed cocopeat extract was used as a growing medium for successful seedling production.

Chrysargyris *et al.* (2013) reported that the use of compost as substrate in different ratios may exhibit some problems such as, unsuitable physical properties *viz*., water holding capacity, aeration, heavy metal toxicity, high salt content, and variable quality and composition. So, care should be taken while taking compost amended growing media.

A study conducted by Ilahi and Ahmad (2017) revealed that addition of perlite into cocopeat improved the physical and hydraulic characteristics *viz*., water holding capacity, porosity, bulk density, particle density wettability and hydraulic conductivity.

A growing medium should have a balanced pH and EC which only can lead to optimum plant growth. Optimum pH range may benefit plants in the uptake of

nutrients (Spehia *et al.,* 2019). Most of the crops grow better in the media having a pH of 5.2 to 7.0 (Raviv *et al*., 1986).

2.1.2. Effect of peat on seedlings:

Arenas *et al.* (2002) attempted to find the optimum growing media for tomato transplants by using sixteen media prepared from peat, cocopeat, vermiculite or perlite. Results indicated that considerable transplant root dry weight, stem diameter, and leaf area were achieved in 50% to 75% peat + 25% to 50% vermiculite in summer. In winter, greatest transplant root dry weight, stem diameter, and leaf area were achieved in eight media: 100% peat, 75% peat + 25% vermiculite, 75% peat + 25% perlite, 50% peat + 50% vermiculite, 50% peat + 50% perlite, 25% peat + 50% cocopeat+ 25% vermiculite, 50% peat + 25% cocopeat + 25% vermiculite, and 25% peat + 25% cocopeat + 25% vermiculite + 25% perlite.

The nursery raising technology of different cucurbitaceous vegetables in soil-less medium was developed and standardised by Singh *et al.* (2009). It was found that soil-less media like coco-peat, vermiculite and perlite (3:1:1 ratio on volume basis) was highly efficient and suitable for vigorous off-season nursery, and was a cost-effective technology for the vegetable growers in northern plains of India.

Ramadani *et al.* (2012) assessed the impact of using different types of peat mixed with different percentage of vermiculite on growth parameters of pepper seedlings. Pepper seedlings grown in peat - vermiculite and peat - vermiculite - organic materials substratum are compact, have smaller leaf area, but their above-ground and root weight is higher than that of seedlings grown in peat. Pepper seedlings grown in vermiculite substratum had higher stalk length, root length, bigger leaf area and the highest number of leaves than the seedlings grown in perlite.

An experiment by Kandemir *et al.* (2013) to study the effect of four different growing media *viz*., commercial peat, garden soil, farm yard manure and perlite on the quality of cucumber seedlings revealed that the seedlings grown in the medium which was a mixture of farm yard manure and garden soil exhibited highest seedling height,

stem diameter, leaf dry weight, root dry weight, leaf area ratio and higher quality than those of the seedlings produced in other seedling media mixtures.

Rahimi *et al.* (2013) evaluated different culture media (peat moss, cocopeat, jahrom palm peat, washed sand and soil) for tomato transplant production under 16 greenhouse conditions. The results showed that seedlings had better growth parameters in peat moss media. In addition, peat moss and cocopeat as pure form or mixed with sand, had better results than other media. Cultivation in soil and coco peat (palm-peat) medium was not suitable for tomato transplant production.

Atif *et al.* (2016) evaluated the effect of ten different growing media on the quality of tomato seedlings. The growing media containing peat, compost and traditional media in equivalent ratio (1:1:1) exhibited highest germination percentage (95), seedling shoot length (26.67 cm), seedling height (35 cm), seedling vigour index (3325) and minimum days to emergence. Maximum dry matter accumulation (34.80%) was recorded in peat. Maximum benefit cost ratio was recorded for soil, sand and farm yard manure in 1:1:1 ratio and hence was the economical treatment for seedling production.

Mathowa *et al.* (2016) investigated seedling emergence, growth and development in 80% net shade house using three locally available commercial growing media *viz*., germination mix, cocopeat and hygromix. They reported that plant height was maximum in hygromix; at par with the medium germination mix while minimum plant height was observed under cocopeat medium. Growing media had no significant influence on seedling emergence rate although, hygromix sown seeds still emerged relatively faster than the other media.

Vivek *et al.* (2017) carried out a study of growth parameters and germination on tomato seedlings with different growing media cocopeat, vermin compost and cocopeat + vermin compost (4:1). The maximum shoot length, root length, stem diameter and number of leaves were observed at 30 days aged seedlings in cocopeat. They arrived at the conclusion that among the three different growing media, cocopeat was a good with acceptable pH, electrical conductivity and other chemical attributes.

Hosseini *et al.* (2017) attempted to use some agricultural wastes, organic matter and management practices to optimize water holding capacity of cultural media, which are suitable for the growth of tomato seedlings. Different combinations of one mineral component (sand (S) 2 - 4 mm or perlite (P) 4 - 6 mm) and one or two organic components (poplar wood chips (C), sugarcane bagasse (B), and oak tree bark (T)) at different volume percentages were used as treatments. Stem length, diameter and shoot weight were highest (25.91 cm and 4.83 mm) in treatment 8 (S30 P10 T30 B0 C30). It was found that the sand fraction as a mineral component had a better performance compared to perlite in growth parameters. The growth of tomato seedlings was best in the treatments with water holding capacity of 90 - 100%.

Peat is the most commonly used media because of its good physical properties and high nutrient exchange capability. Due to escalating demand and expenses for peat, as well as its uncertain supply in the near future due to environmental constraints, an alternative high-quality and low-cost growing media in horticulture is a necessary.

2.1.3. Effect of vermicompost on seedlings:

The combination of growing media and vermicompost is advantageous because both are readily available to farmers all over the world and give the plant with improved growing conditions (Spehia *et al*., 2019).

Atiyeh *et al.* (1999) compared 100% vermicompost as a growing medium to commercial medium (100%) and observed significant growth in plant height and root and shoot biomass with 50% substitution of vermicompost for the same amount of commercial medium. Moreover, improved plant growth and yield per plant over unamended medium was also noticed with substitution of 20% vermicompost in cocopeat.

Mota *et al.* (2007) compared the physical properties of vermicompost and green compost and their mixes as substitutes for peat and found that the mixes with a maximum of 50% of vermicompost or green compost had admissible air filled porosity and easily available water. The level of organic matter, dry bulk density and

shrinkage were adequate in the vermicompost. Still it is not used alone for potting media since porosity and easily available water together were not at the recommended level. The level of organic matter was low in green compost, which increases the dry bulk density and consequently the air filled porosity was diminished. So, it was concluded that vermicompost or green compost should not be used alone but only in mixes with peat like materials up to levels not exceeding 50%.

Incorporation of vermicompost to soil-less growing medium resulted in a positive effect on various growth parameters of tomato, eggplant, and pepper plants in a study conducted by Paul and Metzger (2005). Tomato transplants were taller and had more leaf area, but dry weight did not increase accordingly resulting in slightly poorer quality. Brinjal and pepper transplant quality also improved slightly. Pepper transplants had greater height, stem diameter, leaf area, chlorophyll content, and total dry weight. Eggplant height remained the same but stem diameter, leaf number, and dry weight increased. Although, in all three cases, the positive impact of vermicompost on growth was not great enough to affect the time required to produce plants of sufficient size for transplanting.

Hashemimajd *et al.* (2006) examined the quality of vermicompost produced from different organic wastes including yard leaf (YL), sewage sludge + woodchips (SW), municipal wastes (MW), saw dust (SD), wheat straw + urea (SU), sugar cane filter cake (FC) and dairy cattle manure. Vemicompost had more nutrients compared to the original solid waste. Application of vermicompost to container medium improved porosity and water holding capacity but decreased bulk and particle density of substrate. Vermicompost obtained from sewage sludge + woodchips, municipal waste and nitrogen enriched straw are suitable organic substrates for potting mixes.

Ievinsh (2011) substituted the substrate used for seed germination with vermicompost to test its effect on seed germination and seedling growth of different vegetable crop species. Vermicompost substitution had no positive effect on seedling growth showing almost linear decrease of growth by increased concentration of vermicompost in the substrate. In contrast, when vermicompost extract was used as a

watering solution at different concentrations, the maximum activation effect on bean and pea seedlings was found at 5 - 20% concentration.

Gholamnejad *et al.* (2012) attempted different proportions of cocopeat and vermicompost for better seed emergence and some qualitative and quantitative characteristics of sweet pepper transplant (cv. California Wonder). The treatments comprised vermicompost + cocopeat (3:1), vermicompost + cocopeat (1:3), vermicompost + cocopeat (1:1) (v/v) and normal soil and recorded maximum plant weight (fresh and dry), stem diameter, internode length, leaf area and height of transplant under the treatment vermicompost + cocopeat (3:1).

A study on the effects of organic fertilizers on seed germination and seedling vigour of tomato revealed that germination percentage and co-efficient of germination were significantly higher in trichocompost (compost and *Trichoderma*) which was identical with vermicompost and cow dung based bio slurry but different from kitchen waste compost and control (soil). The seedling growth characters like root length, shoot length, number of roots, number of leaves, fresh and dry weight of ten seedlings and vigour index were notably highest in trichocompost. It also gave better performance against damping off disease (Alam *et al*., 2014).

Chatterjee *et al*. (2016) carried out a study to assess the impact of method of raising seedlings and nutrient sources on growth, quality and vigour of cabbage seedlings and performance in the main field. The results revealed that seedlings raised in plug trays excelled the open field seedlings for different seedling attributes and recorded higher germination per cent (97), plant height (15.84 cm), number of leaves (4.83), leaf chlorophyll (47.29 SPAD value) and seedling vigour (2383). Seedlings grown in vermicompost amended growing media exhibited increased germination rate, plant height, number of leaves per plant, leaf chlorophyll content and seedling vigour. Vermicompost inoculated with *Azophos* biofertilizer recorded maximum seed germination (98.24%), highest seedling height (16.23 cm) and more number of leaves per plant.

Spehia *et al.* (2019) showed that growing media comprising cocopeat and vermicompost in the ratio of 70:30 had more nutrient uptake compared to cocopeat alone.

Use of vermicompost as growing medium had positive effect on some crops while it was deleterious to some others. This may be due to its varying EC value. Some crops show better results in high EC value while some crops had negative effects.

2.1.4. Effect of animal manures on seedlings:

Increased seed germination, seedling growth and avoidance of damping of disease were reported in chilli seedlings by the amendment of poultry refuse, neem compost and vermicompost (Islam and Faruq, 2008).

Gama *et al.* (2015) undertook a study to evaluate the effect of soil media on growth of two tomato cultivars (Makis F1 and Nirvana F1) on different media *viz*., Farm Yard Manure (FYM), compost, canal silt, FYM + compost, FYM + canal silt, compost + silt and FYM + compost + silt. Comparatively, both cultivars exhibited highest plant height for soil media compost manure, canal silt, compost manure + silt (50% + 50%), farm yard manure + compost manure + silt (1:1:1). Makis F1 had the highest seedling girth under soil media + farm yard manure + compost manure + silt and soil (control) while cultivar Nirvana F1 maintained higher seedling girth in all the soil treatments. Farm yard manure + compost + silt recorded the highest dry weight followed by compost + silt. It can be suggested that soil media containing mixture of equal proportion of farm yard manure, compost and canal silt can be used for raising tomato seedling.

Rekani *et al*. (2016) undertook a study on germination and growth of sweet pepper plants in relation to different potting mixtures under greenhouse conditions. Seed germination was increased under the media peat moss and sheep manure compared to soil. Growing media containing peat moss and sheep manure recorded significantly higher growth parameters compared to soil and municipal solid waste compost.

Truong *et al*. (2017) conducted an experiment to evaluate the physical and chemical properties of different media combined with rice husk ash (RHA) and coir fibre (CF) and to determine the best medium to improve seedling quality and growth of two tomato varieties. The results demonstrated that a mixture of cattle manures composted with RHA and CF (1:1:1 by volume), respectively, gave the highest value of germination rate, plant height, leaf number, and plant biomass.

There are so many substrates used for pro-tray seedling production. Use of different substrates as growing media depends on its regional availability. So in Kerala conditions cocopeat can be used efficiently for pro-tray seedling production. An ideal media should have high porosity, water holding capacity and it should be light in weight. In order to improve physical properties of cocopeat, vermiculite or perlite can be mixed.

The high concentrations of Na^+ and K^+ in the cocopeat may be phytotoxic. Before it can be used as a growing medium, it must be washed many times in fresh water and subjected to a buffering process in which calcium nitrate is used to eliminate high sodium and potassium concentrations (Sarl *et al*., 2012).

2.1.5. Cost analysis

Ashoka *et al*. (2019) worked out economic feasibility of chiili seedlings for investment of nursery in shade net condition. The results revealed that seedling production in shade net was economically viable, as evidenced by net profit per seedling (0.26) and capital budgeting approaches such as positive net worth, a comfortable benefit coast ratio and higher Internal Rate of Returns (102%).

Mohana *et al*. (2021) attempted to assess the market potential of vegetable seedlings and the economic viability of commercial vegetable seedling nurseries. According to the findings, the entire cost of producing vegetable seedlings was Rs.10, 62,965, with a net profit of Rs.446537. In terms of Net Present Value (394718) and Benefit Cost Ratio, the investment study demonstrated that sample nurseries were economically viable (1.42).

A study was undertaken by Patil *et al*. (2017) in Southern Transitional, Northern Transitional and Central Dry Zone of Karnataka to examine the economic feasibility of establishing commercial tomato nurseries. The economics of tomato nursery was worked out using budgeting technique. The economic analysis revealed that the per seedling cost worked out to Rs.0.56. The gross returns and net returns per seedling worked out to Rs.0.8 and Rs.0.24, respectively. Hence, seedling production in a poly-house environment proved to be cost-effective.

2.2. Influence of pre sowing seed invigouration techniques:

Seed germination has been found to be delayed and inconsistent in most of the vegetable crops. In some crops like chilli, seed germination itself is the major problem (Syaiful *et al*., 2021). So, seed invigoration techniques can be used efficiently to improve the rate of germination, uniformity, root growth and seedling vigour.

2.2.1. Seed treatment with chemicals:

Significant improvements in seed germination and growth parameters were observed in maize when treated with 1% KNO_3 for 24 hours (Abnavi and Ghobadi, 2012). There was an increase in root length, shoot length, fresh weight and vigour in tomato treated with 5% KNO_3 for 48 hours (Mirabi and Hasanabadi, 2012).

Mushtaq *et al.* (2012) determined the effect of seed priming with different concentrations of KNO_3 and hydropriming on seed germination of gladiolus. The maximum level of germination was found when the seeds were treated with 0.25% KNO_3 while the minimum was exhibited by seeds treated with 3% KNO_3. The germination per cent was high for the seeds treated with 0.25% $KN0_3$, 0.75% KNO_3 and distilled water while the minimum (30%) germination was exhibited by 5% KNO_3. Moreover, non - primed seeds took more time to attain 50% germination compared with primed seeds. It was observed that lower concentration of KNO_3 gave best results regarding number of days taken for 50% germination.

Six varieties of pigeon pea *viz.*, NDA 1, Bahar, LRG 30, UPAS 120, TS 30 and Pusa 2002 - 2 were primed with three concentrations (0.30%, 0.40% and 0.50%) of KNO_3 and tap water for 6 hours by Tiwari *et al*. (2014) to study the effect of KNO_3

and tap water on seed quality parameters, growth and yield of pigeon pea. Among KNO_3 concentrations, 0.30 % showed significantly higher values in characters *viz*., seed germination, seedling length, seedling dry weight, vigour index I and II and finally test weight and grain yield over unprimed control in all the varieties . When the concentration of potassium nitrate exceeded beyond 0.30 % deterioration in seed quality parameters, growth and yield of pigeon pea varieties were noticed.

In a study conducted by Lara *et al.* (2014) to evaluate the effect of potassium nitrate priming in tomato germination it was revealed that the germination time and germination rate of seeds primed in KNO_3 (50 mM) was better compared to other treatments. The benefits of priming with KNO_3 were related to the activity of enzyme nitrate reductase in the production of nitrite/nitric oxide, which acted removing dormancy and promoting a faster germination.

Kulsumbi *et al*. (2020) conducted a study to evaluate the effect of priming on seed quality parameters of spinach and reported that 1% KNO_3 as the best priming treatment to get maximum seed quality parameters viz., field emergence (%), germination (%), speed of germination, root length, shoot length, seedling dry weight, seedling vigour index, germination rate index, peak value of germination, mean germination time, electrical conductivity, dehydrogenase activity and alpha amylase activity compared to other treatments.

Commercially produced seeds of tomato cv. PKM 1, brinjal cv. CO 2 and chilli cv. K2 with 8% moisture content were subjected to different priming techniques such as hydropriming, sand matrix priming, halopriming and osmopriming. Increase in speed of germination, percentage of protrusion of radicle and germination percentage was noticed at 5% concentration of both KNO_3 and NaCl at 36 hours. For tomato seeds, hydropriming for 48 hours (in double the volume of water) and for chilli and egg plant seeds, sand matrix priming at 80% water holding capacity of sand for three days were found to be best in terms of rate and uniformity of germination (Venkatasubramanian and Umarani, 2007).

Golezani and Esmaeilpour (2008) examined the influence of salt priming *viz.,* 3% KNO_3 for 3 days and 1% NaCl for 2 days at 20˚C on germination, seedling

emergence and seedling dry weight of two Iranian cucumber cultivars harvested at 25, 35 and 45 days after anthesis (DAA). Final germination percentages of seeds harvested at 25 DAA were significantly lower than seeds harvested at 35 and 45 DAA in both cultivars. Seed priming with KNO_3 improved the rates and percentages of germination and seedling emergence, under a wide range of environmental conditions.

Nawaz *et al.* (2013) investigated the effects of halopriming on germination, seedling growth and biochemical responses of seeds of two tomato cultivars Angina and Pakit. Seed treatment with 25 mM KNO3 exhibited increased final germination percentage and seedling growth. He concluded that better performance of treated seeds may be due to presence of higher total and reducing sugars, minimum electrical conductivity of seed leachates and greatest alpha amylase activity.

Farook *et al.* (2005) tried osmopriming in seeds of four tomato cultivars with polyethylene glycol, NaCl and KNO_3. Maximum germination percentage, root and shoot length and seedling dry weight was noted in seeds primed with KNO_3 at 3% for 24 hours in all the cultivars. In all the tomato cultivars under study, highest electrical conductivity of seed leachates was noted in untreated seeds while minimum EC was recorded in seeds treated with KNO_3.

Anwar *et al.* (2020) investigated the physiological mechanism of seed priming on growth of cucumber seedlings with different levels GA_3 (100 ppm and 200 ppm) and KNO_3 (1% and 5%). Maximum plant height, fresh and dry weight and strong seedling index was observed in seeds primed with GA_3 and KNO_3 compared to non-treated control. Moreover, seed priming significantly enhanced leaf macro and micro nutrient content. Amid different treatments GA_3 200 ppm and KNO_3 5% were found best.

Hanegave *et al.* (2011) studied the effect of seed priming on maize and reported maximum germination per cent in seeds primed with KNO_3 @ 0.2% (98.67%) for 14 hours. Maximum speed of germination, root length, shoot length, seedling dry weight, vigour index and minimum electrical conductivity were also recorded in seeds primed with KNO_3 @ 0.2%.

Piri *et al.* (2009) carried out seed priming with KNO_3, K_2HPO_4, and NaCl at concentrations of 0%, 1%, 2.5%, and 5% w/v and subsequent germination at incubation temperatures of 15 and 25°C on cucumber. It was found that NaCl - treated seeds performed at a level below that of control seeds regarding seedling dry weight. Seedling fresh weight, dry weight, and root volume were better when primed with KNO_3 at 1% for 24 hours at 15° C. There was no beneficial effect on germination when primed at 25°C.

Ali *et al*. (2020) conducted an experiment to improve the quality of tomato seeds. Seeds were soaked in 0.25%, 0.50%, 0.75%, 1%, and 1.25% KNO_3 for 24 hours. Tomato seeds primed with 0.75% KNO_3 had significant increase in final emergence (%), mean emergence time, and physiological attributes as compared to other concentrations and unprimed control.

KNO_3 was found to be the most commonly used chemical for seed treatment which provides nitrogen and potassium to the seedlings. It improves germination and vigour of the plants. But optimum concentration at which treatment should be done varied with crops. In some crops KNO_3 had a negative effect on growth parameters with increasing concentration while in others improvement in growth parameters with increasing concentration was observed.

2.2.2. Seed treatment with bioagents:

Seeds of tomato bioprimed with *Pseudomonas fluorescens* 8% concentration for 9 hours expressed high rate of germination, root length, shoot length, dry matter production and vigour index over non primed seeds (Raj and Sundareswaran, 2016).

In a study to determine the effect of biopriming with *Trichoderma viride* and *Pseudomonas fluorescens* on qualitative parameters of chilli, it was observed that *Trichoderma viride* and *Pseudomonas fluorescens* were the most effective biological agents on chilli seed germination and their seedling parameters. Bio-priming significantly improved the germination percentage, seedling length (12.85 cm), root length (9.25 cm) and seedling vigour index (1175.00) (Rai and Behera, 2019).

Ananthi *et al*. (2019) had undertaken a study to standardise bioprimed seeds of chilli under moisture stress condition in order to improve seed germination and vigour. The performance of bioprimed seeds under different water holding capacities namely 20, 40, 60 and 80% along with non-primed seeds indicated that the bioprimed seeds with *Pseudomonas fluorescens* 60% for 12 hours improved the germination percentage, root length, shoot length, dry matter production and vigour in all the water holding capacities.

Biopriming of maize seeds with liquid biofertilizers *viz., Azospirillum* and *Phosphobacteria* (concentration: 10%, 15%, and 20%; duration: 6, 12, 18, and 24 hrs.) was done by Karthika and Vanangamudi (2013). The seeds bioprimed with *Azospirillum* 20% for 12 hours registered higher speed of germination (6.9), germination (95%) and measured the longest root (22.5 cm) and shoot (9.8 cm) than non-primed seeds. This treatment also recorded more vigour (3069). Seeds primed with *Phosphobacteria* at 20% concentration for 12 hours also recorded higher germination (95%) which showed an increase of 25% and measured longer root (25.7 cm) and shoot (12.9 cm) compared to non-primed seed.

An investigation was carried out by Sivakumar *et al.* (2017) to study the effect of biopriming in rice seeds with *Phosphobacteria* (concentration: 10%, 15% and 20%; duration: 6, 12, 18 and 24 hours). Seed biopriming with *Phosphobacteria* at 20% for 12 hours was found to be the best biopriming treatment for improving the seed germination and seedling vigour of paddy variety MDU 5.

Moeinzadeh *et al.* (2010) investigated the effect of boipriming with thirty strains of *Pseudomonas fluorescens* on sunflower seeds. Two strains viz., UTPf76 and UTPf86, were selected because they improved seed factors such as germination index, germination percentage, germination rate and vigor index and also seedling growth parameters including root length, shoot height, dry and wet weight of seedlings.

Seed treatment with biocontrol agents like *Pseudomonas* not only improves the germination but also imparts resistance to most of the pathogens mainly, soil-borne pathogens. Treatment having combinations of KNO_3 and *Pseudomonas* may have a positive effect on morphological characters and most of the soil-borne diseases

can be avoided. But the studies on seed treatment with combinations of chemicals and biocontrol agents are scanty.

Musa *et al.* (2014) evaluated the effect of hydropriming durations (2, 4, 6 and 8 hours) on the growth and yield of amaranth and found that amaranth seeds soaked in water for 2 hours produced seedlings with better performance with respect to days to 50% germination, percentage germination, and days to 50% emergence.

Navitha *et al.* (2019) examined the effects of hydro priming treatment on seedling parameters of Basil. Seed priming for 12 hours recorded maximum germination (70%), shoot length (2.4 cm), root length (1.9 cm), and vigour index (301) compared to other treatments.

2.3. Effect of biofertilizers on seedlings:

Application of biofertilizers may not have an effect during the nursery period. But after transplanting it multiplies vigorously in the field which improves the uptake of nutrients which in turn reduces the dosage of fertilizers.

An experiment was carried out by Ozbay and Newman (2004) to test whether *Trichoderma harzianum* strains have any effect on growth of tomato seedlings. Eighteen days old seedlings were inoculated with *Trichoderma harzianum* strains Plantshield^{TM}, T22, and T95 (10^7 conidia plus mycelial fragments/ml) and transplanted into plastic pots filled with Pro-Mix^{TM} potting mixture. The results revealed that there was an increase in seedling emergence by 17% with PlantShield^{TM} compared with control while, T22 and T95 had no effect on emergence of tomato seedlings.

Calvo *et al*. (2014) suggested that microbial inoculants which include free-living bacteria, fungi, and arbuscular mycorrhizal fungi (AMF) had a major role in promoting growth and they can be used in vegetable nursery industry. These can be applied to seed, soil and plant surfaces which can improve nutrient uptake, root biomass and root area.

Co-inoculation had a better effect than inoculation with either AMF or PGPR. Inoculation with PGPR also boosted AMF colonisation and proliferation (Vivas *et al.,* 2003)

Constantino *et al.* (2008) evaluated the effect of two rhizobacteria (*Azotobacter chroococcum* and *Azospirillum brasilense*) and a commercial product containing multiple strains of arbuscular mycorrhizal fungi (AMF) and an NPK fertiliser on the growth and yield of chilli. *A. brasilense* with solid support resulted in a significantly positive effect on the plant height and no. of leaves.

The use of AM fungus proved to promote the development of tomato seedling transplants in a soilless nursery condition, and it could be especially useful in organic farming. AM fungi inoculated seedlings exhibited better transplant performance because of their greater shoot fresh weight (11.28 g plant-1), high shoot/root ratio (avg.0.236), higher root biomass (2.17 g plant-1), and higher relative growth rate (Oseni *et al*., 2010).

A greenhouse study was conducted by Mwangi *et al*. (2011) to investigate the ability of an isolate of *Trichoderma harzianum* and arbuscular mycorrhizal fungi (AMF) in enhancing growth and control of a wilt pathogen in tomato. All growth parameters were found to be higher in *Trichoderma* and AMF treatments individually and in combination. Severity of disease was found to be minimum in the treatment having *Trichoderma* and AMF in combination.

Jayashree and Jagadeesh (2017) tested the effect of a microbial consortium on the growth and biomass of different vegetable seedlings raised in pro-tray nursery. Plant height and biomass increased as a result of the microbial inoculation. The increase in plant height and girth of tomato was 57.48% and. 47.61% respectively. While in case of brinjal, it was 42.10% and 53.60% respectively. As a result of this research, it can be concluded that a microbial consortium can be utilised to treat cocopeat in order to create high-quality vegetable seedlings raised in pro-trays.

Al-Karaki (2017) reported that pepper transplants inoculated with AM fungi showed greater shoot and root dry matter and plant height than non AM plants.

During harvest, fruit fresh yield, fruit weight, and number of fruits per plant were higher in AM than non AM plants.

Angadi *et al*. (2017) studied the effects of biofertilizers on seedling characters, plant growth, and seed yield of tomato. Among various combination of treatments, biofertilizer with RDF recorded maximum thousand seed weight (2.83), germination (85.66%), root length (8.97 cm), shoot length (9.98 cm), seedling dry weight (26.04 mg) and seedling vigour index (1625.29) followed by the treatment of biofertilizer with 50% poultry manure + 50% FYM.

Behera *et al.* (2019) conducted a study to find out the best microbial consortium of Arbuscular Mycorrhizal Fungi and Plant Growth Promoting Rizobacteria on tomato seedlings of Pusa Ruby. Growth parameters like seedling length, stem girth, root length, seedling dry weight were measured. The results showed that the seedlings inoculated with the consortium had improved growth parameters as compared to uninoculated seedlings. It was concluded that inoculation with *Bacillus sonorensis* and *Glomus mosseae* is the best microbial consortium for inoculating tomato seedlings.

A study was carried out by Shakuntala *et al*. (2019) with six different strains of Plant Growth Promoting Rhizobacteria (PGPR) to find its influence on growth of tomato seedlings raised in pro-trays. Seedlings inoculated with *Paenibacillus polymixa* showed maximum shoot length, stem girth, bio-volume index and dry weight. The highest root length was found for seedlings inoculated with *Bacillus sonorensis* but was on par with *Paenibacillus polymixa, Pantoea agglomerans, Azospirillum brasiliense* and *Exiguobacterium acetylicum.*

Microbial consortium consisting of *Bacillus sonorensis* + *Funneliformis mosseae* was added to the planting medium in pro-trays to raise tomato and capsicum seedlings in a poly house. Desai *et al.* (2020) assessed the ability of the consortium to improve seedling growth. The plant height of the inoculated seedlings was significantly greater than the uninoculated seedlings. Inoculation with *B. sonorensis* + *F. mosseae* resulted in significantly higher root length, stem girth and bio volume index compared to uninoculated control in both tomato and pepper seedlings. It was

concluded that inoculation with microbial consortium is advantageous for raising healthy and vigorous growing tomato and capsicum seedlings under poly house condition.

The inoculation of AMF species consortia lead to noticeable enhancement of yield, physiological and quality indicators, antioxidant compounds and activity, and mineral content of *Allium* species (Golubkina *et al*., 2020).

Positive effects of *Glomus intraradices* symbiosis on growth, physiological and biochemical attributes of watermelon (*Citrullus lanatus*) cv. "Crimson Sweet" and "Charleston Gray" in response to chilling stress were investigated by Bidabadi and Mehralian (2020). AMF - inoculated watermelon seedlings exhibited significantly higher root and shoot dry mass than uninoculated plants even though subjected to chilling stress.

Ala *et al.* (2021) studied the effect of various seed treatments with organic liquid formulations on germination and seedling vigour in oriental pickling melon. Results showed that treatment having Panchagavyam + *Pseudomonas* was recorded the highest root and shoot length of seedlings (2.76 cm and 13.63 cm), fresh weight and dry weight of plants (300 mg and 34.66 mg), and vigour index (1581.33).

Colonisation with Arbuscular Mycorrhizal Fungi (AMF) for vegetables resulted in the highest biomass accumulation, photosynthetic rate, in watermelon seedlings. AMF increased the photosynthetic rate and dry weight by 68.6% and 63.4%, respectively, compared with non-AMF plants. Moreover, AMF at optimal dose could enhance the resistance of watermelon to *R. solani* and thus can be considered as a biological control agent for *R. solani* management in cucurbits (Wu *et al.,* 2021).

The applications of AMFs and PGPRs increase the nutrient uptake of the plant from the soil and contribute to plant development, yield, and fruit quality. Otherwise, it is seen that AMF and PGPR application allow plant cultivation in increasing abiotic stress conditions (Seymen *et al*., 2021).

Inoculation with combinations of different microorganisms in the nursery stage may positively affect growth parameters of plants and increase nutrient uptake capacity when transplanted to the field. AMF and PGPR co-inoculation is a potential method for increasing plant growth parameters and drought resistance.

Materials and methods

3. MATERIALS AND METHODS

The study entitled 'Standardisation of operational procedures for pro-tray seedling production of vegetables' was carried out at the Department of Vegetable Science, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, during 2020-21. The study was conducted as three experiments.

3.1. Experiment 1: Standardisation of growing media for pro-tray seedling production

3.2. Experiment 2: Standardising pre-sowing seed invigoration and biopriming treatments for pro-tray seedling production

3.3. Experiment 3: Effect of biofertilizers on pro-tray seedling production

3.1. Experiment 1: Standardisation of growing media for pro-tray seedling production

3.1.1. Experimental material

3.1.1.1. Planting material

Seeds of tomato var. Anagha, chilli var. Anugraha, cucumber var. Heera and okra var. Salkeerthi were collected from the Department of Vegetable Science, College of Agriculture, Vellanikkara and were subjected to germination test. The seeds have been stored for five months at 20^0C and relative humidity 50% before using in the present study. The germination test was conducted by using germination paper as medium (roll towel method). Two replicates of twenty five seeds were germinated in the seed germinator maintained at 27^0C temperature and 90% relative humidity. Total number of seedlings was counted after fourteenth day of sowing and the germination was calculated and expressed in percentage.

3.1.1.2. Growing media

1) Cocopeat

Cocopeat has the ability to retain moisture up to eight times of its volume and was collected from M/s Farm Guide, Coimbatore.

2) Vermicompost

Vermicompost is an excellent nutrient rich organic manure and soil conditioner. It was procured from the Department of Soil Science, College of Agriculture, Vellanikkara.

3) Dried powdered cow dung

It is a natural manure for the plants which supplies three main plant nutrients *viz*., nitrogen, phosphorus and potassium. It was collected from the Department of Vegetable Science, College of Agriculture, Vellanikkara.

4) Soil

Soil is a medium for plant growth which is a mixture of organic matter, minerals, gases, liquids and organisms that together support life. It was collected from the Department of Vegetable Science, College of Agriculture, Vellanikkara.

5) Neem cake

Neem cake is a potential source of organic manure which protects plant roots from nematodes, grubs and termites and also acts as a natural source of nutrients. It was procured from the regional market.

6) Vermiculite

Vermiculite is a lightweight inert medium which improves drainage and enables the seedlings to easily absorb the ammonium, potassium, calcium and magnesium ions from fertilizers necessary for vigorous growth and was procured from the regional market.

7) Perlite

It is a lightweight inert medium and can be found in many potting mixtures as it excels at improving soil drainage and root aeration, which was procured from the regional market.

3.1.2. Experimental site

The experiment was undertaken at the Department of Vegetable Science, College of Agriculture, Vellanikkara. The experiment was conducted under a poly house covered with 200 micron UV stabilized polythene sheet of 200 m^2 area. The site is located at an altitude of 22.5 m above M.S.L, at a latitude of 11°32'N and a longitude of 76°16'E. Light intensity during the growing period of seedlings was measured using digital lux meter.

3.1.3. Experimental design

The experiment was conducted using completely randomized design having seventeen treatments with three replications. Each replication had fourteen plants per treatment. Different media were used individually, in the combinations of two and combinations of three (Table 3.1). Soil alone was avoided due to compaction and difficulty in pulling out the seedlings.

Table 3.1: List of growing media combinations used in the study

Treatments	Growing media
T_1	Cocopeat
T_2	Vermicompost
T_3	Dried powdered cow dung
T_4	Soil: cocopeat (1:1)
T_5	Soil: vermicompost (1:1)
T_6	Soil: dried powdered cow dung (1:1)
T_7	Cocopeat: dried powdered cow dung (1:1)
T_8	Cocopeat: vermicompost (1:1)
T_9	Cocopeat: neem cake (1:1)
T_{10}	Soil: cocopeat: dried powdered cow dung (1:1:1)
T_{11}	Soil: cocopeat: vermicompost (1:1:1)
T_{12}	Cocopeat: vermicompost: neem cake (1:1:1)
T_{13}	Cocopeat: vermiculite: perlite (1:1:1)
T_{14}	Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)
T_{15}	Soil: cocopeat: vermiculite: perlite (1:1:1:1)
T_{16}	Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)
T_{17}	Cocopeat: vermiculite: perlite (3:1:1) – Control

3.1.4. Properties of growing media

Before conducting the study, samples of each growing medium was collected and air dried. Later, the media were subjected to different physico-chemical analysis. The result of analysis of their properties and nutrient status is enumerated in Table 4.1.

3.1.4.1. pH

Composite sample from each growing media was collected and dried by spreading the sample on paper towel and it was allowed to air dry to a uniform consistency. A known quantity of dried sample (10 g) was taken in a beaker and 25 ml of distilled water was added. It was thoroughly mixed with a glass rod and allowed to settle overnight. Then it was filtered using Whatman No. 41 filter paper into a 25 ml beaker and the pH was determined using pH meter (Eutech pH 700) by immersing the electrode in the suspension by allowing the measurement to stabilize for 1 - 3 minutes (Jackson, 1958).

3.1.4.2. EC (mS/cm)

Composite samples from each growing media were collected and dried by spreading the sample on a paper towel and it was allowed to air dry to a uniform consistency. A known quantity of dried sample (10 g) was taken in a beaker and 25 ml of distilled water was added. It was thoroughly mixed with a glass rod and allowed to settle overnight. Then it was filtered using Whatman No. 41 filter paper into a 25 ml beaker and EC was determined using conductivity meter 306 (Jackson, 1958).

3.1.4.3. Weight of media (g/cc)

Properly dried media were taken in a measuring cylinder and the weight of unit volume was measured.

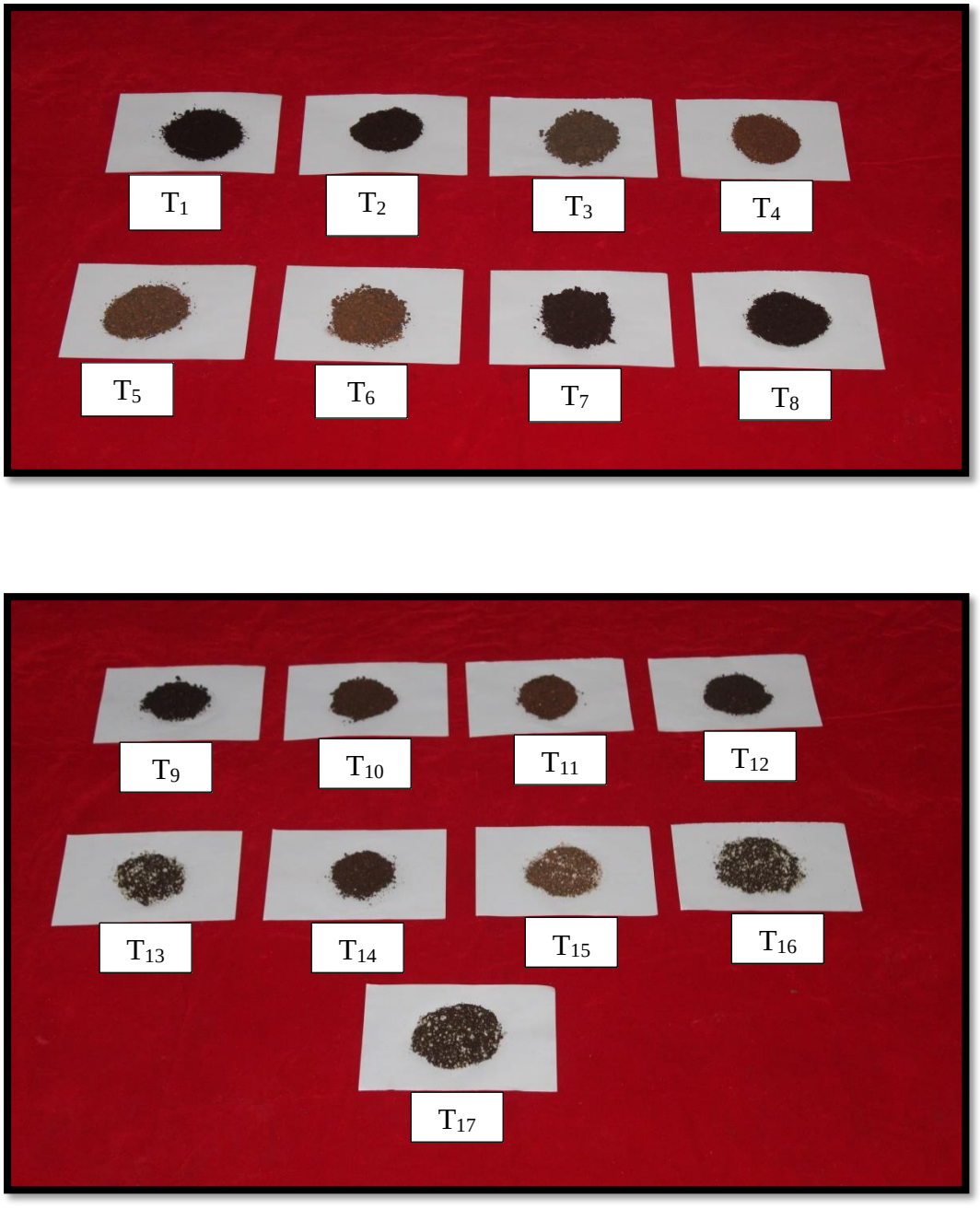


Plate 3.1. Different growing media used in the study

3.1.4.4. Nutrient content (N: P: K)

a) Nitrogen (%)

Nitrogen content of growing media was estimated by Kjeldahl method (Subbiah and Asija, 1956)

Preparation of mixed indicator: 0.1 g Bromocresol green and 0.07 g methyl red were dissolved in 100 ml of ethyl alcohol.

Preparation of 2% boric acid: Boric acid (20 g) was dissolved in some quantity of distilled water and later 20 ml of mixed indicator was added and made up to 1000 ml.

Estimation of nitrogen content: A known quantity of sample (0.5 g) was weighed and added in a digestion tube. Later 20 ml of concentrated H_2SO_4 and a pinch of digestion mixture was added into it and kept overnight. Next day it was digested using block digester. After cooling, it was made up to 100 ml. Fifty ml of it was transferred to a distillation tube and 50 ml of 40% NaOH was added. Later, 20 ml of 2% boric acid and mixed indicator were added and distilled the contents. Then it was titrated against 0.1N H_2SO_4. Appearance of pink colour in solution is the end point of the titration. A blank was performed and noted the titre value.

$$\text{Nitrogen (\%)} = \frac{(\text{Sample T.V - Blank T.V}) \times 0.014 \times 0.1 \times 100 \times 100}{50 \times 0.5}$$

b) Phosphorus and potassium

Di acid digestion of growing media: Di acid mixture prepared by mixing concentrated HNO_3 and $HClO_3$ in the ratio of 9:4 was used for digesting growing media. A known quantity of the sample (0.5 g) was weighed into a 100 ml conical flask and 20 ml of di acid mixture was added and it was kept overnight. It was digested in sand bath till the solution became clear. After cooling the contents, the filtrate was made up to 100 ml.

b) 1. Estimation of phosphorus (%)

From the di acid extract 5 ml was pipetted out into a 25 ml volumetric flask. Later, 4 ml Barton's reagent was added and was made up to 25 ml. The colour intensity was read within 24 hours at 420 nm using spectrophotometer (Koening and Johnson, 1942).

Preparation of standard solution: From 50 ppm P, 0, 0.5, 1, 1.5, 2, 2.5 ml solutions were pipetted out into 25 ml volumetric flasks and 4 ml Barton's reagent was added and made up to 25 ml.

$$\text{Phosphorus (\%)} = \frac{\text{Concentration} \times 2^5 \times 100 \times 100}{10^6 \times 5 \times 0.5}$$

b) 2. Estimation of potassium (%)

The extract was fed to flame photometer and potassium content was calculated.

Preparation of standard solution: From 1000 ppm K, 0, 2, 4, 6, 8, 10 ml of solutions were pipetted out into 100 ml volumetric flasks and were made up to 100 ml (Koening and Johnson, 1942).

$$\text{Potassium (\%)} = \frac{\text{Concentration} \times 100 \times 100}{10^6 \times 0.5}$$

3.1.4.5 Bulk density (g/cm^3)

A known quantity of growing media (W = 50 g) were weighed and transferred to 100 ml dry measuring cylinder. Then it was tapped at least 20 times and recorded the volume (V) (Piper, 1942).

$$\text{Bulk density} = \frac{W}{V}$$

3.1.4.6. Water holding capacity (%)

Water holding capacity was measured by using Keen-Raczkowski box. A suitable filter paper was placed to the perforated base of Keen-Raczkowski box and weighed in a balance (A). Then the box was filled with air dried sample by adding small quantities at a time and tapping the box after each addition to ensure even packing. The surface was leveled when the box was completely filled. The box having media was weighed (B) and then placed in a small tray containing water to a depth of half inch and left it overnight. The box was removed next day and wiped outside with a dry towel and weighed immediately (C) (Piper, 1942).

$$\text{Maximum water holding capacity (\%)} = \frac{C - B}{C - A} \times 100$$

3.1.4.7. Porosity (%)

Porosity measures the proportion of a given volume of soil occupied by pores containing air and water. A graduated cylinder was filled about half with the sample and tapped the cylinder firmly with fingers several times to settle the sample. Volume of packed sample was recorded. Sample was poured out and saved it to use further. Then the graduated cylinder was filled with 70 ml of distilled water. The sample was added slowly into it and stirred with a rod to break up the clumps, kept for five minutes and allowed the bubbles to escape. The final Volume of sample - water mixture was recorded (Piper, 1942).

Volume of solids (ml) = volume of sample plus water mixture - 70 ml water (ml)

Volume of pore space = volume of packed sample - volume of solids (ml)

$$\text{Porosity of sample (\%)} = \frac{\text{Volume of pore space (ml)}}{\text{Volume of packed sample (ml)}} \times 100$$

Buffering of cocopeat

Initially pH and EC of cocopeat were measured. Then it was treated with calcium ammonium nitrate at the rate of 1000 g/100 kg (Sarl, 2012). It was mixed well, made into a small heap, watered, and kept under shade. The heap was watered

daily. It was kept under shade until (the EC decreased below 0.50 mS/cm and stabilised) initial EC was obtained.

3.1.5. Preparation of nursery

The seedling trays are commonly known as pro-trays or plug trays. Pro-trays having 98 cells (14 x 7 cells) with dimensions of 54 × 27 × 3 cm were used for the study. Cells were round in shape and are 25 mm × 25 mm wide and 30 mm deep. Presence of hole at the bottom was ensured to drain the excess water. The trays were filled with treatment combinations of growing media and one seed was sown in each cell and kept in the poly house. The floor was laid with plastic weed mulch. The trays were placed on mulch sheet. Trays were watered with rose can. In order to provide nutrients N: P: K source 19:19:19 was applied after twelve and twenty days of sowing at 3 g/l (Bharathi *et al*., 2014). Five seedlings of each crop were randomly selected and the media was gently removed by washing, for taking observations.

Plate 3.2. General view of experimental plot 1

3.2. Experiment 2: Standardising pre-sowing seed invigoration and biopriming treatments for pro-tray seedling production

This trial was conducted using the best media identified in the first experiment. The purpose of the experiment is to standardise the effect of different concentrations of potassium nitrate individually and in combination with *Pseudomonas* so as to improve the germination percentage and growth parameters of vegetable seedlings.

3.2.1. Experimental material

Seeds of tomato var. Anagha, chilli var. Anugraha, cucumber var. Heera and okra var. Salkeerthi were collected from the Department of Vegetable Science, College of Agriculture, Vellanikkara. The seeds have been stored for five months at 20^0C and relative humidity 50% before using in the present study.

3.2.2. Experimental Design

The study was carried out using completely randomized design which constitutes nine treatments and three replications (Table 3.2). Fourteen plants were planted in one replication.

Table 3.2: List of treatments included in the study

Treatments	Materials
T_1	Direct seeding (control)
T_2	Soaking in water for 12 hrs.
T_3	Soaking in 0.5% KNO_3 for 12 hrs.
T_4	Soaking in 1% KNO_3 for 12 hrs.
T_5	Soaking in 2% KNO_3 for 12 hrs.
T_6	Soaking in 1% *Pseudomonas fluorescens* for 12 hrs.
T_7	Soaking in 0.5% KNO_3 + 1% *Pseudomonas fluorescens* for 12 hrs.
T_8	Soaking in 1% KNO_3 + 1% *Pseudomonas fluorescens* for 12 hrs.
T_9	Soaking in 2% KNO_3 + 1% *Pseudomonas fluorescens* for 12 hrs.

3.2.3. Seed treatment

The seeds were treated separately with different concentrations of KNO_3 and *Pseudomonas* as mentioned in the Table 3.2. Solutions were made by dissolving respective quantity of KNO_3 and *Pseudomonas* in sterile distilled water. Seeds were soaked in double the seed volume in each treatment. After that the seeds were removed from the solution and shade dried for 30 minutes on a paper towel and sown in pro-trays.

3.2.4. Nursery preparation

The media showed best growth parameters in the experiment No.1 was used in the experiment No.2. The treated and non-treated control seeds were sown in pro-trays filled with cocopeat: vermiculite: perlite (3:1:1 ratio on volume basis). The filled pro-trays were kept under rain shelter covered with 200 micron UV stabilized polythene sheet of 100 m^2 area. Watering was done by using rose can. Nutrient solution (19:19:19) was applied as drenching twelve and twenty days after sowing. Five seedlings of each crop were randomly selected and the media was gently removed by washing, for taking observations.

3.2.5. Testing the viability of *Pseudomonas* in KNO_3

The seeds were soaked in KNO_3 (0.5%, 1% and 2%) for 12 hours. Agar plate method was used to study the viability of *Pseudomonas* in KNO_3. Kings B agar medium (20 ml) was poured into sterilised petri plates in aseptic conditions. After the media had set, the seeds were kept equidistantly in Kings B plate. The petri plates were incubated for 2 days at ambient temperature. After incubation the seeds were observed for flourescense through UV light.

Plate 3.3. General view of experimental plot 2

3.3. Experiment 3: Effect of biofertilizers on pro-tray seedling production

3.3.1. Experimental design

The study was carried out in completely randomized design with nine treatments and three replications which had fourteen plants per treatment per replication (Table 3.3). The trial was conducted using the medium cocopeat: vermiculite: perlite (3:1:1 ratio on volume basis).

3.3.2. Experimental material

Seeds of tomato var. Anagha, chilli var. Anugraha, cucumber var. Heera and okra var. Salkeerthi were collected from the Department of Vegetable Science, College of Agriculture, Vellanikkara. The seeds have been stored for six months at 20^0C and relative humidity 50% before using in the present study.

Table 3.3: List of treatments used in the study

Treatments	Materials
T_1	2% PGPR Mix – 1
T_2	2% *Pseudomonas flourescens*
T_3	2% *Trichoderma asperellum*
T_4	Arbuscular Mycorrhizal Fungi (AMF)
T_5	AMF + 2% PGPR Mix-1
T_6	AMF + 2% *Pseudomonas* + 2% PGPR Mix-1
T_7	AMF + 2% *Trichoderma* + 2% PGPR Mix-1
T_8	2% KNO_3 treatment
T_9	Control

1) PGPR Mix – 1

It is a microbial consortium which helps in nitrogen fixation, phosphate solubilization, and potassium mobilization. Moreover, it aids in producing phytohormones like auxins and cytokinins, metabolites and enzymes which enhance

plant growth and development (Goswami *et al*., 2016). It was collected from the Department of Microbiology, College of Agriculture, Vellayani.

2) *Pseudomonas flourescens*

These are a group of bacteria which are very effective in growth promotion and disease management of crop plants. It was procured from the Department of Microbiology, College of Agriculture, Vellanikkara.

3) *Trichoderma asperellum*

It is a fungal biocontrol agent widely used as seed treatments to control various diseases and to promote plant growth and yield. It has the ability to improve seedling vigour and alleviate abiotic stresses. It was obtained from the Department of Microbiology, College of Agriculture, Vellanikkara.

4) Arbuscular Mycorrhizal Fungi (AMF)

AMF are soil borne symbiotic fungi which help in the uptake of plant nutrients and improve resistance to various abiotic stress factors (Sun *et al*., 2018). It can be used as bio inoculant as well as a biofertilizer. It can potentially strengthen plant's adaptability to changing environment. It was procured from Agricultural Technology Information Centre, Mannuthy.

3.3.3. Nursery raising and inoculation of biofertilizers

Microbial inoculum was prepared by mixing respective solid formulation *viz*., 2% PGPR Mix-1, 2% *Psuedomonas* spp. and 2% *Trichoderma* spp. (KAU POP, 2016) in sterile water. Around 1 g AMF was inoculated in the treatment directly into the seedling hole in the substrate. The seeds of tomato, chilli, cucumber and okra were directly sown into the pro-trays filled with the best media selected from experiment-1 i.e., cocopeat: vermiculite: perlite (3:1:1 ratio on volume basis) and covered with the media. The trays were placed on mulch sheet under rain shelter. The microbial suspension was used for soaking the medium after sowing the seeds. The pro-trays were watered daily with rose can. Drenching of nutrient solution (19:19:19) was done at the rate of 0.3% twelve and twenty days after sowing. Five seedlings of each crop

were randomly selected and the media was gently removed by washing, for taking observations.

3.4. Observations recorded

Data on morphological and physiological characters of tomato, chilli, okra and cucumber were recorded for further analysis. Data were collected at 15 days after sowing for okra and cucumber, while for tomato it was done at 25 DAS and for chilli it was done 30 DAS. Five plants were randomly selected for recording observations per treatment in each replication.

3.4.1. Morphological characters

1) Germination per cent (%)

It was calculated using following formula:

$$\text{Germination percentage} = \frac{\text{No. of seeds germinated}}{\text{Total no. of seeds sown}} \times 100$$

2) Plant height (cm)

Mean plant height was measured from base of the plant to the tip of petiole and expressed in cm. It was measured at 15 days after sowing for okra and cucumber, while for tomato it was done at 25 DAS and for chilli it was done 30 DAS.

3) Root length (cm)

Mean root length was measured from the collar to the tip of primary root of five selected plants. It was measured 15 days after sowing for okra and cucumber, 25 days after sowing for tomato, and 30 days after sowing for chilli.

4) Number of leaves

It was counted from five randomly selected plants from each replication and the mean was taken. Number of leaves was counted at 15 days after sowing for okra and cucumber, while for tomato it was done at 25 DAS and for chilli it was done 30 DAS.

5) Leaf area (cm^2)

Leaf area of true leaves was measured using leaf area meter (LI – 3100C) at college of Forestry, Vellanikkara. Data were collected at 15 days after sowing for okra and cucumber, while for tomato it was done at 25 DAS and for chilli it was done 30 DAS.

6) Collar diameter (mm)

Collar diameter was measured using digital vernier caliper (Caliper466). It was measured 15 days after sowing for okra and cucumber, 25 days after sowing for tomato, and 30 days after sowing for chilli.

7) Vigour index

Vigour index was calculated using following formula (Baki and Andersen, 1973).

Vigour index I = Germination per cent × (Root length + Shoot length)

Vigour Index II = Germination per cent × Dry weight of seedling

3.4.2. Physiological parameters

1) Chlorophyll content (mg/g)

Chlorophyll content of leaves was estimated by using the method of Sadasivam and Manickam (1996). One g finely cut and well mixed representative sample of leaf tissue was weighed into a clean mortar and it was ground into a fine pulp by using 20 ml 80% acetone. The pulp was centrifuged at 5000 rpm for 5 minutes and transferred the supernatant to a 100 ml volumetric flask. Made up the volume to 100 ml with 80% acetone. Absorbance of the solution was read at 645, 663 and 652 nm against the solvent (80% acetone) blank.

$$\text{mg total chlorophyll/g tissue} = 20.2\,(A_{645}) + 8.02\,(A_{663}) \times \frac{V}{1000 \times W}$$

3.4.3. Disease and pest incidence

Incidence of major pests and diseases was recorded.

3.4.4. Benefit cost analysis

It was done to evaluate profitability and the economics was calculated based on the current market rates as follows:

Net return = Gross return – Cost of production

$$\text{Benefit Cost ratio} = \frac{\text{Net return}}{\text{Cost of production}}$$

3.4.5. Statistical analysis

The data recorded on different parameters were subjected to statistical analysis using the online statistical tool GRAPES (Gopinath *et al*., 2020). The data were subjected to analysis of variance (ANOVA) and the differences between the treatment means were compared, using the least significant difference test (LSD, $p<0.05$).

3.4.6. Ranking to select best growing medium, seed treatment and biofertilizer

The best growing medium, seed treatment and biofertilizer were selected based on an index which was derived for each experiment using principal component analysis (PCA). PCA was carried out using the characters *viz*., number of leaves, leaf area, collar diameter, vigour index I & II and total chlorophyll content. Weightage for each variable was given based on the loadings of principal components having Eigen value more than one. Based on the weightage the index was calculated using following formula:

$$\text{Index} = \frac{(\text{PC 1 loadings} \times \text{treatment mean}) \times \text{Percentage of variance}}{\text{Cumulative percentage of variance}}$$

Plate 3.4. General view of experimental plot 3

Results

4. RESULTS

The present study entitled “Standardisation of operational procedures for pro-tray seedling production of vegetables” was conducted with the objective of standardising best media, pre-sowing seed invigoration, biopriming treatments, and evaluating the effect of biofertilizers on pro-tray seedling production of vegetables. The results obtained are presented below.

4.1. Standardisation of growing media for pro-tray seedling production

4.1.1. Properties of growing media

Seventeen growing media used in the study were analysed and the results are presented in the Table 4.1.

4.1.1.1. pH

Highest pH of 7.14 was recorded in the media T_8 comprising of cocopeat and vermicompost (1:1 v/v). Whereas, lowest pH of 5.87 was noticed under T_{16} (cocopeat: neemcake: vermiculite: perlite - 1:1:1:1). The media *viz*., T_3 (cow dung), T_7 (cocopeat: dried powdered cow dung - 1:1), T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1) and T_{17} (cocopeat: vermiculite: perlite - 3:1:1) showed nearly neutral pH.

4.1.1.2. EC (mS/cm)

Fresh cocopeat had an EC in the range of 0.27 to 0.28 mS/cm. It had an EC value of 1.50 mS/cm after being treated with calcium ammonium nitrate. It was used only after lowering its EC value to the initial range by buffering treatment. Lowest EC of 0.20 mS/cm was recorded in the T_4 containing soil and cocopeat (1:1 v/v). EC of neem cake was 14.00 mS/cm. Hence all the media containing neem cake T_{12} (12.56), T_{16} (12.34), T_9 (12.00), T_{14} (72.10) exhibited higher EC. No seed germination was recorded in these media having high EC. For other media EC value ranged from 0.20 - 0.80 mS/cm. Three media (T_2 - vermicompost, T_3 - cow dung and T_8 - cocopeat and vermicompost) exhibited EC between 0.80 - 2.00 mS/cm.

In order to test the pH and EC of neem cake, commercially available samples were collected from the market and analysed (Table 4.1). Nine out of the ten samples exhibited a very high EC, ranging from 14.32 to 34.57 mS/cm, which was outside the ideal range for the development of vegetable seedlings.

Table 4.1: EC and pH of neem cake from different firms

Sl. No.	Source	EC (mS/cm)	pH
1	Sample 1	14.32	5.02
2	Sample 2	24.26	5.84
3	Sample 3	34.57	4.45
4	Sample 4	25.43	5.34
5	Sample 5	14.58	5.21
6	Sample 6	18.21	5.47
7	Sample 7	23.16	5.23
8	Sample 8	19.71	5.54
9	Sample 9	23.60	5.63
10	Sample 10	18.41	5.32

Sample 1: Natlo neem cake, sample 2: Subham de-oiled cake, sample 3: Sri Sakthi Agro Industries, sample 4: Neem World - Neem Organic, sample 5: Neem cake pellets, sample 6: SKS- Neem cake, sample 7: Andavar Trading Company, sample 8: R. D. Agro Inputs, sample 9: Jai Kisan Organic Neem cake, sample 10: Sri Vinayaka Mills - Neem Royal

4.1.1.3. Weight of media (g/cc)

The media comprising cocopeat, vermiculite and perlite (1:1:1) recorded the lowest weight (0.29) compared to other treatments. Highest weight of 0.83 was recorded for the media T_5 containing soil and vermicompost (1:1). All the media having soil had higher weight.

4.1.1.4. Bulk density (g/cm^3)

Highest bulk density (1.03) was recorded for the medium containing soil and cocopeat (T_4) which was significantly different than other media. All soil containing media *viz.*, T_{10}, T_5, T_6, and T_{15} recorded higher bulk density of 0.90, 0.89, 0.85, and 0.85 respectively. The treatment T_{13} having cocopeat, vermiculite and perlite (1:1:1)

recorded lowest bulk density of 0.40, while media T_{17} (3:1:1) exhibited a bulk density of 0.57.

4.1.1.5. Water holding capacity (%)

Water holding capacity was highest (62.22) for the medium having cocopeat, vermiculite and perlite (1:1:1) which was significantly varied from other treatments and followed by T_{17} (cocopeat: vermiculite: perlite - 3:1:1). Lowest water holding capacity was 16.06 for the media comprising cocopeat and neem cake in the ratio 1:1 (T_9).

4.1.1.6. Porosity (%)

Highest porosity was recorded (69.39) for the medium T_{13} having cocopeat: vermiculite: perlite (1:1:1) followed by T_3 (67.79) which is having only cow dung. Lowest porosity (41.92) was recorded for the treatment T_7 having cocopeat: dried powdered cow dung (1:1) as growing media.

4.1.1.7. Nitrogen content (%)

Highest nitrogen content (0.52) was observed in the treatment T_2 comprising vermicompost alone and was on par with T_3 (cow dung). While lowest nitrogen content (0.08) was recorded under T_4 (soil: cocopeat - 1:1) and T_{13} (cocopeat: vermiculite: perlite - 1:1:1).

4.1.1.8. Phosphorus content (%)

Higher phosphorus content (0.56) was recorded for the media comprising cocopeat: vermicompost: neem cake (1:1:1) which was significantly different than all other treatments followed by T_3 having only dried powdered cow dung. While the treatments T_4 (soil: cocopeat - 1:1) and T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1) recorded lowest P content (0.01) which were statistically on par.

4.1.1.9. Potassium content (%)

Highest potassium content of 0.72 was noted for the media T_{16} having cocopeat: neemcake: vermiculite: perlite (1:1:1:1) which was significantly higher than

all other treatments followed by T_{15} which recorded 0.67%. While the treatment having only vermicompost (T_2) as the growing media recorded the minimum (0.01).

Table 4.2: Properties of growing media

Sl. No.	Growing medium	pH	EC (mS/cm)	Weight of media (g/cc)	Bulk density (g/cm³)	Water holding capacity (%)	Porosity (%)
1	T_1 - Cocopeat	5.98^{l}	0.26^{o}	0.32^{h}	0.61^{h}	34.14^{h}	48.19^{k}
2	T_2 - Vermicompost	6.66^{f}	1.96^{f}	0.44^{ef}	0.60^{i}	36.99^{f}	57.96^{e}
3	T_3 - Dried powdered cow dung	7.03^{b}	2.16^{e}	0.48^{d}	0.57^{j}	33.54^{i}	67.79^{b}
4	T_4 - Soil: cocopeat (1:1)	6.26^{k}	0.20^{q}	0.68^{b}	1.03^{a}	23.66^{n}	50.97^{i}
5	T_5 - Soil: Vermicompost (1:1)	6.60^{h}	0.73^{j}	0.83^{a}	0.89^{c}	31.18^{k}	53.70^{h}
6	T_6 - Soil: dried powdered cow dung (1:1)	6.75^{e}	0.59^{k}	0.68^{b}	0.85^{d}	24.69^{m}	54.29^{h}
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	6.89^{c}	0.96^{h}	0.45^{def}	0.79^{f}	33.36^{i}	41.92^{m}
8	T_8 - Cocopeat: vermicompost (1:1)	7.14^{a}	1.19^{g}	0.37^{g}	0.62^{g}	36.38^{g}	46.81^{l}
9	T_9 - Cocopeat: neem cake (1:1)	5.89^{m}	12.00^{c}	0.44^{def}	0.80^{e}	32.11^{j}	50.00^{j}
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	6.88^{c}	0.85^{i}	0.54^{c}	0.90^{b}	26.86^{l}	57.95^{e}
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	6.79^{d}	0.40^{l}	0.56^{c}	0.78^{f}	33.33^{i}	56.57^{fg}
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	6.42^{i}	12.56^{a}	0.33^{gh}	0.55^{k}	42.61^{c}	57.18^{ef}
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	6.67^{f}	0.31^{m}	0.30^{h}	0.40^{l}	62.22^{a}	69.39^{a}
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	6.31^{j}	7.21^{d}	0.57^{c}	0.78^{f}	22.18^{o}	56.35^{g}
15	T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)	6.63^{g}	0.21^{p}	0.46^{de}	0.85^{d}	38.39^{e}	62.30^{c}
16	T_{16} - Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	5.87^{n}	12.34^{b}	0.41^{f}	0.59^{i}	38.88^{d}	57.84^{e}
17	T_{17} - Cocopeat: vermiculite: perlite (3:1:1) - Control	6.88^{c}	0.30^{n}	0.33^{gh}	0.57^{j}	46.36^{b}	60.82^{d}
	CD (0.05)	0.01	0.01	0.05	0.01	0.40	0.81
	SE (m)	0.01	0.30	0.02	0.03	0.14	0.28
	CV (%)	0.08	0.01	5.63	0.67	0.69	0.87

Table 4.3: Nutrient content of growing media

Sl. No.	Growing medium	Nutrient content		
		Nitrogen (%)	Phosphorus (%)	Potassium (%)
1	T_1 - Cocopeat	0.24	0.023	0.056
2	T_2 - Vermicompost	0.52	0.133	0.013
3	T_3 - Dried powdered cow dung	0.52	0.312	0.345
4	T_4 - Soil: cocopeat (1:1)	0.08	0.006	0.086
5	T_5 - Soil: Vermicompost (1:1)	0.26	0.066	0.361
6	T_6 - Soil: dried powdered cow dung (1:1)	0.15	0.040	0.227
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	0.22	0.135	0.204
8	T_8 - Cocopeat: vermicompost (1:1)	0.45	0.123	0.137
9	T_9 - Cocopeat: neem cake (1:1)	0.24	0.058	0.217
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	0.24	0.006	0.216
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	0.24	0.019	0.123
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	0.49	0.560	0.245
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	0.06	0.047	0.177
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	0.19	0.026	0.346
15	T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)	0.19	0.018	0.670
16	T_{16} - Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	0.15	0.073	0.720
17	T_{17} - Cocopeat: vermiculite: perlite (3:1:1) - Control	0.13	0.027	0.331
	CD (0.05)	0.05	0.03	0.02
	SE (m)	0.02	0.01	0.01
	CV (%)	11.02	18.20	4.93

4.1.2. Effect of growing media on plant growth

4.1.2.1. Germination per cent

Tomato, chilli, cucumber and okra seeds did not germinate in media containing neem cake since these media had a high EC value. The media showed nil germination were T_9 (cocopeat: neem cake - 1:1), T_{12} (cocopeat: vermicompost: neem cake - 1:1:1), T_{14} (soil: cocopeat: dried powdered cow dung: neem cake - 1:1:1:1) and T_{16} (cocopeat: neemcake: vermiculite: perlite - 1:1:1:1).

In tomato 100% germination was recorded in T_{17} (cocopeat: vermiculite: perlite - 3:1:1) which was on par with T_6 (95.2), T_{13} (95.2), T_5 (92.8) and T_{10} (92.8). Among the media, minimum germination per cent of 35.7 was recorded under T_7 (cocopeat: dried powdered cow dung - 1:1) (Table 4.3). While in chilli maximum germination of 92.8% was recorded in T_{11} (soil: cocopeat: vermicompost - 1:1:1), T_{13} (cocopeat: vermiculite: perlite - 1:1:1), T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1) and T_{17}. Minimum of 50% was recorded in media having vermicompost alone (Table 4.4). In cucumber, 100% germination was noted in T_5, T_{10}, T_{13} and T_{17}. Minimum of 57.1% was recorded under T_{11} (soil: cocopeat: vermicompost - 1:1:1) (Table 4.5). In okra maximum germination of 97.6% was recorded in the treatment T_{17} (cocopeat: vermiculite: perlite - 3:1:1) which was on par with T_4, T_5, T_6, T_{10}, T_{13} and T_{15}. Minimum of 50% was noted under T_3 having dried cow dung alone (Table 4.6).

Since the media *viz.*, T_9 (cocopeat: neem cake - 1:1), T_{12} (cocopeat: vermicompost: neem cake - 1:1:1), T_{14} (soil: cocopeat: dried powdered cow dung: neem cake - 1:1:1:1) and T_{16} (cocopeat: neemcake: vermiculite: perlite - 1:1:1:1) had nil germination, the growth parameters like plant height, root length, number of leaves, leaf area *etc*. could not be recorded.

4.1.2.2. Plant height (cm)

Plant height is an important parameter related to growth and development of the crop. Growing media had a significant effect on plant height for all the four crops studied. Crops *viz*., chilli, cucumber and okra grown in T_{17} (cocopeat: vermiculite:

perlite - 3:1:1) recorded the maximum plant height of 10.37 cm, 17.77 cm, and 11.89 cm respectively on 30 DAS in chilli and 15 DAS in cucumber and okra. In tomato highest plant height of 10.11 cm was noted in T_{10} which was on par with T_6, T_5 and T_{17} having plant height of 10.09 cm, 9.90 cm and 9.37 cm respectively. In chilli the second highest plant height of 9.71 cm was observed for T_6 (soil: dried powdered cow dung - 1:1) and minimum of 7.57 cm was noted under T_5. In okra T_4 (soil: cocopeat - 1:1) recorded a plant height of 10.91 cm which was the second highest. Minimum of 5.82 cm was recorded for T_2 having only vermicompost. While in cucumber T_5 (soil: vermicompost - 1:1) was followed by T_{17} with a value of 16.57 cm. Minimum value of 11.65 cm was noted for T_8 (cocopeat: vermicompost - 1:1).

4.1.2.3. Root length (cm)

Plants grown in the medium T_{13} having cocopeat: vermiculite: perlite (1:1:1) recorded highest root length in tomato (4.97 cm) which was on par with T_{10}. The minimum root length (2.19 cm) was noted under T_4 containing soil: cocopeat (1:1). In chilli T_{13} (cocopeat: vermiculite: perlite - 1:1:1) recorded maximum root length of 2.95 cm which was on par with T_{17} having a value of 2.93 cm on 30 DAS. Minimum root length of 1.07 cm was noted for T_4. T_{17} recorded the highest root length of 6.66 cm in cucumber which was followed by T_{13}. Minimum root length of 3.08 cm was recorded for the seedlings grown in vermicompost. In okra maximum root length of 6.34 cm was recorded in T_{13} (cocopeat: vermiculite: perlite - 1:1:1) which was on par with T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1) and T_2 having only vermicompost. Minimum root length of 3.57 cm was noted under T_4 (soil and cocopeat - 1:1).

4.1.2.4. Number of leaves

In tomato maximum of 4.47 leaves were observed on 30 DAS in T_{17} (cocopeat: vermiculite: perlite - 3:1:1) which was on par with T_{13} (cocopeat: vermiculite: perlite - 1:1:1) having 4.40 leaves. Minimum of 2.53 leaves was observed for treatments T_1 (cocopeat) and T_2 (vermicompost). In chilli maximum of 4.87 leaves were noted 30 DAS under treatment T_{13} which was on par with T_{17} having 4.73 leaves. Seedlings grown in vermicompost had the minimum of 3.47 leaves. Number

of leaves in cucumber 15 DAS was found to be highest (1.87) in T_5 (soil: vermicompost - 1:1) followed by T_8 (cocopeat: vermicompost - 1:1) which was 1.67. Minimum (1.00) was under media having vermicompost alone. The maximum of leaves (1.60) was observed 15 DAS in okra grown in T_5 (soil: vermicompost - 1:1) which was on par with T_2 (vermicompost).

4.1.2.5. Leaf area (cm^2)

Treatment T_{11} having soil: cocopeat: vermicompost in the ratio 1:1:1 recorded maximum leaf area (14.12) in tomato. Second highest (12.38) was recorded under T_{10} (soil: cocopeat: dried powdered cow dung (1:1:1) which was on par with T_{17} with a value of 12.19. Minimum of 3.17 was noted under T_8 which contain cocopeat and vermicompost in equal proportion. In chilli leaf area was found to be higher (16.72) under T_{13} followed by T_{17} which was 15.45. Minimum leaf area of 7.36 was noted for T_8. The maximum leaf area of 27.99 was recorded in okra grown in T_4 (soil: cocopeat - 1:1) followed by T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1). Minimum leaf area of 8.84 was noted under T_1 having only cocopeat. Leaf area of cucumber was found to be highest (33.83) for T_{11} (soil: cocopeat: vermicompost - 1:1:1) followed by T_{13} which was 30.17. Minimum leaf area of 15.64 was recorded under T_1 having cocopeat alone.

4.1.2.6. Collar diameter (mm)

In tomato and chilli T_{17} having cocopeat, vermiculite and perlite (3:1:1) recorded maximum collar diameter of 3.17 and 1.35 respectively. T_{11} noted maximum collar diameter of 4.33 in cucumber followed by T_6. Minimum collar diameter of 2.47 was noted in T_{15}. In okra maximum collar diameter of 2.62 was recorded in T_5 which was on par with T_{17}, T_7 and T_4. Minimum collar diameter of 1.61 was recorded under media having only cocopeat.

4.1.2.7. Vigour index I

In tomato highest vigour index I of 1434.00 was recorded for T_{17} (cocopeat: vermiculite: perlite in the ratio 3:1:1 which was on par with T_6 (1395.78) having soil and cow dung in equal proportion which was on par with T_{10} (1373.44) having soil, cocopeat and dried cow dung in equal proportion. Minimum VI I of 419.83 was noted

for T_7 (cocopeat: dried powdered cow dung - 1:1). In chilli T_{17} had the highest VI I of 1234.24 followed by T_{15} with a value of 1109.27. Minimum VI I of 438.00 was obtained for T_4 containing soil and cocopeat in equal proportion. In okra, maximum VI I of 1617.31 was obtained for T_{17} which was on par with T_{10} (1526.25). Minimum VI I of 564.67 was recorded under T_3 having only cow dung. In cucumber maximum vigour index I of 2442.67 was noted under T_{17} followed by T_{13} (2119.33). Minimum of 1038.38 was recorded under T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1).

4.1.2.8. Vigour index II

Vigour Index II showed wide variation between treatments. In tomato maximum VI II of 19.40 was noted for T_{17} (cocopeat: vermiculite: perlite - 3:1:1) which was on par with T_6 (18.22). Lowest of 4.87 was recorded under T_2 having vermicompost alone. In chilli T_{11} (soil: cocopeat: vermicompost - 1:1:1) recorded maximum vigour index of 14.04 followed by T_{15} which recorded a VI II of 12.93. Lowest of 2.29 was recorded under T_3 having dried cow dung. In cucumber highest VI II of 60.07 was noted under T_{17} which was on par with T_5 with a value of 57.60. T_{11} recorded minimum VI II of 27.14. In okra T_{17} recorded the maximum VI II of 40.68 followed by T_6 (37.43) having soil and dried powdered cow dung in equal proportion. Minimum VI II of 11.77 was recorded under T_2 having only vermicompost.

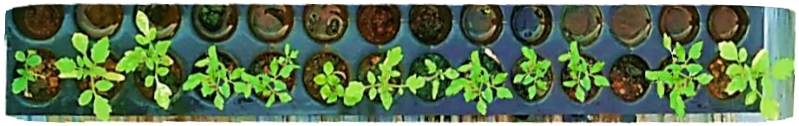
Table 4.4: Effect of growing media on morphological characters of tomato

Sl.No	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II
1	T_1 - Cocopeat	76.17^{c}	4.90^{e}	3.15^{e}	2.53^{h}	3.41^{h}	1.63^{g}	616.19^{de}	8.79^{g}
2	T_2 - Vermicompost	50.00^{e}	7.08^{cd}	3.54^{d}	2.53^{h}	4.67^{g}	2.21^{d}	531.00^{ef}	4.87^{i}
3	T_3 - Dried powdered cow dung	90.43^{b}	8.75^{b}	2.79^{f}	3.66^{cd}	8.77^{d}	2.35^{bc}	1043.60^{c}	12.05^{e}
4	T_4 - Soil: cocopeat (1:1)	59.50^{d}	7.64^{c}	2.19^{h}	3.40^{e}	8.02^{e}	2.24^{cd}	577.93^{ef}	7.52^{h}
5	T_5 - Soil: Vermicompost (1:1)	92.80^{ab}	9.91^{a}	4.10^{c}	3.33^{e}	11.38^{c}	1.87^{e}	1299.82^{b}	15.34^{c}
6	T_6 - Soil: dried powdered cow dung (1:1)	95.20^{ab}	10.09^{a}	4.56^{b}	4.00^{b}	8.87^{d}	2.43^{b}	1395.78^{ab}	18.22^{ab}
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	35.70^{f}	7.56^{c}	4.20^{c}	4.00^{b}	5.99^{f}	1.87^{e}	419.83^{g}	5.31^{i}
8	T_8 - Cocopeat: vermicompost (1:1)	57.10^{de}	6.44^{d}	2.25^{h}	3.07^{f}	3.17^{h}	1.49^{h}	496.39^{fg}	9.97^{fg}
9	T_9 - Cocopeat: neem cake (1:1)	0.00^{g}	0.00^{f}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{h}	0.00^{j}
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	92.80^{ab}	10.11^{a}	4.69^{b}	3.73^{c}	12.38^{b}	2.42^{b}	1373.44^{ab}	13.55^{d}
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	40.47^{f}	8.75^{b}	3.53^{d}	3.47^{de}	14.12^{a}	1.71^{fg}	499.51^{fg}	4.91^{i}
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	0.00^{g}	0.00^{f}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{i}	0.00^{h}	0.00^{j}
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	95.20^{ab}	7.36^{c}	4.25^{c}	4.40^{a}	8.61^{d}	2.30^{cd}	1103.36^{c}	17.25^{b}

Table 4.4. Contd.

Sl.No	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm2)	Collar diameter (mm)	Vigour index I	Vigour Index II
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	0.00g	0.00f	0.00i	0.00i	0.00i	0.00i	0.00h	0.00j
15	T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)	88.07b	5.27e	2.53g	2.80g	3.28h	1.76ef	686.45d	10.86ef
16	T_{16} - Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	0.00g	0.00f	0.00i	0.00i	0.00i	0.00i	0.00h	0.00j
17	T_{17} - Cocopeat: vermiculite: perlite (3:1:1) - Control	100.00a	9.37ab	4.97a	4.47a	12.19b	3.17a	1434.00a	19.40a
	CD (0.05)	8.77	0.84	0.25	0.24	0.54	0.12	103.00	1.20
	SE (m)	3.05	0.29	0.09	0.08	0.19	0.04	35.84	0.42
	CV (%)	9.23	8.30	5.59	5.35	5.23	4.44	9.19	8.33

T_{17} - Cocopeat: vermiculite: perlite (3:1:1)



T_{6} - Soil: dried powdered cow dung (1:1)

T_{13} - Cocopeat: vermiculite: perlite (1:1:1)

T_{10} - Soil: cocopeat: cow dung (1:1:1)

Plate 4.1. Tomato seedlings grown in different media

T_1 T_2 T_3 T_4 T_5 T_6 T_7 T_8

T_{10} T_{11} T_{13} T_{15} T_{17}

Plate 4.2. Effect of growing media on tomato seedlings

Table 4.5: Effect of growing media on morphological characters of chilli

Sl.No	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II
1	T_1 - Cocopeat	50.00^{d}	8.27^{h}	1.57^{g}	3.87^{de}	9.40^{g}	0.66^{h}	491.67^{g}	2.93^{g}
2	T_2 - Vermicompost	50.00^{d}	8.33^{h}	1.39^{h}	3.47^{g}	9.33^{gh}	0.95^{f}	487.06^{gh}	3.00^{g}
3	T_3 - Dried powdered cow dung	52.38^{d}	9.15^{e}	2.03^{f}	3.73^{ef}	8.89^{h}	1.18^{b}	586.04^{f}	2.30^{h}
4	T_4 - Soil: cocopeat (1:1)	50.00^{d}	7.69^{i}	1.07^{j}	4.00^{d}	9.93^{ef}	0.61^{h}	438.00^{h}	2.83^{g}
5	T_5 - Soil: Vermicompost (1:1)	61.90^{c}	7.57^{i}	1.23^{i}	3.87^{de}	9.52^{fg}	0.85^{g}	545.10^{f}	4.96^{f}
6	T_6 - Soil: dried powdered cow dung (1:1)	85.71^{b}	9.71^{b}	2.14^{ef}	4.27^{bc}	11.89^{d}	1.08^{de}	1015.95^{c}	9.54^{d}
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	61.90^{c}	9.14^{e}	2.78^{b}	3.73^{ef}	10.16^{e}	0.67^{h}	737.94^{d}	6.19^{e}
8	T_8 - Cocopeat: vermicompost (1:1)	59.52^{c}	8.35^{h}	2.44^{d}	4.00^{d}	7.36^{i}	0.95^{f}	642.44^{e}	5.23^{f}
9	T_9 - Cocopeat: neem cake (1:1)	0.00^{e}	0.00^{j}	0.00^{k}	0.00^{h}	0.00^{j}	0.00^{i}	0.00^{i}	0.00^{i}
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	85.71^{b}	9.52^{c}	2.22^{e}	4.33^{b}	12.93^{c}	1.15^{bc}	1006.24^{c}	5.77^{e}
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	92.80^{a}	8.67^{g}	2.27^{e}	4.07^{cd}	11.58^{d}	1.01^{ef}	1015.23^{c}	14.04^{a}

Table 4.5. Contd.

Sl.No	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm2)	Collar diameter (mm)	Vigour index I	Vigour Index II
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	0.00^{e}	0.00^{j}	0.00^{k}	0.00^{h}	0.00^{j}	0.00^{i}	0.00^{i}	0.00^{i}
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	92.80^{a}	8.93^{f}	2.95^{a}	4.87^{a}	16.72^{a}	1.09^{cd}	1101.85^{b}	11.88^{c}
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	0.00^{e}	0.00^{j}	0.00^{k}	0.00^{h}	0.00^{j}	0.00^{i}	0.00^{i}	0.00^{i}
15	T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)	92.80^{a}	9.333^{d}	2.62^{c}	3.60^{fg}	11.59^{d}	1.16^{bc}	1109.27^{b}	12.93^{b}
16	T_{16} - Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	0.00^{e}	0.00^{j}	0.00^{k}	0.00^{h}	0.00^{j}	0.00^{i}	0.00^{i}	0.00^{i}
17	T_{17} - Cocopeat: vermiculite: perlite (3:1:1) - Control	92.80^{a}	10.37^{a}	2.93^{a}	4.73^{a}	15.45^{b}	1.35^{a}	1234.24^{a}	9.96^{d}
	CD (0.05	4.39	0.13	0.13	0.22	0.48	0.07	52.60	0.44
	SE (m)	1.53	0.04	0.05	0.08	0.17	0.02	18.30	0.15
	CV (%)	4.85	1.13	4.87	4.25	3.39	5.64	5.18	4.90

T_{17} - Cocopeat: vermiculite: perlite (3:1:1)

T_{13} - Cocopeat: vermiculite: perlite (1:1:1)

T_{11} - Soil: cocopeat: vermicompost (1:1:1)

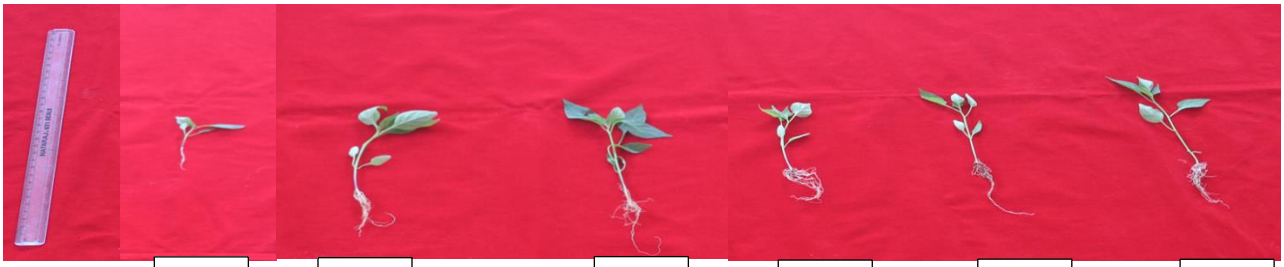
T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)

T_6 - Soil: dried powdered cow dung (1:1)

T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)

Plate 4.3. Chilli seedlings grown in different growing media

T_1 T_2 T_3 T_4 T_5 T_6 T_7



T_8 T_{10} T_{11} T_{13} T_{15} T_{17}

Plate 4.4. Effect of growing media on chilli seedlings

Table 4.6: Effect of growing media on morphological characters of cucumber

Sl.No	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II
1	T_1 - Cocopeat	78.50^{c}	11.72^{g}	4.01^{cd}	1.06^{g}	15.64^{e}	2.63^{ef}	1235.07^{gh}	39.15^{f}
2	T_2 - Vermicompost	71.40^{d}	13.09^{f}	3.09^{e}	1.00^{g}	17.29^{e}	2.85^{de}	1154.77^{hi}	32.60^{g}
3	T_3 - Dried powdered cow dung	92.80^{b}	13.59^{ef}	3.95^{cd}	1.06^{g}	21.43^{d}	3.64^{c}	1627.71^{d}	43.74^{e}
4	T_4 - Soil: cocopeat (1:1)	92.80^{b}	12.21^{g}	3.10^{e}	1.27^{ef}	24.11^{cd}	2.56^{f}	1420.46^{ef}	48.13^{d}
5	T_5 - Soil: Vermicompost (1:1)	100.00^{a}	16.57^{b}	3.39^{e}	1.87^{a}	24.38^{cd}	3.58^{c}	1996.00^{c}	57.60^{ab}
6	T_6 - Soil: dried powdered cow dung (1:1)	88.03^{b}	13.03^{f}	3.55^{de}	1.53^{bc}	24.09^{cd}	3.98^{b}	1459.12^{e}	52.42^{c}
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	92.83^{b}	13.85^{e}	3.96^{cd}	1.13^{fg}	25.66^{c}	3.45^{c}	1649.75^{d}	52.49^{c}
8	T_8 - Cocopeat: vermicompost (1:1)	80.90^{c}	11.65^{g}	4.79^{b}	1.67^{b}	21.69^{d}	3.59^{c}	1330.62^{fg}	42.98^{e}
9	T_9 - Cocopeat: neem cake (1:1)	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{g}	0.00^{k}	0.00^{i}
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	100.00^{a}	15.76^{c}	4.92^{b}	1.33^{de}	25.84^{c}	3.45^{c}	2068.00^{bc}	56.13^{b}
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	57.10^{e}	14.76^{d}	4.87^{b}	1.47^{cd}	33.83^{a}	4.33^{a}	1121.06^{ij}	27.14^{h}
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{g}	0.00^{k}	0.00^{i}
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	100.00^{a}	16.12^{bc}	5.07^{b}	1.13^{fg}	30.17^{b}	2.92^{d}	2119.33^{b}	56.40^{b}
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{g}	0.00^{k}	0.00^{i}

Table 4.6. Contd.

Sl.No	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm2)	Collar diameter (mm)	Vigour index I	Vigour Index II
15	T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)	59.46^{e}	13.31^{ef}	4.15^{c}	1.07^{g}	21.82^{d}	2.47^{f}	1038.38^{j}	29.69^{h}
16	T_{16} - Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{h}	0.00^{f}	0.00^{g}	0.00^{k}	0.00^{i}
17	T_{17} - Cocopeat: vermiculite: perlite (3:1:1) - Control	100.00^{a}	17.77^{a}	6.66^{a}	1.60^{bc}	26.36^{c}	2.87^{de}	2442.67^{a}	60.07^{a}
	CD (0.05)	4.98	0.72	0.54	0.19	3.51	0.24	110.52	2.89
	SE (m)	1.73	0.25	0.19	0.07	1.22	0.08	38.47	1.00
	CV (%)	4.58	4.02	9.98	11.41	11.53	5.92	5.48	4.95

Table 4.7: Effect of growing media on morphological characters of okra

Sl.No.	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II
1	T_1 - Cocopeat	71.40^{b}	8.48^{f}	4.04^{fg}	1.00^{d}	8.84^{f}	1.61^{g}	893.93^{e}	19.08^{f}
2	T_2 - Vermicompost	50.00^{d}	5.82^{h}	6.03^{a}	1.47^{abc}	16.32^{d}	2.37^{cd}	592.33^{f}	11.10^{h}
3	T_3 - Dried powdered cow dung	50.00^{d}	7.13^{g}	4.17^{efg}	1.07^{cd}	13.98^{e}	2.12^{ef}	564.67^{f}	11.77^{h}
4	T_4 - Soil: cocopeat (1:1)	95.20^{a}	10.91^{b}	3.57^{g}	1.40^{abcd}	27.99^{a}	2.42^{bcd}	1378.54^{cd}	33.52^{c}
5	T_5 - Soil: Vermicompost (1:1)	92.80^{a}	10.41^{c}	4.77^{bcde}	1.60^{a}	20.77^{c}	2.62^{a}	1408.70^{cd}	29.32^{d}
6	T_6 - Soil: dried powdered cow dung (1:1)	92.80^{a}	10.43^{c}	4.61^{def}	1.00^{d}	21.41^{c}	1.95^{f}	1395.71^{cd}	37.43^{b}
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	69.00^{bc}	8.43^{f}	4.82^{bd}	1.00^{d}	16.71^{d}	2.45^{abc}	915.52^{e}	21.70^{e}
8	T_8 - Cocopeat: vermicompost (1:1)	64.23^{c}	8.39^{f}	4.79^{bcd}	1.40^{abcd}	13.37^{e}	2.00^{f}	845.69^{e}	18.49^{f}
9	T_9 - Cocopeat: neem cake (1:1)	0.00^{e}	0.00^{i}	0.00^{h}	0.00^{e}	0.00^{g}	0.00^{h}	0.00^{g}	0.00^{i}
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	92.80^{a}	10.39^{c}	6.06^{a}	1.07^{cd}	24.95^{b}	2.05^{f}	1526.25^{ab}	29.26^{d}
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	54.73^{d}	9.82^{d}	5.27^{bc}	1.00^{d}	16.74^{d}	2.28^{de}	824.72^{e}	16.09^{g}
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	0.00^{e}	0.00^{i}	0.00^{h}	0.00^{e}	0.00^{g}	0.00^{h}	0.00^{g}	0.00^{i}
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	92.80^{a}	9.47^{de}	6.34^{a}	1.13^{bcd}	21.27^{c}	2.07^{f}	1467.48^{bc}	36.44^{b}
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	0.00^{e}	0.00^{i}	0.00^{h}	0.00^{e}	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{i}

Table 4.7. Contd.

Sl.No.	Growing medium	Morphological characters							
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm2)	Collar diameter (mm)	Vigour index I	Vigour Index II
15	T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)	92.80[a]	9.13[e]	5.31[b]	1.13b[cd]	14.69[de]	2.34[cd]	1340.03[d]	27.78[d]
16	T_{16} - Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	0.00[e]	0.00[i]	0.00[h]	0.00[e]	0.00[g]	0.00[g]	0.00[g]	0.00[i]
17	T_{17} - Cocopeat: vermiculite: perlite (3:1:1) - Control	97.60[a]	11.88[a]	4.68[cde]	1.53[ab]	23.71[b]	2.57[ab]	1617.31[a]	40.68[a]
	CD (0.05)	5.99	0.44	0.60	0.42	2.27	0.17	95.68	2.09
	SE (m)	2.08	0.15	0.21	0.15	0.79	0.06	33.29	0.73
	CV (%)	6.03	3.72	9.59	27.11	9.68	5.99	6.63	6.45

T_{17} - Cocopeat: vermiculite: perlite (3:1:1)

T_5 - Soil: vermicompost (1:1)

T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)

T_{13} - Cocopeat: vermiculite: perlite (1:1:1)

Plate 4.5. Cucumber and okra seedlings grown in different growing media

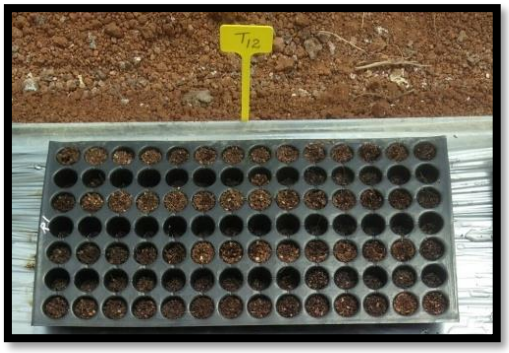
T_4 - Soil: cocopeat (1:1)

T_6 - Soil: dried powdered cow dung (1:1)

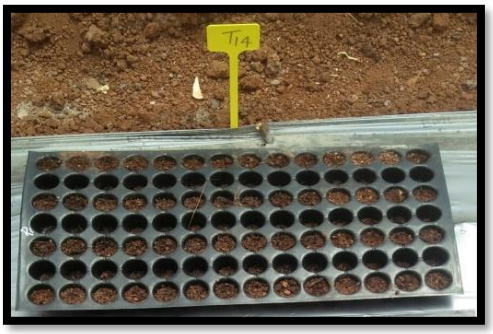
T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)

Plate 4.5. Cucumber and okra seedlings grown in different growing media (Contd.)

T_9 - Cocopeat: neem cake (1:1)



T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)



T_{14} - Soil: cocopeat: cow dung: neem cake (1:1:1:1)

T_{16} - Cocopeat: neem cake: vermiculite: perlite (1:1:1:1)

Plate 4.6. No germination in the media amended with neem cake

4.1.2.9. Total chlorophyll content (mg/g)

In tomato, the maximum total chlorophyll content of 1.74 was recorded under soil and vermicompost in equal proportion (T_5) as medium which was significantly superior to other media followed by T_{15} having soil, cocopeat, vermiculite and perlite in equal proportion. Minimum total chlorophyll content of 0.33 was recorded for the medium having only dried powdered cow dung. Chilli recorded maximum total chlorophyll content of 1.45 in the treatment having soil, cocopeat and vermicompost in equal proportion (T_{11}) followed by T_8 (cocopeat: vermicompost - 1:1). In cucumber the maximum value of 1.53 was noted under T_3 having cow dung and was significantly superior followed by T_{17} (1.27). Minimum of 0.46 was noted under T_7 having soil and cow dung in equal proportion. In okra maximum of 0.68 was recorded under T_{17} followed by T_4 which was on par with T_{10}. Minimum of 0.28 was noted under T_7 (Table 4.7).

Table 4.8: Effect of growing media on physiological parameters

Sl. No.	Growing medium	Total chlorophyll content (mg/g)			
		Tomato	Chilli	Cucumber	Okra
1	T_1 - Cocopeat	0.42^{l}	0.55^{i}	0.59^{l}	0.39^{i}
2	T_2 - Vermicompost	0.98^{e}	1.35^{c}	0.69^{k}	0.57^{d}
3	T_3 - Dried powdered cow dung	0.33^{m}	0.55^{i}	1.53^{a}	0.43^{g}
4	T_4 - Soil: cocopeat (1:1)	0.66^{j}	0.94^{g}	1.13^{f}	0.64^{b}
5	T_5 - Soil: Vermicompost (1:1)	1.74^{a}	1.37^{b}	1.24^{d}	0.37^{j}
6	T_6 - Soil: dried powdered cow dung (1:1)	0.82^{f}	0.93^{g}	0.93^{i}	0.52^{f}
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	0.46^{k}	0.75^{h}	0.46^{m}	0.28^{l}
8	T_8 - Cocopeat: vermicompost (1:1)	0.79^{i}	1.38^{b}	0.96^{h}	0.40^{h}
9	T_9 - Cocopeat: neem cake (1:1)	0.00^{n}	0.00^{j}	0.00^{n}	0.00^{m}
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	0.79^{h}	1.32^{de}	1.25^{c}	0.64^{b}
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	0.81^{g}	1.45^{a}	0.75^{j}	0.56^{e}
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	0.00^{n}	0.00^{j}	0.00^{n}	0.00^{m}
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	1.65^{c}	1.31^{e}	1.01^{g}	0.36^{k}
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	0.00^{n}	0.00^{j}	0.00^{n}	0.00^{m}
15	T_{15}- Soil: cocopeat: vermiculite: perlite (1: 1: 1: 1)	1.72^{b}	1.34^{cd}	1.20^{e}	0.63^{c}

Table 4.8. Contd.

Sl. No.	Growing medium	Total chlorophyll content (mg/g)			
		Tomato	Chilli	Cucumber	Okra
16	T_{16}- Cocopeat: neemcake: vermiculite: perlite (1: 1: 1: 1)	0.00^{n}	0.00^{j}	0.00^{n}	0.00^{m}
17	T_{17}- Cocopeat: vermiculite: perlite (3: 1: 1) - Control	1.54^{d}	1.05^{f}	1.27^{b}	0.68^{a}
	CD (0.05)	0.02	0.02	0.06	0.04
	SE (m)	0.01	0.07	0.02	0.01
	CV (%)	0.15	1.42	0.48	0.58

4.1.3. Disease and pest analysis

There was no disease and pests observed for all the crops studied.

4.1.4. Cost analysis

Cost of production was calculated for nursery area of 100 m^2 from variable and fixed cost and the details of input costs are given in the Table 4.8. To find out the benefit, total and net income was calculated. Benefit cost ratio of different media are enumerated in Table 4.9. BC ratio was found highest (3.16) for T_6 comprising soil and cow dung in equal proportion in tomato, followed by T_3 (2.91) comprising only cow dung. The minimum BC ratio (0.47) was noted in T_7 (cocopeat and cow dung - 1:1). In chilli highest BC ratio (2.91) was recorded under T_6 followed by T_{15} comprising soil, cocopeat, vermiculite and perlite in equal proportion (2.85). The minimum ratio of 1.16 was recorded in T_4 (soil and cocopeat). Medium having soil, cocopeat and cow dung (T_{10}) recorded the highest BC ratio (2.93) in cucumber. Minimum BC ratio of 1.04 was noted under T_{11} (soil, cocopeat and vermicompost - 1:1:1). In okra it was highest (3.38) for T_6 having soil and dried powdered cow dung in equal proportion. Minimum BC ratio was noted for T_2 (0.73).

Table 4.9: Input cost for nursery seedling production (nursery area 100 m^2)

Cost	Item	Total cost (Rs.)
Variable cost	Tomato seeds	1750
	Chilli seeds	816
	Cucumber seeds	14000
	Okra seeds	7370
	Pro-trays with 98 cells	7500
	Fertilizers	35.20
	Plant protection chemicals	80.00
	labour	5760
	Cocopeat	2800
	Vermicompost	7700
	Dried powdered cow dung	511.84
	Soil: cocopeat (1:1)	1400
	Soil: Vermicompost (1:1)	3840
	Soil: dried powdered cow dung (1:1)	255.92
	Cocopeat: dried powdered cow dung (1:1)	1655.92
	Cocopeat: vermicompost (1:1)	5260
	Cocopeat: neem cake (1:1)	11280
	Soil: cocopeat: dried powdered cow dung (1:1:1)	1100.18
	Soil: cocopeat: vermicompost (1:1:1)	3490
	Cocopeat: vermicompost: neem cake (1:1:1)	10050
	Cocopeat: vermiculite: perlite (1:1:1)	3172
	Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	5747.96
	Soil: cocopeat: vermiculite: perlite (1:1:1:1)	2400
	Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	7063
	Cocopeat: vermiculite: perlite (3:1:1) - Control	3040
Fixed cost	Structure cost + labour cost + administration cost + land cost	7000

Table 4.10: Benefit cost ratio (100m^2/month) of different crops grown in different media

Sl. No.	Growing medium	Cost of media	Benefit Cost Ratio			
			Tomato	Chilli	Cucumber	Okra
1	T_1 - Cocopeat	2800	1.99	1.04	1.89	2.00
2	T_2 - Vermicompost	7700	0.64	1.59	1.22	0.73
3	T_3 - Dried powdered cow dung	511.84	2.91	1.36	2.73	1.33
4	T_4 - Soil: cocopeat (1:1)	1400	1.47	1.16	2.60	3.25
5	T_5 - Soil: Vermicompost (1:1)	3840	2.50	1.42	2.54	2.73
6	T_6 - Soil: dried powdered cow dung (1:1)	255.92	3.16	2.91	2.58	3.38
7	T_7 - Cocopeat: dried powdered cow dung (1:1)	1655.92	0.47	1.65	2.57	2.05
8	T_8 - Cocopeat: vermicompost (1:1)	5260	1.04	1.20	1.72	1.44
9	T_9 - Cocopeat: neem cake (1:1)	11280	0	0	0	0
10	T_{10} - Soil: cocopeat: dried powdered cow dung (1:1:1)	1100.18	2.91	2.76	2.93	3.20
11	T_{11} - Soil: cocopeat: vermicompost (1:1:1)	3490	0.54	2.68	1.04	1.23
12	T_{12} - Cocopeat: vermicompost: neem cake (1:1:1)	10050	0	0	0	0
13	T_{13} - Cocopeat: vermiculite: perlite (1:1:1)	3172	2.68	2.73	2.63	2.84
14	T_{14} - Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)	5747.96	0	0	0	0
15	T_{15} - Soil: cocopeat: vermiculite: perlite (1:1:1:1)	2400	2.51	2.85	1.22	2.97
16	T_{16} - Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	7063	0	0	0	0
17	T_{17} - Cocopeat: vermiculite: perlite (3:1:1) - Control	3040	2.89	2.75	2.64	3.06

4.1.5. Criteria for selecting best growing media

Media were selected based on an index which was calculated using principal component analysis (PCA). PCA was carried out using the characters *viz*., number of

leaves, leaf area, collar diameter, vigour index I & II and total chlorophyll content. The PCA analysis did not include germination percentage, root length and plant height because these data are part of VI I. It is found that in tomato (Fig. 4.1.1), chilli (Fig.4.1.2), cucumber (Fig.4.1.3) and okra (Fig 4.1.4) PC 1 (Eigen value > 1) was explaining about 83.19%, 87.83%, 89.51% and 89.15% of the variance respectively. So weightage for each variable was derived based on the loadings of PC 1. Index was constructed based on weightage of each characters selected. The medium having higher index was ranked first.

The results showed that, in all the four crops studied T_{17} (cocopeat, vermiculite and perlite - 3:1:1) had a maximum index and was on top. It was followed by T_6 (soil and dried powdered cow dung - 1:1) and T_{10} (soil, cocopeat and cow dung - 1:1:1) in tomato (Table 4.10), T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1) and T_{13} (cocopeat: vermiculite: perlite- 1:1:1) in chilli (Table 4.11), T_{13} and T_{10} in cucumber (Table 4.12) and okra (Table 4.13).

Table 4.11: Ranking for selection of best growing media for tomato

Suitability	Growing media	Index	Rank
Highly suitable (482 - 629)	T_{17} (cocopeat: vermiculite: perlite - 3:1:1)	627	1
	T_6 (soil: dried powdered cow dung - 1:1)	608	2
	T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1)	598	2
	T_5 (soil: vermicompost - 1:1)	567	3
	T_{13} (cocopeat: vermiculite: perlite - 1:1:1)	484	4
Moderately suitable (334 - 481)	T_3 (dried powdered cow dung)	455	5
Less suitable (186 - 333)	T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1)	300	6
	T_1 (cocopeat)	269	6
	T_4 (soil: cocopeat - 1:1)	255	7
	T_2 (vermicompost)	232	7
	T_{11} (soil: cocopeat: vermicompost - 1:1:1)	222	8
	T_8 (cocopeat: vermicompost - 1:1)	219	8
	T_7 (cocopeat: dried powdered cow dung - 1:1)	186	8

Table 4.12: Ranking for selection of best growing media for chilli

Suitability	Growing media	Index	Rank
Highly suitable (422 - 536)	T_{17} (cocopeat: vermiculite: perlite - 3:1:1)	534	1
	T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1)	480	2
	T_{13} (cocopeat: vermiculite: perlite - 1:1:1)	479	2
	T_{11} (soil: cocopeat: vermicompost - 1:1:1)	441	3
	T_6 (soil: dried powdered cow dung - 1:1)	439	3
	T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1)	435	3
Moderately suitable (307 - 421)	T_7 (cocopeat: dried powdered cow dung - 1:1)	320	4
Less suitable (192 -306)	T_4 (soil: cocopeat - 1:1)	278	5
	T_2 (vermicompost)	254	6
	T_1 (cocopeat)	238	6
	T_5 (soil: vermicompost - 1:1)	214	7
	T_3 (dried powdered cow dung)	212	7
	T_8 (cocopeat: vermicompost - 1:1)	192	7

Table 4.13: Ranking for selection of best growing media for cucumber

Suitability	Growing media	Index	Rank
Highly suitable (848 - 1046)	T_{17} (cocopeat: vermiculite: perlite- 3:1:1)	1044	1
	T_{13} (cocopeat: vermiculite: perlite- 1:1:1)	910	2
	T_{10} (soil: cocopeat: dried powdered cow dung- 1:1:1)	888	2
	T_5 (soil: vermicompost- 1:1)	858	3
Moderately suitable (396-546)	T_7 (cocopeat: dried powdered cow dung- 1:1)	714	4
	T_3 (dried powdered cow dung)	700	4
Less suitable (245-395)	T_6 (soil: dried powdered cow dung- 1:1)	635	5
	T_4 (soil: cocopeat- 1:1)	617	5
	T_8 (cocopeat: vermicompost- 1:1)	577	5
	T_1 (cocopeat)	533	5
	T_2 (vermicompost)	498	5
	T_{11} (soil: cocopeat: vermicompost- 1:1:1)	489	5
	T_{15} (soil: cocopeat: vermiculite: perlite- 1:1:1:1)	450	6

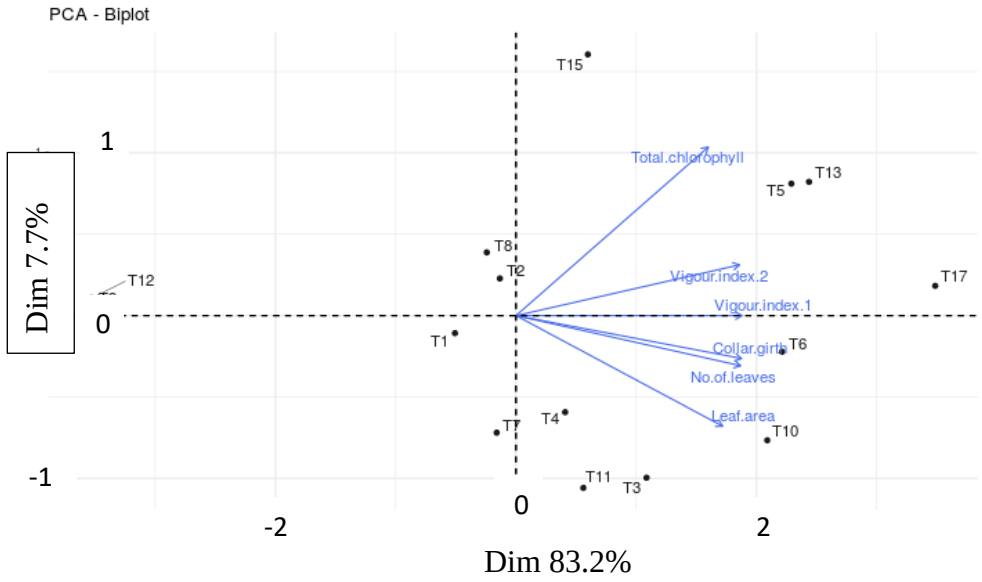


Figure 4.1.1. Loading plot of PC's in relation with various morphological characters of tomato

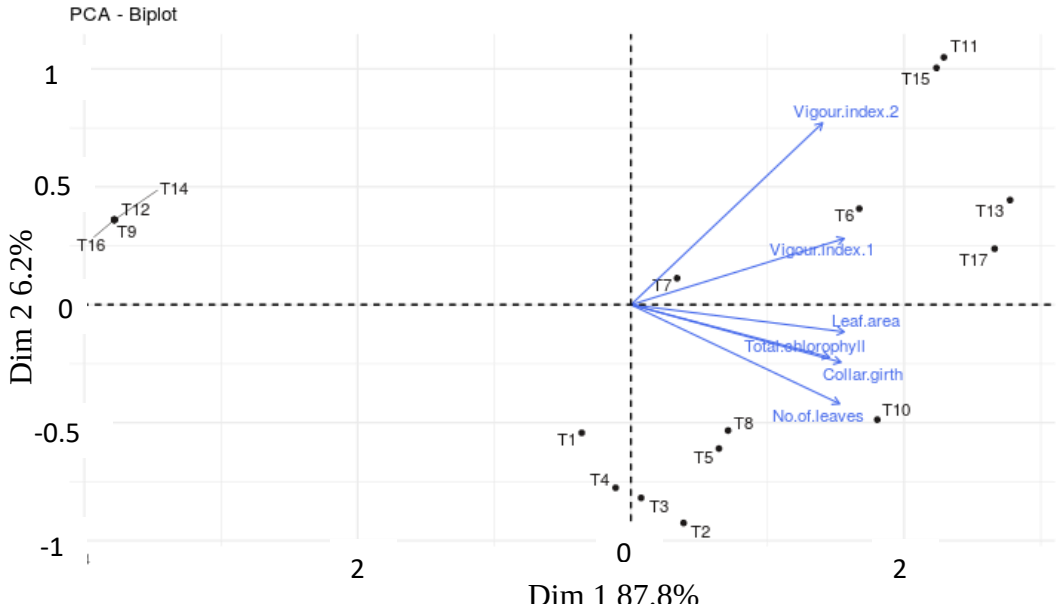


Figure 4.1.2. Loading plot of PC's in relation with various morphological characters of chilli

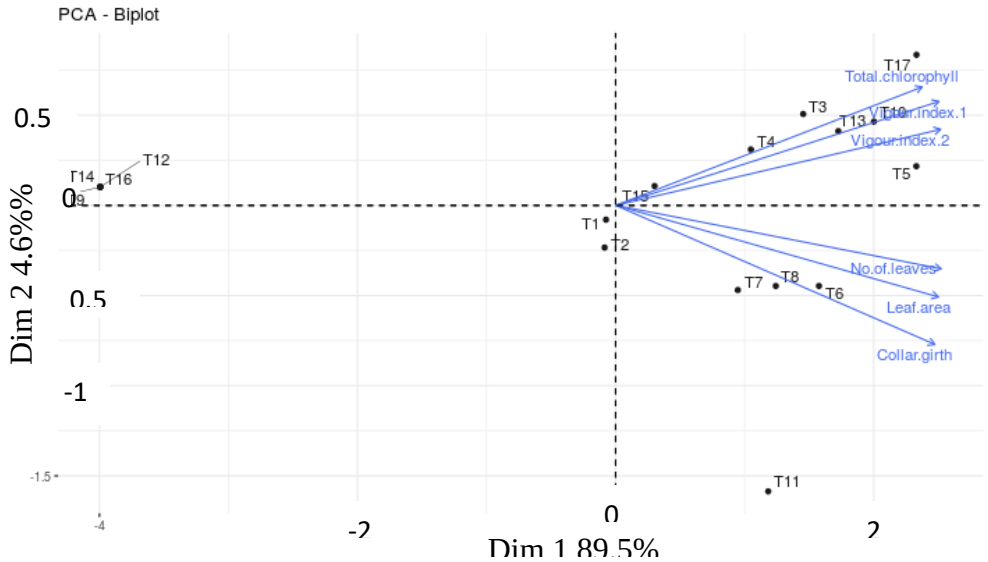


Figure 4.1.4. Loading plot of PC's in relation with various morphological characters of cucumber

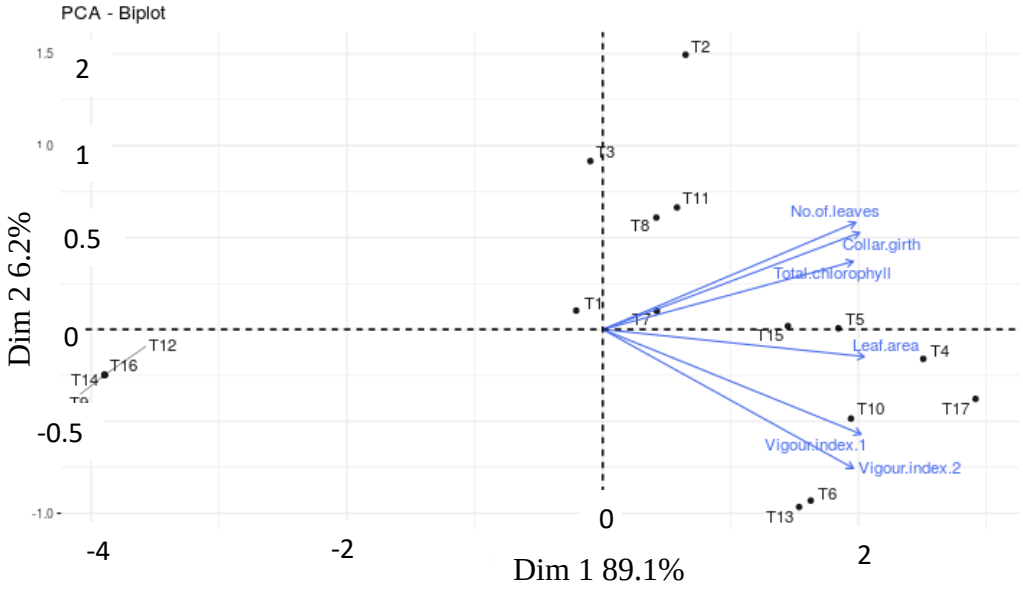


Figure 4.1.4. Loading plot of PC's in relation with various morphological characters of okra

Table 4.14: Ranking for selection of best growing media for okra

Suitability	Growing media	Index	Rank
Highly suitable (547 - 697)	T_{17} (cocopeat: vermiculite: perlite - 3:1:1)	696	1
	T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1)	654	2
	T_{13} (cocopeat: vermiculite: perlite - 1:1:1)	631	2
	T_5 (soil: vermicompost - 1:1)	604	3
	T_6 (soil: dried powdered cow dung - 1:1)	601	3
	T_4 (soil: cocopeat - 1:1)	596	3
	T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1)	572	4
Moderately suitable (396 - 546)	T_7 (cocopeat: dried powdered cow dung - 1:1)	397	5
Less suitable (245 -395)	T_1 (cocopeat)	381	5
	T_8 (cocopeat: vermicompost - 1:1)	363	5
	T_{11} (soil: cocopeat: vermicompost - 1:1:1)	355	5
	T_2 (vermicompost)	257	6
	T_3 (dried powdered cow dung)	245	6

4.1.6. Selection of best soil-less and soil containing media based on benefit cost ratio

Based on the benefit cost ratio, the best soil-less medium for all the four crops was found to be T_{17} (cocopeat: vermiculite: perlite - 3:1:1) followed by T_{13} (cocopeat: vermiculite: perlite - 1:1:1). In tomato and okra, the best soil containing medium was T_6 having soil and dried powdered cow dung in equal proportion followed by T_{10} (soil: cocopeat: dried powdered cow dung - 1:1:1). In chilli, best soil containing medium was T_6 (soil: dried powdered cow dung - 1:1) which was followed by T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1). Soil, cocopeat and dried powdered cow dung in equal proportion was found to be good for cucumber followed by T_5 (soil: vermicompost - 1:1).

4.2. Standardising pre-sowing seed invigoration and biopriming treatments for pro-tray seedling production

4.2.1. Effect of pre sowing seed invigoration on plant growth

The experiment was conducted in the media having cocopeat, vermiculite and perlite in the ratio of 3:1:1 which was selected as the best medium from the first experiment. Different growth parameters of tomato, chilli, cucumber and okra were measured and are enumerated in the Table 4.14, 4.15, 4.16 and 4.17 respectively.

4.2.1.1. Germination per cent

In tomato and cucumber 100% germination was observed in all the treatments except T_5 and T_9 which recorded 88.06%. In okra 100% germination was obtained for T_7 (0.5% KNO_3 + 1% *Pseudomonas*) and it was on par with T_2 (97.60), T_3 (97.60), T_8 (97.60), and T_4 (95.20). Minimum germination of 80.90% was recorded for T_5 having seeds treated with 2% KNO_3. In chilli 100% germination was recorded under T_3, T_4, T_5, T_7, T_8, and T_9. Minimum of 90.43% was noted under direct seeding.

4.2.1.2. Plant height (cm)

Plant height was found to be significantly different for all the four crops studied. In tomato maximum of 19.34 cm was obtained for the treatment T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*) which was on par with T_3 (19.16 cm) treated with 0.5% KNO_3. In chilli T_4 having seeds treated with 1% KNO_3 recorded maximum plant height of 14.33 cm which was significantly superior. Maximum plant height of 28.73 cm was recorded for the treatment T_8 in cucumber which was significantly superior. Second highest was for the treatment T_5 (26.55 cm) which was on par with T_7 (26.36 cm). In okra T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*) recorded maximum of 15.53 cm and that was on par with T_3 (15.39 cm) and T_5 (15.23 cm). Minimum plant height of 10.27 cm, 8.16 cm, 19.74 cm and 11.71 cm were recorded in tomato, chilli, cucumber and okra respectively for untreated control (T_1).

4.2.1.3. Root length (cm)

Root length had a significant difference among all the treatments in all the crops. In tomato T_4 (1% KNO_3) was significantly superior having a length of 6.24 cm followed by T_3 (5.35 cm) which was on par with T_5 (5.31 cm) and T_7 (5.19 cm). Minimum root length of 2.19 cm was recorded for the treatment T_9 having 2% KNO_3 and 1% *Pseudomonas fluorescens*. In chilli maximum root length of 6.1 cm was obtained for water soaked seeds followed by T_6 (5.34 cm) which was on par with T_4 (5.14 cm) and T_7 (5.09 cm). Lowest was recorded for T_8 (1% KNO_3 + 1% *Pseudomonas fluorescens*) that was 4.06 cm. In cucumber highest root length was noticed for T_5 (7.67 cm) which were on par with T_4 (7.35 cm) and T_3 (7.32 cm). Minimum of 4.13 cm was obtained for T_9. In okra maximum root length of 5.45 cm

was recorded for T_4 having seeds treated with 1% KNO_3 which was on par with T_5 (5.40 cm). Minimum of 3.52 cm was recorded for untreated control.

4.2.1.4. Number of leaves

In tomato more number of leaves were observed for T_7 (6.40) having a combination of 0.5% KNO_3 and 1% *Pseudomonas fluorescens* which was significantly superior followed by T_3 (5.87) which was on par with treatments viz., T_6 (5.60), T_9 (5.53), T_8 (5.26) and T_4 (5.00). Lowest was noticed in T_5 (2% KNO_3) which was 4.47. In chilli highest number of leaves was noticed for T_7 (7.40) which were on par with T_3 (7.33). Treatments *viz*., T_8 (6.87), T_2 (6.73), and T_4 (6.67) were found to be on par. Minimum number of leaves was recorded for T_9 (2% KNO_3 + 1% *Pseudomonas fluorescens*) and was 5.53. There was no significant difference among treatments in number of leaves of cucumber. Treatments *viz*., T_3, T_4, T_6, T_7, and T_8 recorded maximum (2.00) number of leaves in okra. Minimum of 1.27 was recorded for untreated control.

4.2.1.5. Leaf area (cm^2)

In tomato highest leaf area (53.10) was observed under treatment T_7 (0.5% KNO_3 + 1% *Pseudomonas*) which was significantly higher than other treatments while lowest leaf area (18.84) was observed under T_1 (control). Second highest leaf area was recorded for T_8 (1% KNO_3 + 1% *Pseudomonas*) which was 43.20 followed by T_3 (0.5% KNO_3). In chilli highest leaf area was recorded for T_3 which was 28.81 followed by T_4 (26.81) and T_5 (25.49). Minimum leaf area (16.20) was noted under the treatment T_1 having control. Maximum leaf area of cucumber was obtained for the treatment T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*) which was 63.66 followed by T_3 (63.81) and T_8 (59.65). Minimum leaf area of 43.07 was recorded for control. In okra highest leaf area was 63.28 which were recorded for the treatment T_7 and that was significantly higher. Second highest was noted for the treatment T_8 having seeds treated with 1% KNO_3 + 1% *Pseudomonas* (59.69) which was on par with treatment having 0.5% KNO_3 (59.54). The minimum of 42.39 was recorded for untreated seeds.

4.2.1.6. Collar diameter (mm)

Maximum collar diameter was noted for the seedlings under treatment T_3 (0.5% KNO_3) for all crops studied except okra which recorded maximum collar diameter in T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*).

4.2.1.7. Vigour index I

It varied significantly among all the treatments in all the crops studied. In tomato VI I was found higher (2453.33) for the treatment T_7 having 0.5% KNO_3 + 1% *Pseudomonas* which was on par with the treatment T_3 (2451.33), and T_4 (2450.67). Minimum of 1276.07 was noted under T_9 (2% KNO_3 + 1% *Pseudomonas*). In chilli T_4 (1% KNO_3) showed maximum vigour index of 1946.67 followed by T_8 having a vigour index of 1778.67. Minimum vigour index of 1125.23 was noted under control. Cucumber recorded maximum VI I in the treatment T_8 (3380.67) having seeds treated with 1% KNO_3 and 1% *Pseudomonas fluorescens* and was on par with T_4 (3351.33). Minimum VI I of 2462.82 was recorded under T_9. Maximum VI I of 2015.04 in okra was noted in T_3 which was on par with T_7 (1996.00). Minimum of 1413.65 was noted under control.

4.2.1.8. Vigour Index II

In tomato, there was no significant difference in VI II among treatments. Chilli had highest VI II (12.60) under T_3 having 0.5% KNO_3 which was on par with T_2. Minimum VI II of 9.72 was noted under control. In cucumber highest VI II of 67.93 was recorded under T_2 having seeds treated with water which was found to be significantly superior. Minimum VI II of 33.33 was noted under T_7 having 0.5% KNO_3 + 1% *Pseudomonas.* In okra maximum VI II of 50.60 was recorded under T_7 and minimum of 19.54 was recorded under T_5 having 2% KNO_3.

4.2.1.9. Chlorophyll content (mg/g)

In tomato, chlorophyll content (2.07 mg/g) was found high in T_2 (water-soaked seeds) followed by T_4 (1% KNO_3) which recorded a chlorophyll content of 2.00 mg/g. Minimum chlorophyll content of 1.54 was obtained in T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*). In chilli, maximum chlorophyll content of 1.07 was recorded in the treatment T_2 (water-soaked seeds) followed by T_1 (1.04 - untreated seeds). Minimum chlorophyll content of 0.65 mg/g was noted in T_4 (1% KNO_3). Chlorophyll content of cucumber was found higher (1.80) in T_6 having 1%

Pseudomonas followed by T_9 (2% KNO_3 + 1% *Pseudomonas fluorescens*) which is 1.78. Minimum chlorophyll content of 1.31 mg/g recorded in T_2 (water-soaked seeds). T_3 having seeds treated with 0.5% KNO_3 was recorded maximum chlorophyll content in okra (1.77) followed by T_6 having 1% *Pseudomonas* (1.75) and by T_4 (1.72). Minimum chlorophyll content of 0.88 was noted for the control.

Table 4.15: Effect of seed invigoration techniques on morphological and physiological characters of tomato

Sl.No	Seed invigoration treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - Direct seeding (control)	100.00^{a}	10.27^{g}	2.57^{f}	4.53^{g}	18.84^{h}	2.98^{c}	1284.00^{f}	19.40	1.61^{f}
2	T_2 - Soaking in water	100.00^{a}	11.65^{f}	2.54^{f}	4.93^{f}	28.69^{f}	3.02^{c}	1418.67^{e}	26.27	2.07^{a}
3	T_3 - 0.5% KNO_3	100.00^{a}	19.16^{a}	5.35^{b}	5.87^{b}	40.18^{c}	3.33^{a}	2451.33^{a}	32.40	1.75^{e}
4	T_4 - 1% KNO_3	100.00^{a}	18.27^{b}	6.24^{a}	5.00^{ef}	40.09^{c}	3.19^{b}	2450.67^{a}	27.20	2.00^{b}
5	T_5 - 2% KNO3	88.07^{b}	16.09^{c}	5.30^{bc}	4.47^{g}	36.39^{e}	2.82^{d}	1883.49^{c}	20.65	1.94^{c}
6	T_6 - 1% *Pseudomonas fluorescens*	100.00^{a}	18.07^{b}	4.44^{d}	5.60^{bc}	38.99^{d}	3.17^{b}	2250.67^{b}	20.00	1.84^{d}
7	T_7 - 0.5% KNO3 + 1% *Pseudomonas fluorescens*	100.00^{a}	19.34^{a}	5.19^{c}	6.40^{a}	53.10^{a}	3.28^{ab}	2453.33^{a}	26.60	1.54^{i}
8	T_8 - 1% KNO_3 + 1% *Pseudomonas fluorescens*	100.00^{a}	13.91^{d}	4.03^{e}	5.27^{de}	43.20^{b}	2.81^{d}	1793.33^{d}	24.87	1.60^{g}
9	T_9 - 2% KNO_3 + 1% *Pseudomonas fluorescens*	88.07^{b}	12.31^{e}	2.19^{g}	5.53^{cd}	27.35^{g}	2.60^{e}	1276.07^{f}	27.40	1.58^{h}
	CD (0.05)	3.31	0.38	0.154	0.28	0.84	0.12	53.59	NS	0.07
	SE (m)	1.12	0.13	0.05	0.09	0.28	0.04	18.03	3.29	0.02
	CV (%)	1.98	1.42	2.14	3.09	1.36	2.41	1.63	22.84	0.24

Table 4.16: Effect of seed invigoration techniques on morphological characters of chilli

Sl.No	Seed invigoration treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - Direct seeding (control)	90.43^{c}	8.16^{h}	4.28^{ef}	6.33^{c}	16.20^{h}	1.25^{f}	1125.23^{f}	9.72^{de}	1.04^{b}
2	T_2 - Soaking in water	92.80^{b}	11.10^{f}	6.10^{a}	6.73^{b}	19.37^{g}	1.38^{e}	1596.16^{d}	12.50^{a}	1.07^{a}
3	T_3 - 0.5% KNO_3	100.00^{a}	12.91^{d}	4.34^{e}	7.33^{a}	28.81^{a}	1.83^{a}	1725.33^{c}	12.60^{a}	0.81^{e}
4	T_4 - 1% KNO_3	100.00^{a}	14.33^{a}	5.14^{bc}	6.67^{b}	26.81^{b}	1.63^{c}	1946.67^{a}	11.07^{bc}	0.65^{h}
5	T_5 - 2% KNO3	100.00^{a}	12.35^{e}	2.38^{g}	6.27^{c}	25.48^{c}	1.45^{d}	1473.33^{e}	8.60^{f}	0.79^{f}
6	T_6 - 1% *Pseudomonas fluorescens*	92.80^{b}	13.13^{c}	5.34^{b}	6.67^{b}	25.48^{c}	1.68^{b}	1713.71^{c}	11.07^{bc}	0.66^{g}
7	T_7 - 0.5% KNO3 + 1% *Pseudomonas fluorescens*	100.00^{a}	11.27^{f}	5.09^{c}	7.40^{a}	23.54^{d}	1.71^{b}	1636.00^{d}	12.07^{ab}	0.96^{c}
8	T_8 - 1% KNO_3 + 1% *Pseudomonas fluorescens*	100.00^{a}	13.73^{b}	4.06^{f}	6.87^{b}	22.40^{e}	1.58^{c}	1778.67^{b}	10.53^{cd}	0.84^{d}
9	T_9 - 2% KNO_3 + 1% *Pseudomonas fluorescens*	100.00^{a}	10.36^{g}	4.61^{d}	5.53^{d}	21.32^{f}	1.42^{de}	1496.67^{e}	8.73^{ef}	0.79^{f}
	CD (0.05)	2.34	0.19	0.23	0.25	0.59	0.05	42.21	1.09	0.09
	SE (m)	0.79	0.07	0.08	0.08	0.19	0.02	14.20	0.37	0.03
	CV (%)	1.40	0.97	2.96	2.17	1.47	1.86	1.53	5.90	0.64

Table 4.17: Effect of seed invigoration techniques on morphological characters of cucumber

Sl.No	Seed invigoration treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - Direct seeding (control)	100.00^{a}	19.74^{f}	6.11^{c}	2	43.07^{h}	3.200^{f}	2585.33^{f}	60.33^{c}	1.38^{g}
2	T_2 - Soaking in water	100.00^{a}	22.50^{e}	6.27^{c}	2	50.91^{g}	3.960^{e}	2877.33^{e}	67.93^{a}	1.31^{h}
3	T_3 - 0.5% KNO_3	100.00^{a}	24.21^{d}	7.32^{b}	2	61.81^{b}	4.800^{a}	3152.67^{b}	63.40^{b}	1.74^{c}
4	T_4 - 1% KNO_3	100.00^{a}	26.16^{b}	7.35^{ab}	2	56.03^{d}	4.707^{ab}	3351.33^{a}	38.67^{e}	1.47^{f}
5	T_5 - 2% KNO3	88.07^{b}	26.55^{b}	7.66^{a}	2	51.75^{ef}	4.173^{d}	3013.17^{d}	35.64^{f}	1.78^{b}
6	T_6 - 1% *Pseudomonas fluorescens*	100.00^{a}	24.83^{c}	5.61^{d}	2	52.47^{e}	4.507^{c}	3044.00^{cd}	33.60^{g}	1.80^{a}
7	T_7 - 0.5% KNO3 + 1% *Pseudomonas fluorescens*	100.00^{a}	26.36^{b}	5.11^{e}	2	63.66^{a}	4.620^{bc}	3147.33^{bc}	33.33^{g}	1.48^{e}
8	T_8 - 1% KNO_3 + 1% *Pseudomonas fluorescens*	100.00^{a}	28.73^{a}	5.07^{e}	2	59.66^{c}	4.51^{c}	3380.67^{a}	43.73^{d}	1.59^{d}
9	T_9 - 2% KNO_3 + 1% *Pseudomonas fluorescens*	88.07^{b}	23.83^{d}	4.13^{f}	2	51.22^{fg}	4.13^{d}	2462.82^{g}	37.11^{ef}	1.78^{b}
	CD (0.05)	3.31	0.39	0.34	NS	0.82	0.16	108.28	1.90	0.01
	SE (m)	1.11	0.13	0.11	NS	0.27	0.05	36.45	0.64	0.04
	CV (%)	1.98	0.94	3.21	NS	0.87	2.18	2.10	2.41	0.42

Table 4.18: Effect of seed invigoration techniques on morphological characters of okra

Sl.No	Seed invigoration treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - Direct seeding (control)	92.80^{b}	11.71^{f}	3.52^{g}	1.27^{d}	42.39^{f}	2.27^{f}	1413.65^{f}	38.23^{c}	0.87^{i}
2	T_2 - Soaking in water	97.60^{ab}	13.91^{d}	4.27^{e}	1.80^{b}	49.73^{e}	2.26^{f}	1773.98^{de}	31.18^{d}	0.93^{h}
3	T_3 - 0.5% KNO_3	97.60^{ab}	15.39^{ab}	5.25^{b}	2.00^{a}	59.55^{b}	3.36^{ab}	2015.04^{a}	40.02^{c}	1.77^{a}
4	T_4 - 1% KNO_3	95.20^{ab}	14.40^{c}	5.45^{a}	2.00^{a}	57.36^{c}	3.38^{a}	1889.34^{bc}	27.62^{e}	1.72^{c}
5	T_5 - 2% KNO3	80.90^{c}	15.23^{b}	5.40^{a}	1.73^{b}	52.17^{d}	2.65^{e}	1668.59^{e}	19.54^{f}	1.58^{e}
6	T_6 - 1% *Pseudomonas fluorescens*	92.80^{b}	13.61^{e}	5.15^{b}	2.00^{a}	52.54^{d}	3.21^{bc}	1740.31^{e}	43.74^{b}	1.75^{b}
7	T_7 - 0.5% KNO3 + 1% *Pseudomonas fluorescens*	100.00^{a}	15.53^{a}	4.43^{d}	2.00^{a}	63.28^{a}	3.43^{a}	1996.00^{ab}	50.60^{a}	1.70^{d}
8	T_8 - 1% KNO_3 + 1% *Pseudomonas fluorescens*	97.60^{ab}	14.26^{c}	4.83^{c}	2.00^{a}	59.693^{b}	3.16^{c}	1862.92^{cd}	49.39^{a}	1.48^{f}
9	T_9 - 2% KNO_3 + 1% *Pseudomonas fluorescens*	85.70^{c}	13.49^{e}	3.93^{f}	1.53^{c}	50.147^{e}	2.80^{d}	1493.46^{f}	38.91^{c}	1.24^{g}
	CD (0.05)	5.31	0.28	0.11	0.16	0.83	0.15	109.32	3.07	0.06
	SE (m)	1.79	0.09	0.04	0.05	0.28	0.05	36.79	1.03	0.02
	CV (%)	3.32	1.17	1.37	5.19	0.89	3.02	3.61	4.75	0.23

4.2.2. Disease and pest incidence

All the four crops were free from disease and pest attack.

4.2.3. Cost analysis

Table 4.19: Benefit cost ratio (100m^2/month) of different crops

Sl. No.	Treatments	Benefit Cost Ratio			
		Tomato	Chilli	Cucumber	Okra
1	T_1 - Direct seeding (control)	2.89	2.65	2.64	2.86
2	T_2 - Soaking in water	2.89	2.75	2.64	3.06
3	T_3 - 0.5% KNO_3	2.89	3.04	2.64	3.05
4	T_4 - 1% KNO_3	2.88	3.03	2.64	2.95
5	T_5 - 2% KNO3	2.42	3.03	2.20	2.35
6	T_6 - 1% *Pseudomonas fluorescens*	2.89	2.75	2.64	2.85
7	T_7 - 0.5% KNO3 + 1% *Pseudomonas fluorescens*	2.88	3.03	2.64	3.15
8	T_8 - 1% KNO_3 + 1% *Pseudomonas fluorescens*	2.88	3.03	2.63	3.04
9	T_9 - 2% KNO_3 + 1% *Pseudomonas fluorescens*	2.41	3.03	2.19	2.54

4.2.4. Criteria for selecting best pre-sowing seed treatment

The best seed treatment was selected based on an index which was calculated using principal component analysis (PCA). PCA was carried out using characters *viz*., leaf area, collar diameter, vigour index I & II and total chlorophyll content. Germination percentage, root length and plant height were not included in the PCA analysis because these parameters are included as a part of VI I. It was found that in tomato, chilli and cucumber, the first two components had Eigen value more than one. The first two principal components extracted from other components accounted for 74.22%, 90.66% and 83.28% of the total variation in tomato (Fig 4.2.1), chilli (Fig.4.2.2) and cucumber (Fig 4.2.3) respectively. So weightage for each variable was given based on the loadings of PC 1 & PC 2. In okra, only the first principal component had Eigen value more than one. So weightage was calculated based on loadings of PC 1 only (Fig 4.2.4).

In all the four crops, 0.5% KNO_3, 1% KNO_3 and combination of these with 1% *Pseudomonas* were ranked first (Table 4.19, 4.20, 4.21, 4.22).

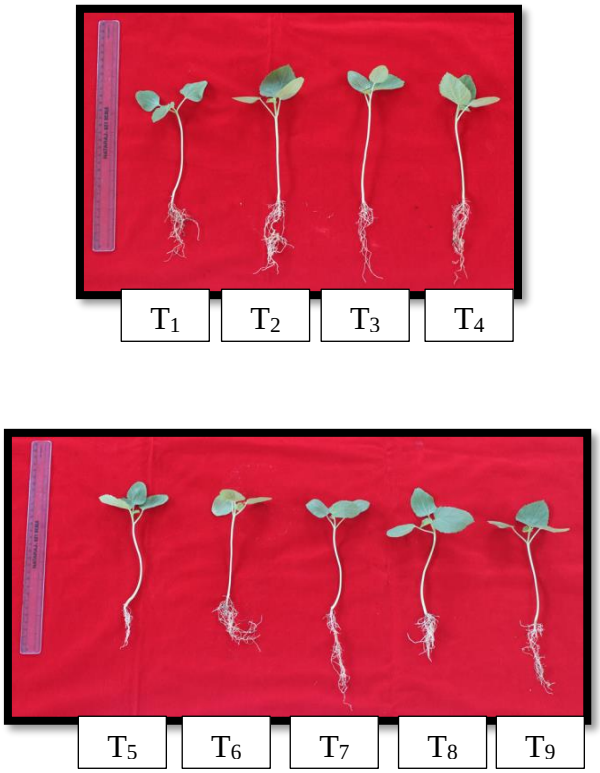
Tomato seedlings

Chilli seedlings

T_1: Control, T_2: Soaking in water, T_3: 0.5% KNO_3, T_4: 1% KNO_3, T_5: 2% KNO_3, T_6: 1% *Pseudomonas*, T_7: 0.5% KNO_3 + 1% *Pseudomonas*, T_8: 1% KNO_3 + 1% *Pseudomonas*, T_9: 2% KNO_3 + 1% *Pseudomonas*

Plate 4.7. Effect of pre-sowing seed invigoration on growth parameters of tomato and chilli seedlings

Cucumber seedlings



Okra seedlings

T_1: Control, T_2: Soaking in water, T_3: 0.5% KNO_3, T_4: 1% KNO_3, T_5: 2% KNO_3, T_6: 1% *Pseudomonas*, T_7: 0.5% KNO_3 + 1% *Pseudomonas*, T_8: 1% KNO_3 + 1% *Pseudomonas*, T_9: 2% KNO_3 + 1% *Pseudomonas*

Plate 4.8. Effect of pre-sowing seed invigoration on growth parameters of cucumber and okra seedlings

Table 4.20: Ranking of seed invigouration technique in tomato based on index

Suitability	Invigouration technique	Index	Rank
Highly suitable (885 - 1052)	T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*)	1052	1
	T_3 (0.5% KNO_3)	1048	1
	T_4 (1% KNO_3)	1046	1
	T_6 (1% *Pseudomonas fluorescens*)	961	2
Moderately suitable (717 - 884)	T_5 (2% KNO_3)	806	3
Less suitable (549 – 716)	T_8 (1% KNO_3 + 1% *Pseudomonas fluorescens*)	772	4
	T_2 (Soaking in water)	610	5
	T_9 (2% KNO3 + 1% *Pseudomonas fluorescens*)	550	6
	T_1 (Direct seeding)	549	6

Table 4.21: Ranking of seed invigouration technique in chilli based on index

Suitability	Invigouration technique	Index	Rank
Highly suitable (642 - 746)	T_4 (1% KNO_3)	745	1
	T_8 (1% KNO_3 + 1% *Pseudomonas fluorescens*)	680	2
	T_3 (0.5% KNO_3)	663	3
	T_6 (1% *Pseudomonas fluorescens*)	657	3
Moderately suitable (537 - 641)	T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*)	628	4
	T_2 (Soaking in water)	611	5
	T_9 (2% KNO3 + 1% *Pseudomonas fluorescens*)	573	6
	T_5 (2% KNO_3)	566	6
Less suitable (432 - 536)	T_1 (Direct seeding)	432	7

Table 4.22: Ranking of seed invigouration technique in cucumber based on index

Suitability	Invigouration technique	Index	Rank
Highly suitable (625 - 687)	T_8 (1% KNO_3 + 1% *Pseudomonas fluorescens*)	685	1
	T_4 (1% KNO_3)	680	1
	T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*)	643	2
	T_3 (0.5% KNO_3)	632	2
Moderately suitable (562 - 624)	T_6 (1% *Pseudomonas fluorescens*)	619	3
	T_5 (2% KNO_3)	611	3
	T_2 (Soaking in water)	571	4
Less suitable (499 - 561)	T_1 (Direct seeding)	512	5
	T_9 (2% KNO3 + 1% *Pseudomonas fluorescens*)	499	5

Table 4.23: Ranking of seed invigouration technique in okra based on index

Suitability	Invigouration technique	Index	Rank
Highly suitable (890 - 987)	T_3 (0.5% KNO_3)	986	1
	T_7 (0.5% KNO_3 + 1% *Pseudomonas fluorescens*)	982	1
	T_4 (1% KNO_3)	924	2
	T_8 (1% KNO_3 + 1% *Pseudomonas fluorescens*)	917	2
Moderately suitable (792 - 889)	T_2 (Soaking in water)	865	3
	T_6 (1% *Pseudomonas fluorescens*)	855	4
	T_5 (2% KNO_3)	815	4
Less suitable (694 - 791)	T_9 (2% KNO3 + 1% *Pseudomonas fluorescens*)	736	5
	T_1 (Direct seeding)	694	5

4.2.5. Viability of *Pseudomonas* in KNO_3 solution

Agar plate method was used to examine the viability of *Pseudomonas* in KNO_3 solution. Seeds treated with *Pseudomonas* and KNO_3 was inoculated in Kings B medium and it was incubated for two days and observed in UV light. Fluorescent colonies were found in all the three concentrations of KNO_3, namely 0.5%, 1%, and 2%. It showed that *Pseudomonas* can survive at all the above KNO_3 concentrations.

4.3. Effect of biofertilizers on pro-tray seedling production

The experiment was conducted in the media having cocopeat, vermiculite and perlite in the ratio of 3:1:1 which was selected as the best medium from the first experiment. Different growth parameters of tomato, chilli, cucumber and okra were measured and are enumerated in the Table 4.23, 4.24, 4.25 and 4.26 respectively.

4.3.1. Germination per cent

Tomato showed 100% germination in all the treatments. In chilli 100% germination was recorded in T_7 having a combination of AMF, *Trichoderma* and PGPR Mix-1 and T_8 having 2% KNO_3. Minimum germination of 90.43% was recorded for T_9 (control). 100% germination was obtained in cucumber for all the treatments except T_4 (97.6) and T_8 (88.06). In okra 100% germination was recorded in T_6 having a combination of AMF, *Pseudomonas* and PGPR Mix-1. Lowest germination of 83.3 % was recorded for T_8 having seeds treated with 2% KNO_3.

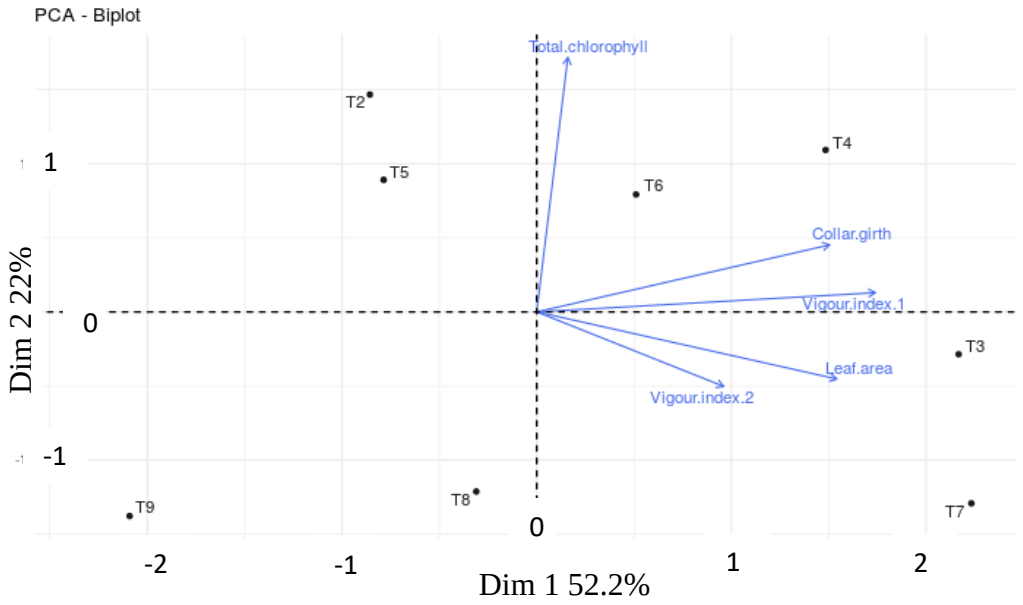


Figure 4.2.1. Loading plot of PC's in relation with various morphological characters of tomato

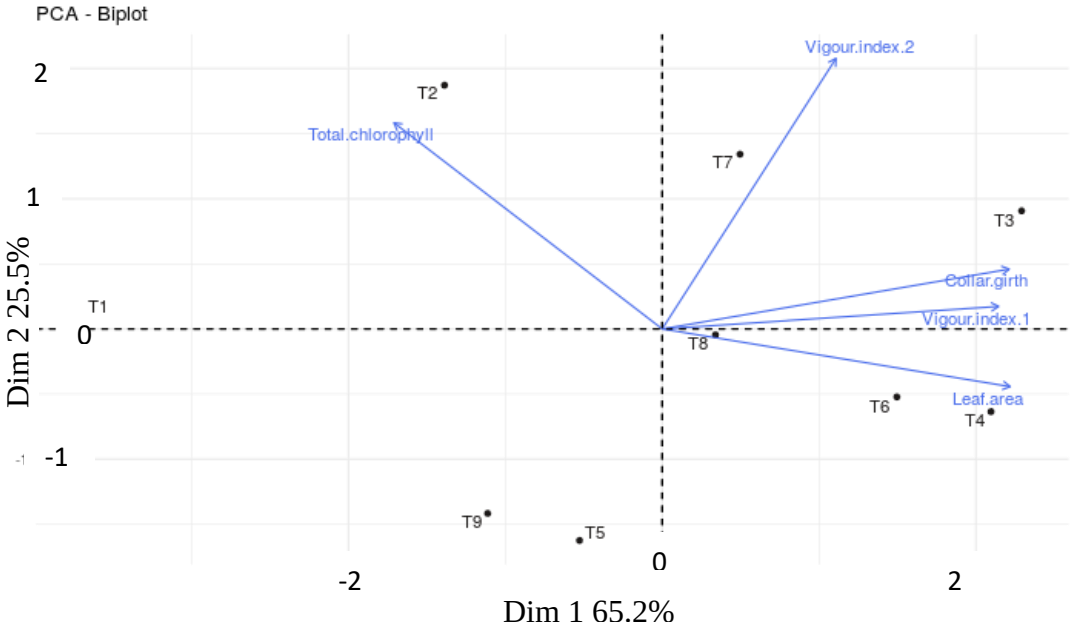


Figure 4.2.2. Loading plot of PC's in relation with various morphological characters of chilli

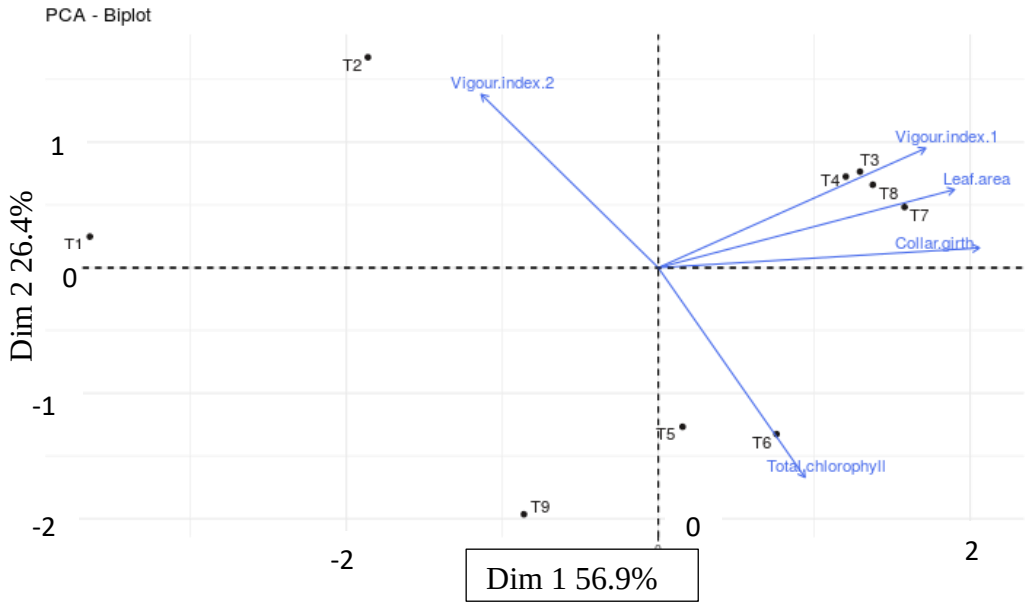


Figure 4.2.3. Loading plot of PC's in relation with various morphological characters of cucumber

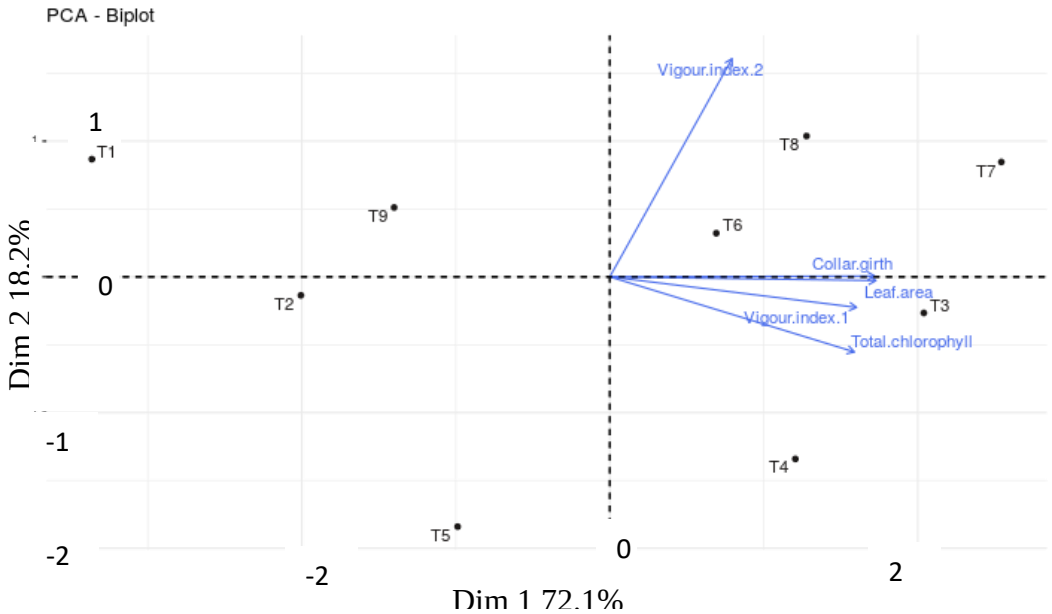
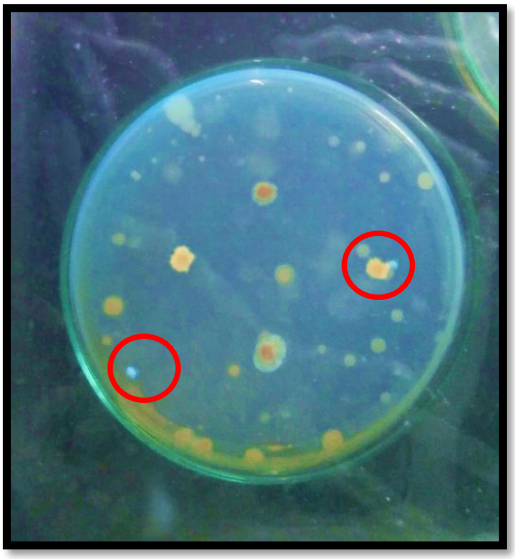
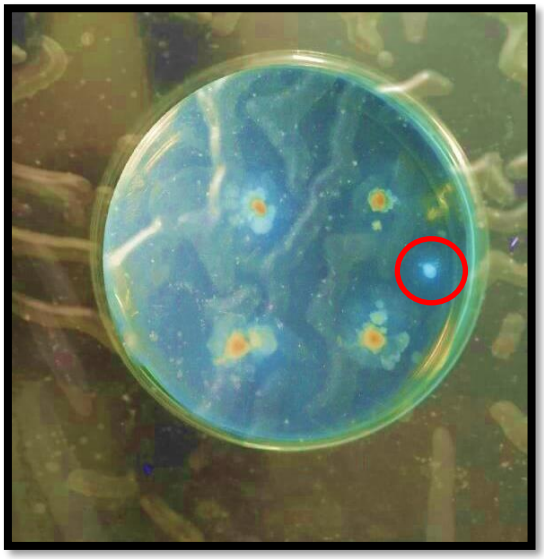


Figure 4.2.4. Loading plot of PC's in relation with various morphological characters of okra

Agar plate method to test the viability of *Pseudomonas* in KNO_3



0.5% KNO_3 + 1 % *Pseudomonas*



1% KNO_3 + 1 % *Pseudomonas*

Plate 4.9. Presence of fluorescent colonies of *Pseudomonas* in 0.5% and 1% KNO_3 solutions under UV light

4.3.2. Plant height (cm)

The plant height varied significantly among treatments in all crops. Highest plant height in tomato was 14.71 cm which was recorded in T_7 having a combination of AMF, *Trichoderma* and PGPR Mix-1 and was significantly superior to other treatments. It was followed by T_5 (AMF + PGPR Mix-1) which had a height of 13.96 cm which was on par with treatments T_1, T_8 and T_4. Plant height was low in untreated control which was 10.39 cm. Highest plant height (9.67 cm) in chilli was recorded in T_6 (AMF + *Pseudomonas* + PGPR Mix-1) which was on par with T_5 (9.65 cm) followed by T_3 (9.45 cm). Minimum plant height of 6.74 cm was noted in T_4 containing AMF. Maximum plant height in cucumber (23.91 cm) was recorded in T_1 comprising media inoculated with PGPR mix-1 which was on par with T_5 (23.91 cm), T_4 (23.64 cm) and T_6 (23.48 cm). Minimum plant height (19.99 cm) was recorded in treatment T_7 (AMF + *Trichoderma* + PGPR Mix-1). In okra highest plant height of 18.67 cm was recorded under T_8 (2% KNO_3) treatment followed by T_2 (17.54 cm) having media inoculated with *Pseudomonas* which was on par with T_9 (17.33 cm) and T_6 (17.27 cm). Minimum plant height of 15.69 was noted under T_7.

4.3.3. Root length (cm)

In tomato maximum root length (5.64 cm) was recorded in T_6 comprising AMF, *Pseudomonas* and PGPR Mix-1 which was on par with T_7 (5.55 cm) and T_5 (5.47 cm). Minimum root length of 3.86 cm was recorded in T_2 (*Pseudomonas*). In chilli maximum root length was recorded in T_5 (6.23 cm) and was significantly superior. Minimum root length of 2.79 cm was recorded in T_8. In cucumber maximum root length of 6.58 cm was noted in T_7 and minimum of 3.93 cm was recorded in T_9 which was the control. In okra maximum root length of 6.77 cm was recorded under T_6 followed by T_8 (6.12). Minimum was obtained under T_2 which was 3.75 cm.

4.3.4. Number of leaves

In tomato T_5 (AMF + PGPR Mix-1) exhibited more number of leaves (6.33) which was significantly superior and was followed by T_3 (5.47) which was on par with T_8 (5.27) and T_4 (5.07). Minimum number of leaves (4.53) was observed under treatment having untreated control. In chilli T_6 (AMF + *Pseudomonas* + PGPR Mix-

1) and T_5 (AMF + PGPR Mix-1) was found to have highest number of leaves was on par having leaves of 6.80 and 6.73, respectively. Minimum (4.67) was observed under T_1 treated with PGPR mix-1. Cucumber had a maximum of 2.40 leaves under T_7. Minimum of 1.73 leaves were observed under control. In okra all treatments were found to be on par having two leaves except T_9 (1.67) having untreated seeds.

4.3.5. Leaf area (cm^2)

In tomato leaf area was higher (36.19 cm^2) for the treatment T_8 (2% KNO_3) followed by T_7 (29.51 cm^2) and T_6 (25.86 cm^2). Minimum leaf area of 19.90 cm^2 was recorded in T_9 which is the control. Significant difference was observed in chilli which ranged from 11.48 to 19.10 cm^2. T_3 treated with *Trichoderma* recorded the maximum followed by T_5 (17.84 cm^2) and T_9 (15.52 cm^2) which were on par with T_8 (15.51 cm^2). Highest leaf area in cucumber was recorded under T_3 (65.27 cm^2) which was on par with T_6 (64.58 cm^2). Minimum leaf area of 44.18 cm^2 was in T_9. T_5 recorded maximum leaf area of 62.74 cm^2 in okra followed by T_4 (61.64 cm^2). Minimum leaf area was in T_1 (31.73 cm^2).

4.3.6. Collar diameter (mm)

It significantly varied among all the treatments for all crops. In tomato T_6 (AMF + *Pseudomonas* + PGPR Mix-1) recorded maximum collar diameter of 3.35 mm followed by T_1 comprising PGPR Mix-1 (3.23 mm). Minimum collar diameter of 2.47 was noted in T_4 (AMF). In chilli T_5 (AMF + PGPR Mix-1) recorded the maximum collar diameter (2.17 mm) which was on par with T_7 (AMF + *Trichoderma* + PGPR Mix-1). In cucumber T_8 (2% KNO_3) recorded the maximum of 4.82 mm. Okra recorded maximum collar diameter of 4.28 mm under T_6 (AMF + *Pseudomonas* + PGPR Mix-1). Minimum collar diameter in chilli (1.26 mm), cucumber (3.49 mm) and okra (2.65 mm) were noted under untreated control.

4.3.7. Vigour index I

In tomato, maximum VI I of 2026.67 was recorded in T_7 (AMF + *Trichoderma* + PGPR Mix-1) and was found significantly higher. Second highest was for the treatment T_5 comprising AMF + PGPR Mix-1 (1942.67) which was on par

with treatments T_8 (1922.00), T_4 (1908.00) and T_6 (1903.33). Minimum of 1444.67 was obtained for the control. In chilli T_6 (AMF + *Pseudomonas* + PGPR Mix-1) was significantly superior with a VI I of 1506.04 followed by T_5 (1474.28). Minimum VI I of 1075.59 was obtained for T_4 having AMF. In cucumber maximum VI I of 2946.67 was recorded under T_6 which was on par with T_5 (2936.67), T_4 (2859.44) and T_1 (2829.33). Minimum VI I of 2383.56 was noted for T_8 (2% KNO_3). In okra, highest VI I of 2404.67 was recorded under T_6 which was significantly superior followed by T_9 (2085.40). Minimum VI I of 1864.16 was obtained for the treatment T_4 (AMF).

4.3.8. Vigour Index II

In tomato maximum VI II of 32.80 was noted under T_3 and was significantly superior followed by T_8 (28.40). Minimum VI II of 19.27 was recorded for T_1 (PGPR Mix-1). In chilli it was found higher under T_7 (14.80) followed by T_8 (12.40). Minimum VI II of 9.16 was noted under control. T_1 (PGPR Mix-1) recorded the maximum VI II of 63.00 in cucumber and was significantly superior followed by T_6 (55.73). Minimum VI II of 42.07 was recorded under T_2. In okra maximum VI II of 60.73 was recorded in T_1 having PGPR Mix-1 followed by T_3 (55.06) having *Trichoderma*. Minimum VI II of 11.37 was noted under T_8 having 2% KNO_3.

4.3.9. Chlorophyll content (mg/g)

The total chlorophyll content of leaves showed significant difference among the treatments. In tomato highest chlorophyll content was recorded in T_4 (2.00 mg/g) having AMF, followed by T_5 (1.97 mg/g). In chilli highest total chlorophyll content was recorded in T_4 (1.36 mg/g) and minimum total chlorophyll content was noted in T_8 (0.80 mg/g). In cucumber maximum chlorophyll content of 1.63 mg/g was recorded for T_6 (AMF + *Pseudomonas* + PGPR Mix-1) followed by T_5 which was 1.59 mg/g. In okra maximum chlorophyll content (0.88 mg/g) was recorded for control. Minimum chlorophyll content in tomato (1.51 mg/g), cucumber (0.74 mg/g) and okra (0.22 mg/g) was noted under T_2 having media inoculated with *Pseudomonas flourescens.*

Table 4.24: Effect of biofertilizers on morphological and physiological characters of tomato

Sl.No	Treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - PGPR Mix 1	100.00	13.92^{b}	4.24^{e}	4.53^{e}	21.61^{e}	3.23^{b}	1816.00^{c}	19.27^{e}	1.61^{g}
2	T_2 - *Pseudomonas flourescens*	100.00	12.88^{c}	3.86^{f}	4.73^{e}	24.96^{d}	2.92^{c}	1674.00^{d}	20.40^{de}	1.51^{i}
3	T_3 - *Trichoderma* spp.	100.00	12.01^{d}	4.73^{d}	5.47^{b}	21.65^{e}	2.79^{d}	1674.00^{d}	32.80^{a}	1.54^{h}
4	T_4 - Arbuscular Mycorrhizal Fungi (AMF)	100.00	13.69^{b}	5.39^{bc}	5.07^{cd}	24.86^{d}	2.47^{f}	1908.00^{b}	23.33^{c}	2.00^{a}
5	T_5 - AMF + PGPR Mix-1	100.00	13.96^{b}	5.47^{abc}	6.33^{a}	20.33^{f}	2.57^{e}	1942.67^{b}	22.80^{cd}	1.97^{b}
6	T_6 - AMF + *Pseudomonas* + PGPR Mix-1	100.00	13.39^{bc}	5.64^{a}	4.80^{de}	25.86^{c}	3.35^{a}	1903.33^{b}	23.47^{c}	1.95^{c}
7	T_7 - AMF + *Trichoderma* + PGPR Mix-1	100.00	14.71^{a}	5.55^{ab}	4.80^{de}	29.51^{b}	2.88^{cd}	2026.67^{a}	24.40^{c}	1.81^{e}
8	T_8 - 2% KNO_3 treatment	100.00	13.90^{b}	5.32^{c}	5.27^{bc}	36.19^{a}	2.80^{d}	1922.00^{b}	28.40^{b}	1.94^{d}
9	T_9 - control	100.00	10.39^{e}	4.06^{ef}	4.53^{e}	19.90^{f}	2.88^{cd}	1444.67^{e}	23.80^{c}	1.74^{f}
	CD (0.05)	NS	0.61	0.23	0.28	0.62	0.09	60.91	2.59	0.07
	SE (m)	-	0.21	0.07	0.09	0.21	0.03	20.50	0.87	0.02
	CV (%)	-	2.69	2.72	3.32	1.45	2.01	1.96	6.23	0.21

Table 4.25: Effect of biofertilizers on morphological and physiological characters of chilli

Sl.No	Treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - PGPR Mix 1	92.80^{b}	7.96^{e}	5.24^{c}	4.67^{e}	11.47^{g}	1.80^{d}	1224.96^{d}	9.65^{cd}	0.89^{f}
2	T_2 - *Pseudomonas flourescens*	92.80^{b}	8.59^{c}	3.73^{e}	5.67^{c}	13.11^{f}	1.87^{c}	1143.92^{e}	10.64^{c}	0.81^{h}
3	T_3 - *Trichoderma* spp.	92.80^{b}	9.45^{b}	5.91^{b}	5.73^{c}	19.09^{a}	1.86^{cd}	1425.41^{b}	9.28^{d}	0.86^{g}
4	T_4 - Arbuscular Mycorrhizal Fungi (AMF)	90.43^{b}	6.74^{f}	5.15^{c}	5.00^{d}	12.93^{f}	1.81^{cd}	1075.59^{g}	9.82^{cd}	1.36^{a}
5	T_5 - AMF + PGPR Mix-1	92.80^{b}	9.65^{a}	6.23^{a}	6.73^{a}	17.84^{b}	2.17^{a}	1474.28^{ab}	9.58^{cd}	1.08^{c}
6	T_6 - AMF + *Pseudomonas* + PGPR Mix-1	97.60^{a}	9.67^{a}	5.76^{b}	6.80^{a}	14.85^{d}	2.08^{b}	1506.04^{a}	10.42^{cd}	0.94^{e}
7	T_7 - AMF + *Trichoderma* + PGPR Mix-1	100.00^{a}	8.34^{d}	5.15^{c}	5.20^{d}	14.18^{e}	2.15^{a}	1348.67^{c}	14.80^{a}	1.14^{b}
8	T_8 - 2% KNO_3 treatment	100.00^{a}	8.12^{e}	2.78^{f}	6.00^{b}	15.51^{c}	1.41^{e}	1090.67^{fg}	12.40^{b}	0.80^{i}
9	T_9 - control	92.80^{b}	7.99^{e}	4.15^{d}	6.00^{b}	15.52^{c}	1.26^{f}	1126.59^{ef}	9.16^{d}	1.04^{d}
	CD (0.05)	3.34	0.19	0.24	0.24	0.56	0.07	49.64	1.27	0.07
	SE (m)	1.12	0.06	0.08	0.08	0.18	0.02	16.70	0.43	0.02
	CV (%)	2.05	1.32	2.80	2.41	2.17	2.13	2.28	6.96	0.39

Table 4.26: Effect of biofertilizers on morphological and physiological characters of cucumber

Sl.No	Treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - PGPR Mix 1	100.00^{a}	23.91^{a}	4.38^{e}	2.00^{b}	48.55^{e}	4.40^{c}	2829.33^{a}	63.00^{a}	1.26^{g}
2	T_2 - *Pseudomonas flourescens*	100.00^{a}	21.68^{b}	4.48^{e}	2.00^{b}	51.87^{d}	4.37^{c}	2616.67^{b}	42.07^{e}	0.74^{i}
3	T_3 - *Trichoderma* spp.	100.00^{a}	21.05^{bc}	5.42^{c}	2.00^{b}	65.27^{a}	4.18^{d}	2647.33^{b}	52.93^{c}	1.53^{c}
4	T_4 - Arbuscular Mycorrhizal Fungi (AMF)	97.60^{a}	23.64^{a}	5.67^{bc}	2.00^{b}	45.20^{f}	4.36^{c}	2859.44^{a}	53.57^{c}	1.43^{d}
5	T_5 - AMF + PGPR Mix-1	100.00^{a}	23.91^{a}	5.46^{c}	2.00^{b}	55.16^{b}	4.37^{c}	2936.67^{a}	52.87^{cd}	1.59^{b}
6	T_6 - AMF + *Pseudomonas* + PGPR Mix-1	100.00^{a}	23.48^{a}	5.98^{b}	2.00^{b}	64.58^{a}	4.71^{b}	2946.67^{a}	55.73^{b}	1.63^{a}
7	T_7 - AMF + *Trichoderma* + PGPR Mix-1	100.00^{a}	19.99^{c}	6.58^{a}	2.40^{a}	54.21^{c}	4.11^{e}	2656.67^{b}	50.73^{d}	1.07^{h}
8	T_8 - 2% KNO_3 treatment	88.06^{b}	22.16^{b}	4.91^{d}	2.00^{b}	53.96^{c}	4.82^{a}	2383.56^{c}	53.53^{c}	1.31^{f}
9	T_9 - control	100.00^{a}	20.08^{c}	3.93^{f}	1.73^{c}	44.17^{g}	3.48^{f}	2402.00^{c}	52.73^{cd}	1.36^{e}
	CD (0.05)	3.34	1.29	0.33	0.13	0.85	0.06	153.47	2.15	0.07
	SE (m)	1.12	0.43	0.11	0.04	0.29	0.02	51.65	0.72	0.02
	CV (%)	1.98	3.38	3.69	3.82	0.92	0.88	3.31	2.36	0.29

Table 4.27: Effect of biofertilizers on morphological and physiological characters of okra

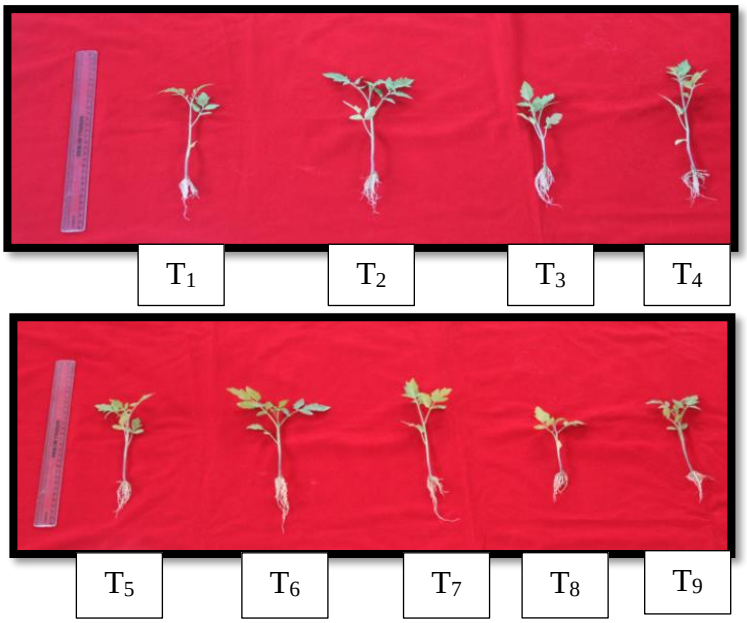
Sl.No	Treatments	Morphological characters								Physiological parameters
		Germination per cent	Plant height (cm)	Root length (cm)	Number of leaves	Leaf area (cm^2)	Collar diameter (mm)	Vigour index I	Vigour Index II	Chlorophyll content (mg/g)
1	T_1 - PGPR Mix 1	85.70^{de}	16.43^{de}	5.45^{c}	2.00^{a}	31.73^{h}	3.40^{c}	1875.687^{d}	60.73^{a}	0.26^{h}
2	T_2 - *Pseudomonas flourescens*	92.80^{bc}	17.54^{b}	3.75^{e}	2.00^{a}	51.82^{d}	3.10^{e}	1975.403^{bcd}	39.10^{c}	0.22^{i}
3	T_3 - *Trichoderma* spp.	90.43^{bcd}	16.46^{de}	4.64^{d}	2.00^{a}	42.00^{g}	3.13^{de}	1908.664^{d}	55.06^{b}	0.69^{d}
4	T_4 - Arbuscular Mycorrhizal Fungi (AMF)	90.43^{bcd}	15.98^{ef}	4.63^{d}	2.00^{a}	61.64^{b}	4.13^{b}	1864.164^{d}	17.86^{g}	0.54^{f}
5	T_5 - AMF + PGPR Mix-1	88.07^{cde}	16.90^{cd}	5.31^{c}	2.00^{a}	62.73^{a}	4.07^{b}	1955.462^{cd}	18.14^{g}	0.55^{e}
6	T_6 - AMF + *Pseudomonas* + PGPR Mix-1	100.00^{a}	17.27^{bc}	6.77^{a}	2.00^{a}	48.85^{e}	4.28^{a}	2404.667^{a}	31.60^{d}	0.38^{g}
7	T_7 - AMF + *Trichoderma* + PGPR Mix-1	92.80^{bc}	15.68^{f}	5.51^{c}	2.00^{a}	46.94^{f}	2.93^{f}	1966.741^{bcd}	22.03^{f}	0.84^{c}
8	T_8 - 2% KNO_3 treatment	83.30^{e}	18.67^{a}	6.12^{b}	2.00^{a}	57.97^{c}	3.19^{d}	2064.693^{bc}	11.37^{h}	0.85^{b}
9	T_9 - control	95.20^{ab}	17.33^{bc}	4.57^{d}	1.67^{b}	42.65^{g}	2.65^{g}	2085.403^{b}	29.38^{e}	0.88^{a}
	CD (0.05)	5.27	0.60	0.24	0.06	0.97	0.08	127.38	1.99	0.06
	SE (m)	1.77	0.20	0.08	0.02	0.33	0.03	42.87	0.67	0.02
	CV (%)	3.38	2.10	2.67	1.96	1.14	1.29	3.69	3.68	0.58

4.3.3. Disease and pest incidence

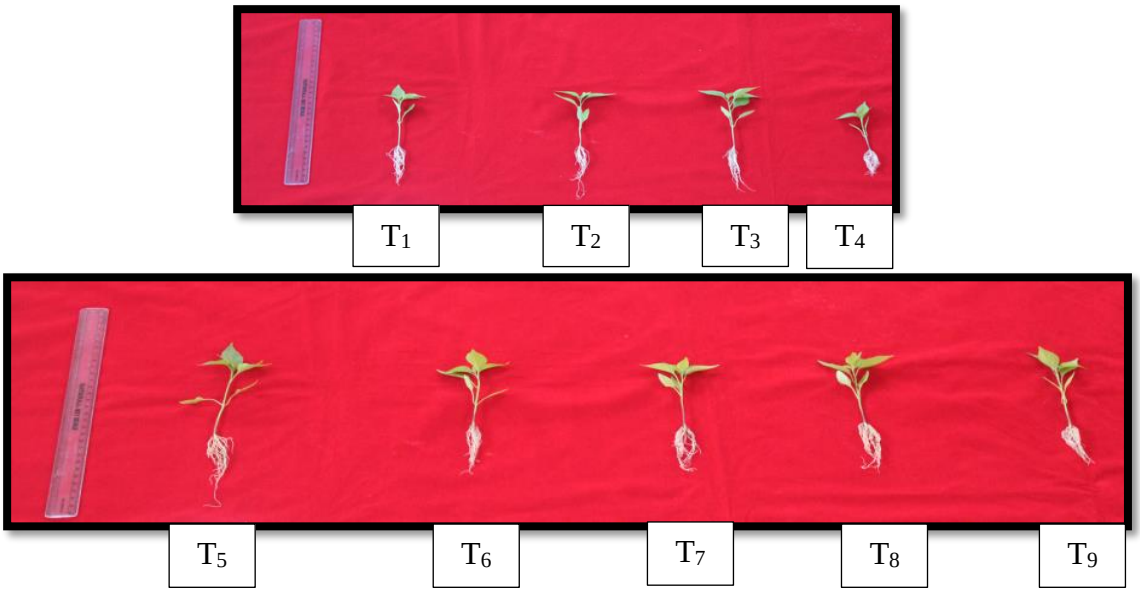
All crops were free from diseases and pests except tomato which was affected with *Alternaria* leaf spot (Table 4.27)

Table 4.28: Incidence of *Alternaria* leaf spot in tomato in tomato

Sl. No.	Treatments	*Alternaria* leaf spot
1	T_1 - PGPR Mix 1	Present
2	T_2 - *Pseudomonas flourescens*	Absent
3	T_3 - *Trichoderma* spp.	Present
4	T_4 - Arbuscular Mycorrhizal Fungi (AMF)	Present
5	T_5 - AMF + PGPR Mix-1	Present
6	T_6 - AMF + *Pseudomonas* + PGPR Mix-1	Absent
7	T_7 - AMF + *Trichoderma* + PGPR Mix-1	Present
8	T_8 - 2% KNO_3 treatment	Absent
9	T_9 - control	Present



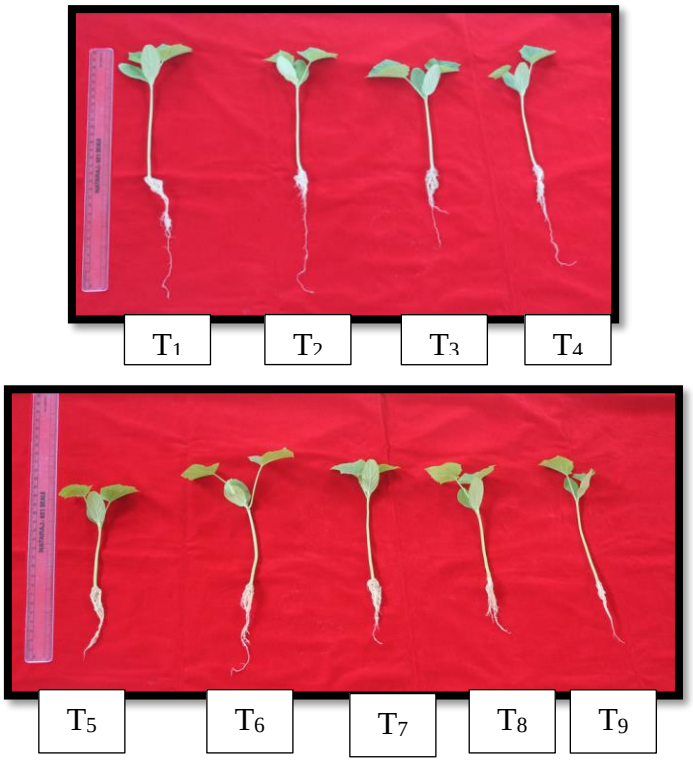
Tomato seedlings



Chilli seedlings

T_1: 2% PGPR Mix-1, T_2: 2% *Pseudomonas*, T_3: 2% *Trichoderma*, T_4: AMF, T_5: 2% PGPR Mix-1 + AMF, T_6: 2% PGPR Mix-1 + 2% *Pseudomonas* + AMF, T_7: 2% PGPR Mix-1 + 2% *Trichoderma* + AMF, T_8: 2% KNO3, T_9: Control

Plate 4.10. Effect of biofertilizers on growth parameters of tomato and chili seedlings



Cucumber seedlings

Okra seedlings

T_1: 2% PGPR Mix-1, T_2: 2% *Pseudomonas*, T_3: 2% *Trichoderma*, T_4: AMF, T_5: 2% PGPR Mix-1 + AMF, T_6: 2% PGPR Mix-1 + 2% *Pseudomonas* + AMF, T_7: 2% PGPR Mix-1 + 2% *Trichoderma* + AMF, T_8: 2% KNO3, T_9: Control

Plate 4.11. Effect of biofertilizers on growth parameters of cucumber and okra seedlings

Plate 4.12. Incidence of *Alternaria* leaf spot in tomato

4.3.4. Cost analysis

There was no much variation in the BC ratio between treatments (Table 4.28).

Table 4.29: Benefit cost ratio (100m^2/month) of different crops

Sl. No.	Treatments	Benefit Cost Ratio			
		Tomato	Chilli	Cucumber	Okra
1	T_1 - PGPR Mix 1	2.88	2.74	2.64	2.56
2	T_2 - *Pseudomonas flourescens*	2.89	2.74	2.64	2.85
3	T_3 - *Trichoderma* spp.	2.89	2.75	2.64	2.76
4	T_4 - Arbuscular Mycorrhizal Fungi (AMF)	2.34	2.12	2.08	2.19
5	T_5 - AMF + PGPR Mix-1	2.33	2.19	2.15	2.10
6	T_6 - AMF + *Pseudomonas* + PGPR Mix-1	2.33	2.36	2.14	2.52
7	T_7 - AMF + *Trichoderma* + PGPR Mix-1	2.33	2.44	2.15	2.27
8	T_8 - 2% KNO_3 treatment	2.33	3.03	2.20	2.95
9	T_9 - control	2.89	2.75	2.63	2.96

4.3.5. Criteria for selecting best biofertilizer in pro-tray seedling production

The best biofertilizer in pro-tray seedling raising was selected based on index which was calculated using principal component analysis (PCA). PCA was carried out using characters *viz*., number of leaves, leaf area, collar diameter, vigour index I & II and total chlorophyll content. Germination percentage, root length and plant height are part of VI I, hence these are not included in PCA analysis. It is showed that in tomato and okra, the first three components had Eigen value more than one. The first three principal components extracted from other components accounted for 82.67% and 87.83% of the total variation in tomato (Fig 4.3.1) and okra (Fig 4.3.4) respectively. So weightage for each variable was given based on the loadings of PC 1, PC 2 and PC 3. In chilli (Fig 4.3.2) and cucumber (Fig 4.3.3), the first two principal components had Eigen value more than one. So weightage was calculated based on loadings of PC 1 and PC 2. Combination of AMF, PGPR Mix-1 and either *Pseudomonas* or *Trichoderma* were ranked first in all the crops studied (Table 4.29, 4.30, 4.31, 4.32).

Table 4.30: Ranking of biofertilizers in tomato

Suitability	Biofertilizers	Index	Rank
Highly suitable (707 - 782)	T_7 (AMF + *Trichoderma* + PGPR Mix-1)	780	1
	T_5 (AMF + PGPR Mix-1)	749	2
	T_8 (2% KNO_3)	738	2
	T_4 (Arbuscular Mycorrhizal Fungi)	735	2
	T_6 (AMF + *Pseudomonas* + PGPR Mix-1)	733	2
Moderately suitable (631 - 706)	T_1 (PGPR Mix 1)	700	3
	T_2 (*Pseudomonas flourescens*)	644	4
	T_3 (*Trichoderma* spp.)	643	4
Less suitable (555 - 630)	T_9 (control)	555	5

Table 4.31: Ranking of biofertilizers in chilli

Suitability	Biofertilizers	Index	Rank
Highly suitable (625 - 690)	T_6 (AMF + *Pseudomonas* + PGPR Mix-1)	689	1
	T_5 (AMF + PGPR Mix-1)	675	1
	T_3 (*Trichoderma* spp.)	653	2
Moderately suitable (559 - 624)	T_7 (AMF + *Trichoderma* + PGPR Mix-1)	617	3
	T_1 (PGPR Mix 1)	560	4
Less suitable (493 - 558)	T_2 (*Pseudomonas flourescens*)	524	5
	T_9 (control)	516	5
	T_8 (2% KNO_3)	500	6
	T_4 (Arbuscular Mycorrhizal Fungi)	493	6

Table 4.32: Ranking of biofertilizers in cucumber

Suitability	Biofertilizers	Index	Rank
Highly suitable (751 - 800)	T_6 (AMF + *Pseudomonas* + PGPR Mix-1)	800	1
	T_5 (AMF + PGPR Mix-1)	795	1
	T_4 (Arbuscular Mycorrhizal Fungi)	774	1
	T_1 (PGPR Mix 1)	770	1
Moderately suitable (701 - 750)	T_7 (AMF + *Trichoderma* + PGPR Mix-1)	721	2
	T_3 (*Trichoderma* spp.)	721	2
	T_2 (*Pseudomonas flourescens*)	706	2
Less suitable (651 - 700)	T_9 (control)	654	3
	T_8 (2% KNO_3)	651	3

Table 4.33: Ranking of biofertilizers in okra

Suitability	Biofertilizers	Index	Rank
Highly suitable (633 - 688)	T_6 (AMF + *Pseudomonas* + PGPR Mix-1)	687	1
Moderately suitable (577 - 632)	T_8 (2% KNO_3)	600	2
	T_9 (control)	595	3
Less suitable (521 - 576)	T_5 (AMF + PGPR Mix-1)	568	3
	T_7 (AMF + *Trichoderma* + PGPR Mix-1)	565	3
	T_2 (*Pseudomonas flourescens*)	563	4
	T_4 (Arbuscular Mycorrhizal Fungi)	542	5
	T_3 (*Trichoderma* spp.)	535	5
	T_1 (PGPR Mix 1)	521	5

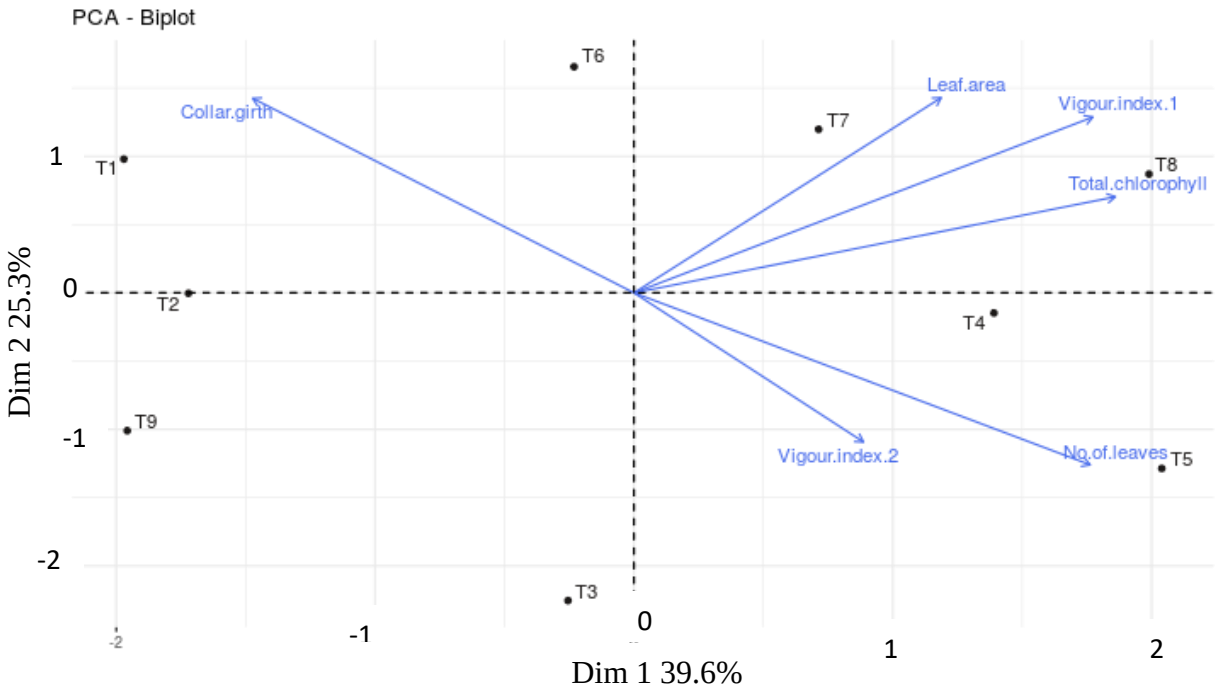


Figure 4.3.1. Loading plot of PC's in relation with various morphological characters of tomato

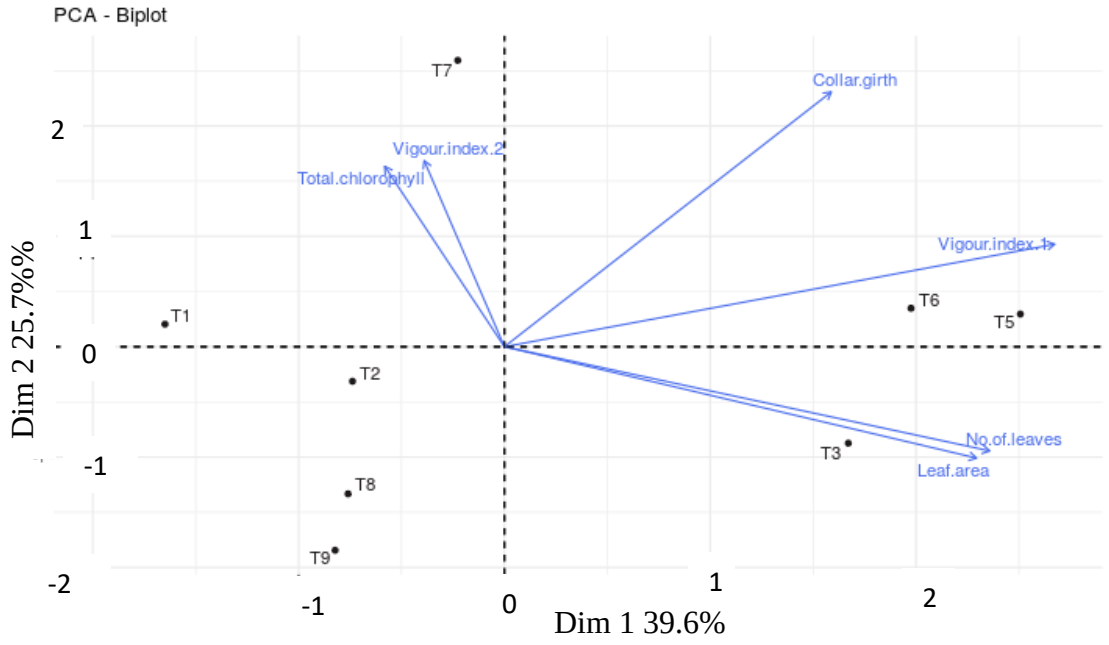


Figure 4.3.2. Loading plot of PC's in relation with various morphological characters of chilli

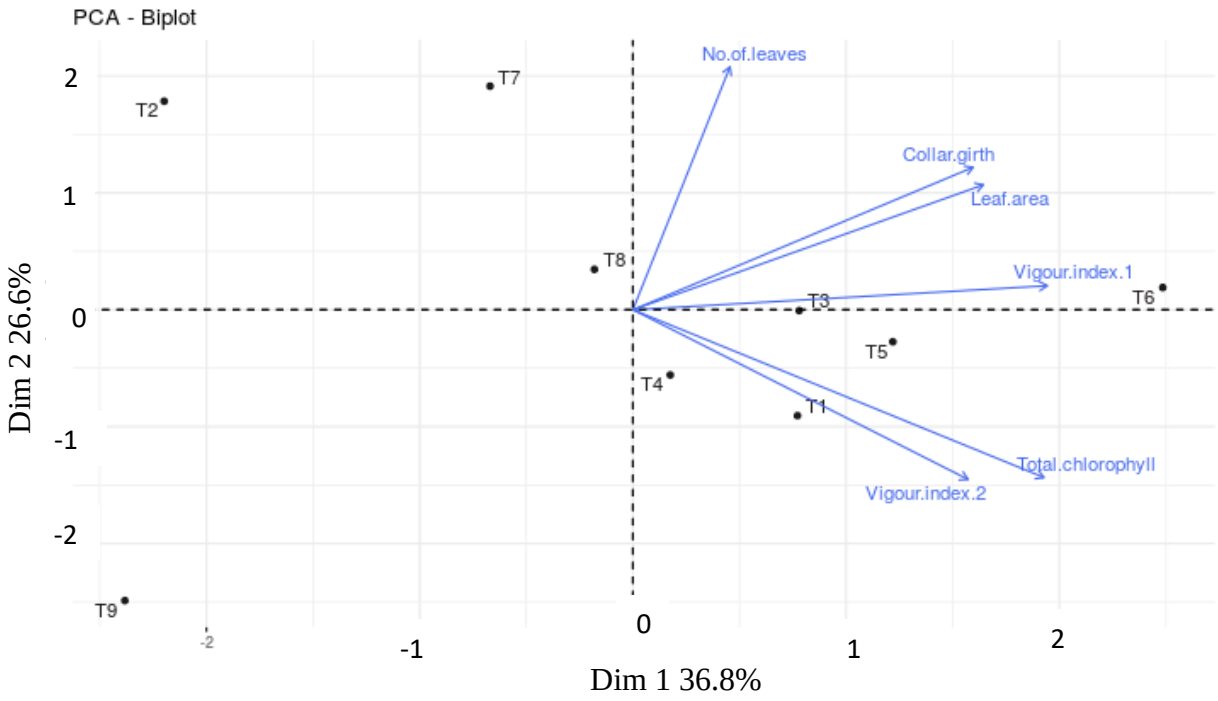


Figure 4.3.3. Loading plot of PC's in relation with various morphological characters of cucumber

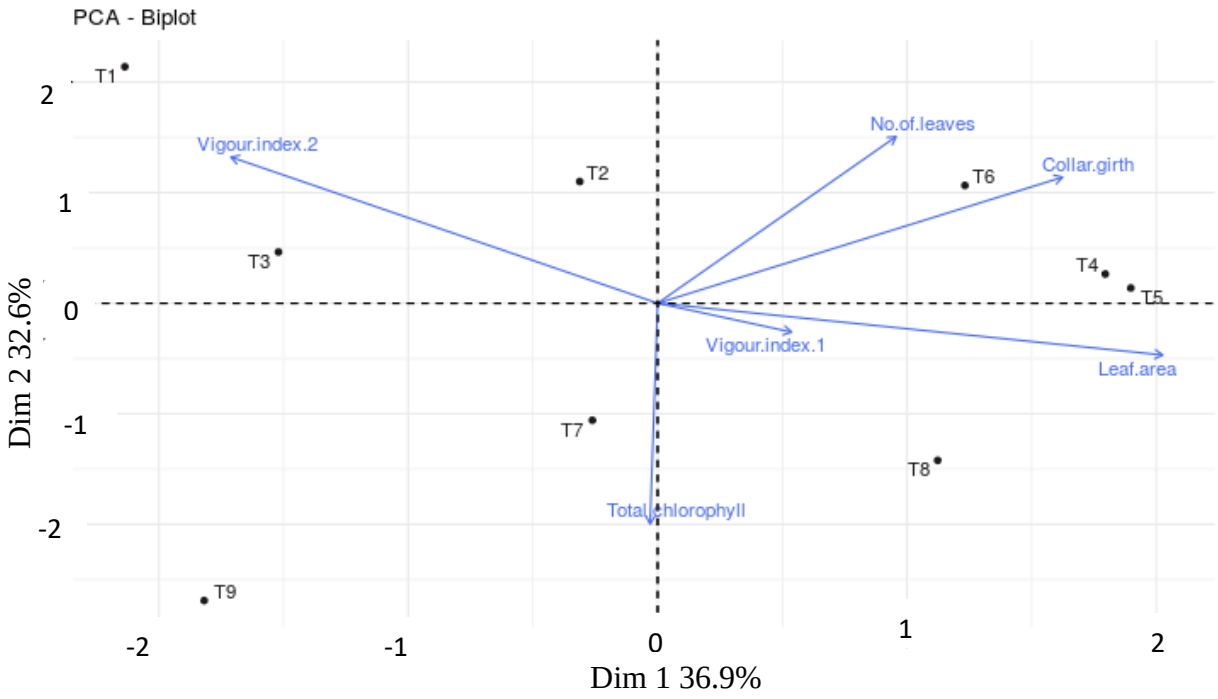


Figure 4.3.4. Loading plot of PC's in relation with various morphological characters of okra

Discussion

5. DISCUSSION

The pro-tray method for production of vegetable seedlings is gaining popularity and is an integral part of open precision farming since it produces high-quality vegetable transplants. Many factors influence the quality of vegetable transplants; as a result, transplant production requires extensive knowledge and experience. In the present investigation effect of different growing media, pre-sowing seed invigoration treatments and the use of biofertilizers on pro-tray seedling production were studied.

5.1. Experiment 1: Effect of different growing media on pro-tray seedling production

Many nursery growers use several combinations of growing media for pro-tray seedling production based on its availability. It ranges from natural materials like soil, cow dung, vermicompost *etc*. to synthetic materials like vermiculite and perlite. Some of the materials have growth-promoting character by providing nutrients while others are inert materials which provide support to the plant growth. This trial was conducted to identify the best combination of different materials. In the present study, seventeen different media for pro-tray seedling production were analysed for their properties and the seedlings were evaluated for morphological characters.

5.1.1. Physical properties of growing media

The pH of the growing media ranged from 5.86 to 7.14. Raviv *et al.* (1986) has reported that the optimum range of pH should be between 5.20 and 7.00. Hence, the pH of all the media studied was in the optimum range. Highest pH was recorded for the media having cocopeat and vermicompost in equal proportion. All media combinations taken in the study had a near neutral pH which will benefit the uptake of nutrients by seedlings. Similar results were reported by Spehia *et al.* (2019).

According to Noguera *et al*. (2000), the preferred EC for growing media should be less than 3.5 mS/cm. In the present study the EC of media containing neem cake was exceptionally high and was in the range of 7.21 - 12.34 mS/cm. In the other media combinations, the EC was in the range of 0.20 to 2.16 mS/cm which was within

the optimum range for the growth of vegetable seedlings. High EC value in neem cake added media indicated that the media contain excess salts, which could cause salinity injury to plants and also inhibit nutrient uptake by seedlings. Vegetable seeds (tomato, chilli, cucumber ad okra) sown in the media having high EC value did not germinate at all due to the salinity injury caused by excess salts. The results were in agreement with the findings of Mariyappillai and Arumugam (2021), who reported that the germination percentage and growth parameters were reduced with the increase in EC value. Hence it can be inferred that in spite of the possible advantages, if at all neemcake has to be used in pro-tray media its EC must be checked.

In order to test the pH and EC of neem cake, ten commercially available samples were collected from the market and were analysed. Nine of the ten samples had very high EC in the range of 14.32 to 34.57 mS/cm which was outside the optimum range for vegetable seedling production. The sample no. 3 had an EC as high as 34.57 mS/cm which was highly detrimental to the plant growth. Only one sample recorded EC value of 2.36 mS/cm which was in the optimum range. The pH values of all the samples were in the optimum range. As a result, it may be deduced that adulterated neem cake should not be used as an amendment in the growing media for pro-tray seedling production of vegetables.

Bulk density had significant differences among media which ranged from 0.40 g/cm^3 to 1.03 g/cm^3. All the media containing soil exhibited higher bulk density. Similarly, media having soil had higher weight. Growing media with very high bulk density may not be desirable for transportation. Agarwal *et al*. (2021) reported that the medium having bulk density of more than 1 g/cm^3 is not suitable for seedling production.

Water holding capacity of the media ranged from 16.06% to 62.22%. When cocopeat was mixed with vermiculite and perlite it reduced the bulk density and increased the water holding capacity which is desirable for good plant growth and easiness of handling and transportation as reported by Baillu *et al*. (2017). Cocopeat holds water eight times of its volume. As a result, adding cocopeat to the growing

media can increase the water holding capacity, thereby reducing the need for frequent irrigation.

Porosity ranged from 41.92% to 69.39% among the media studied. High porosity is essential for aeration in the media and for ensuring root growth. High porosity was exhibited by media having cocopeat, vermiculite and perlite in equal proportion. Acceptable porosity level leads to good root growth due to adequate root gas exchanges. This may be the reason why seedlings grown in media having cocopeat, vermiculite and perlite in equal proportion (T_{13}) had significantly higher root growth in all the crops studied. Inclusion of perlite to the media reduced the bulk density, increased the water holding capacity and porosity. Ilahi and Ahmad (2017) had reported that perlite can be added to a medium to increase the aeration and drainage. It is reported to be ideal for mixing with growing media because it has large particles and a low water retention capacity.

5.1.2. Nutrient content of growing media

Highest nitrogen content was recorded for the media having vermicompost. Similar result was reported by Mariyappillai and Arumugam (2021). Highest phosphorus content was recorded for the medium having cocopeat, vermicompost and neem cake in equal proportion. Media comprising cocopeat, neem cake, vermiculite and perlite recorded maximum potassium content.

Cocopeat, vermiculite, and perlite containing medium had reduced NPK concentration. The medium including vermicompost, neem cake, and soil had comparatively higher nutritional content, but the levels of N, P and K were still low. So, the nutritional content of growing media has only a minor impact on seedlings. Hence, soluble fertilizers such as 19:19:19 and KNO_3 should be supplemented for better growth of seedlings. The medium containing neem cake noted maximum phosphorus and potassium content. But the nutrients were unavailable and these media displayed no germination because of high EC value.

5.1.3. Influence of growing media on growth parameters

There was no germination in the media comprising neem cake *viz*., T_9, T_{12}, T_{14} and T_{16} because of its high EC value. Since the germination per cent was zero, the growth parameters *viz*., plant height, root length, number of leaves, leaf area, collar diameter, Vigour index I & 2 and total chlorophyll content also recorded zero.

The present study showed significant differences among media for all the morphological and physiological characters studied. In tomato, chilli, cucumber and okra soil-less media in which highest germination was recorded is T_{17} (cocopeat, vermiculite and perlite - 3:1:1) and T_{13} (cocopeat, vermiculite and perlite - 1:1:1) (Fig. 5.1.1). In tomato, media containing soil in which highest germination was recorded include T_6 (soil and cow dung - 1:1), T_5 (soil and vermicompost - 1:1) and T_{10} (soil, cocopeat and cow dung -1:1:1). In chilli, soil containing media in which highest germination recorded was in T_{15} (soil, cocopeat, vermiculite and perlite - 1:1:1:1) and T_{11} (soil, cocopeat and vermicompost - 1:1:1). In cucumber soil containing media T_5 and T_{10} recorded the maximum germination. In okra soil containing media T_5, T_6, T_{10} and T_{15} recorded the maximum germination percentage. Chilli had uneven germination in most of the growing medium tested. It had a severe germination problem, with a maximum germination rate of only 92.80%. Syaiful *et al*. (2021) had reported problem of low germination in chilli.

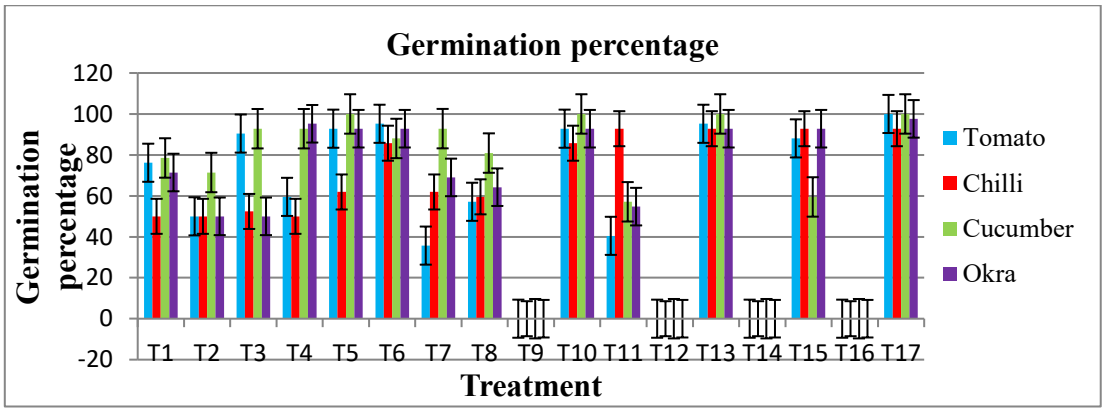


Figure 5.1.1. Effect of growing media on germination percentage

In tomato, chilli, cucumber and okra, soil-less medium T_{17} (cocopeat, vermiculite and perlite - 3:1:1) recorded the maximum plant height (Fig.5.1.2). In tomato, cucumber and okra, soil containing media T_5, T_6 and T_{10} recorded maximum

plant height. In chilli T_6 and T_{10} which is having soil recorded higher plant height. Lin *et al*. (2015) reported that soil, cocopeat and cow dung in the ratio of 1:2:1 as good mixture for seedling production. Minimum plant height in chilli, cucumber and okra was recorded in the media having vermicompost. This indicates the inhibition of seedling growth due to the presence of vermicompost in the substrate. The results were in accordance with the findings of Ievinsh (2011) who reported reduction in growth parameters with increase in the concentration of vermicompost in the growing media. This could be possibly due to the presence of allelochemicals in vermicompost or higher sensitivity to EC which may have inhibitory effect on germination in chilli.

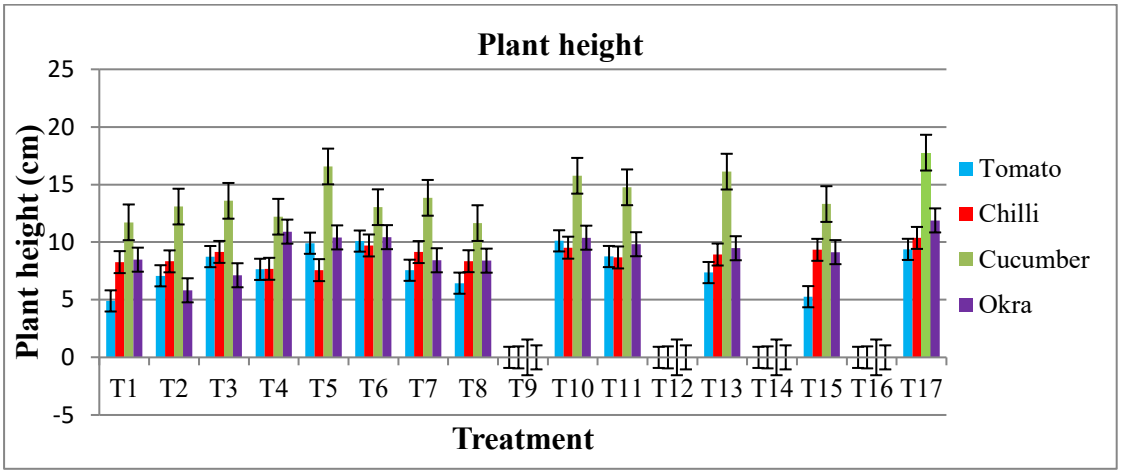


Figure 5.1.2. Effect of growing media on plant height

Among soil-less media, in tomato, chilli and cucumber root length was higher in T_{17} and T_{13} (Fig. 5.1.3). This might be due to high porosity exhibited by the media as reported by Ilahi and Ahmad (2017). T_{17} and T_{13} can be recommended as an ideal media to raise root stocks for vegetable grafting since these media exhibit good root establishment. In okra T_{13} and T_2 had higher root length. Soil containing media T_6 and T_{10} recorded higher root length in all the four crops. This could be possibly due to the higher porosity and thereby aeration in the medium which leads to better root development. T_4 comprising soil and cocopeat in equal proportion exhibited lower root length in all the four crops studied. This may be due to the high bulk density exhibited by the medium.

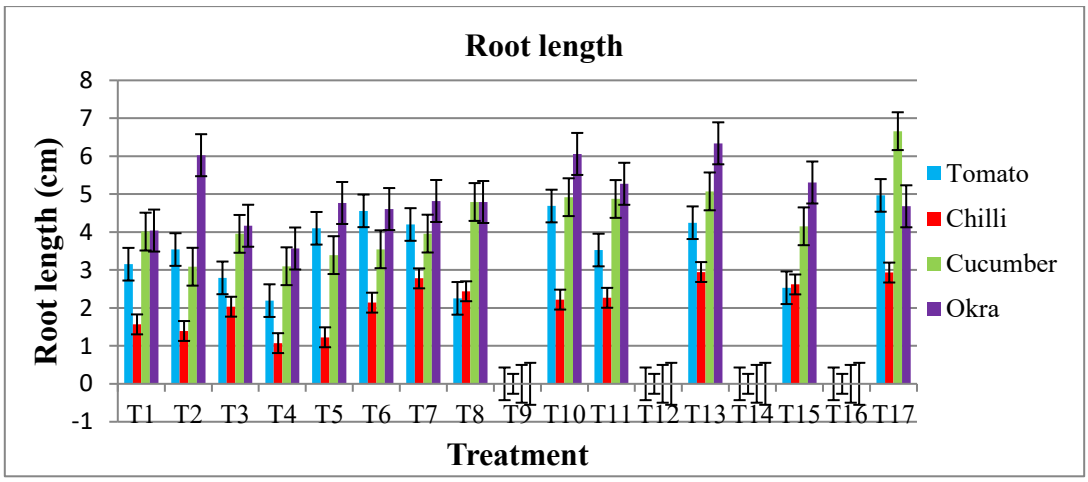


Figure 5.1.3. Effect of growing media on root length

Amid soil-less media, more number of leaves was recorded in T_{17} and T_{13} in all the crops studied (Fig.5.1.4). In cucumber T_8 (cocopeat and vermicompost - 1: 1) also had more leaves. Soil containing media in which greater number of leaves observed was T_5, T_6 and T_{10}. Leaf area was uniformly higher in T_{17} and T_{13} (soil-less media) in all the crops (Fig.5.1.5). Soil containing media T_{10} recorded the maximum leaf area in tomato, chilli and okra. In cucumber soil containing medium T_{11} (soil, cocopeat and vermicompost - 1: 1: 1) recorded the maximum. Seedlings grown in these media had good root growth hence more nutrient uptake, which possibly resulted in more number of leaves and leaf area.

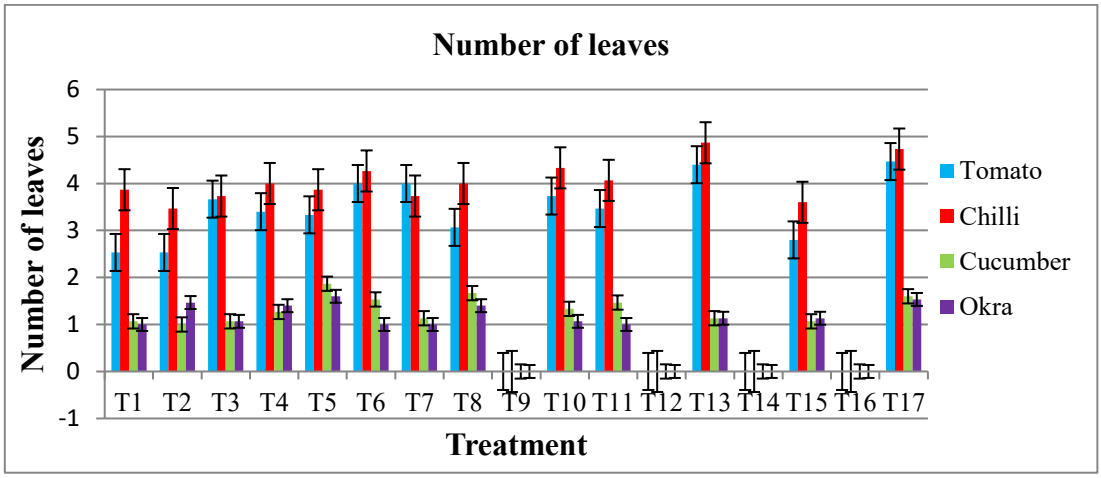


Figure 5.1.4. Effect of growing media on number of leaves

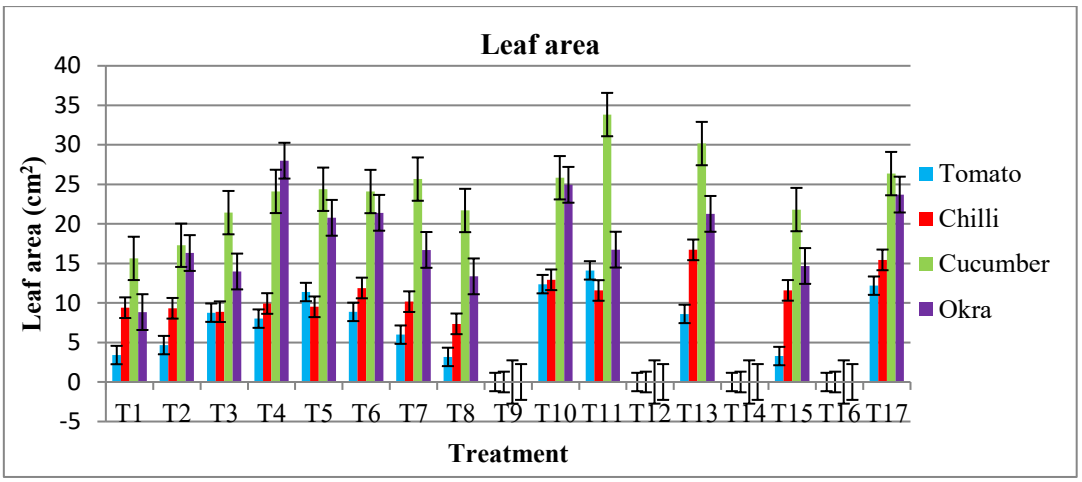


Figure 5.1.5. Effect of growing media on leaf area

Soil-less medium in which maximum collar diameter recorded was T_{17} in tomato, chilli and okra (Fig.5.1.6). While in cucumber, collar diameter was higher for the medium T_3 having dried cow dung only. Soil containing media *viz*., T_6 & T_{10}, T_{10} & T_{15}, T_{11} & T_6 and T_5 recorded higher collar diameter in tomato, chilli, cucumber and okra respectively.

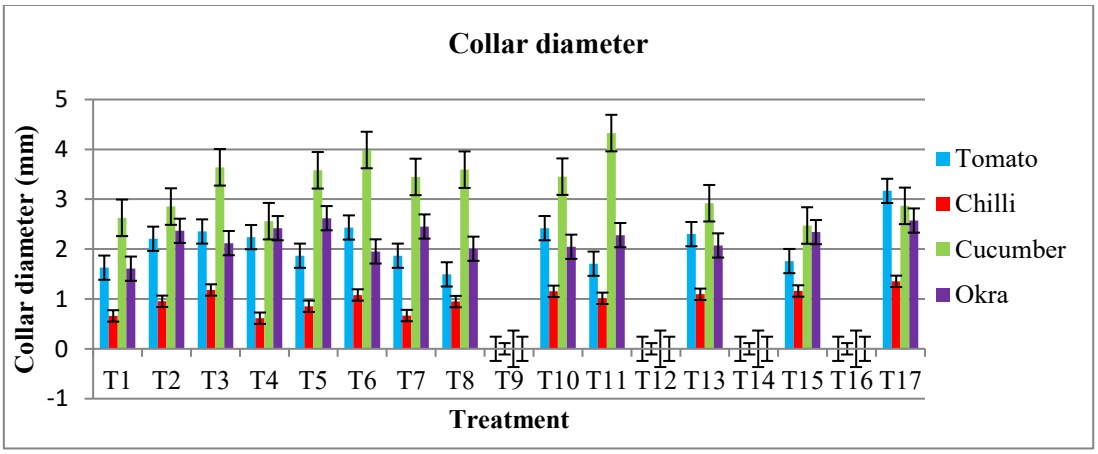


Figure 5.1.6. Effect of growing media on collar diameter

Soil-less media, cocopeat, vermiculite and perlite in the ratio of 3:1:1 and 1:1:1 had higher VI I & VI II in all the crops studied (Fig.5.1.7 & Fig.5.1.8). This might be due its good physicochemical characters which lead to vigorous seedlings as reported by Baillu *et al*. (2017). Among soil containing media T_{10} had higher Vigour index I and T_6 and T_{10} recorded higher VI II in tomato, cucumber and okra. In chilli maximum VI I and VI II was recorded in T_{15} and T_{11}.

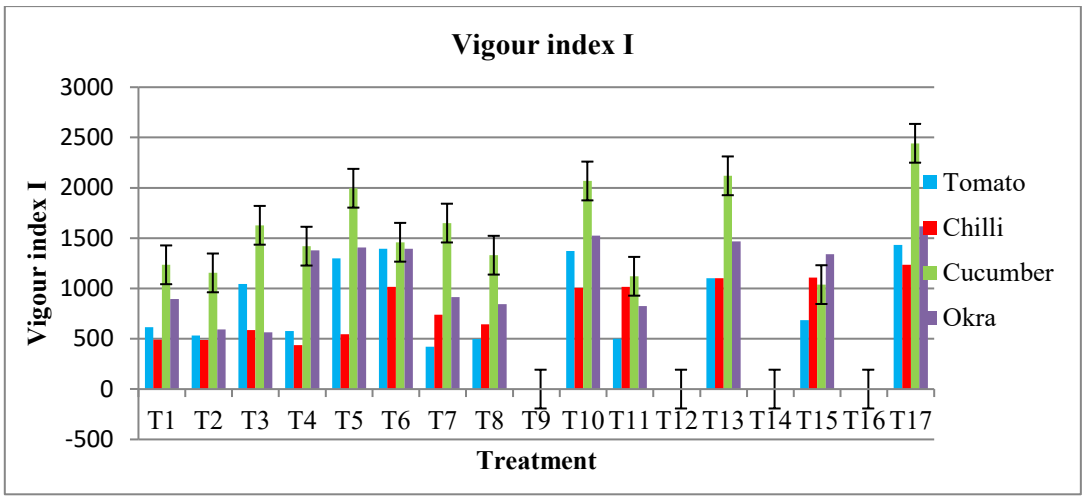


Figure 5.1.7. Effect of growing media on Vigour index I

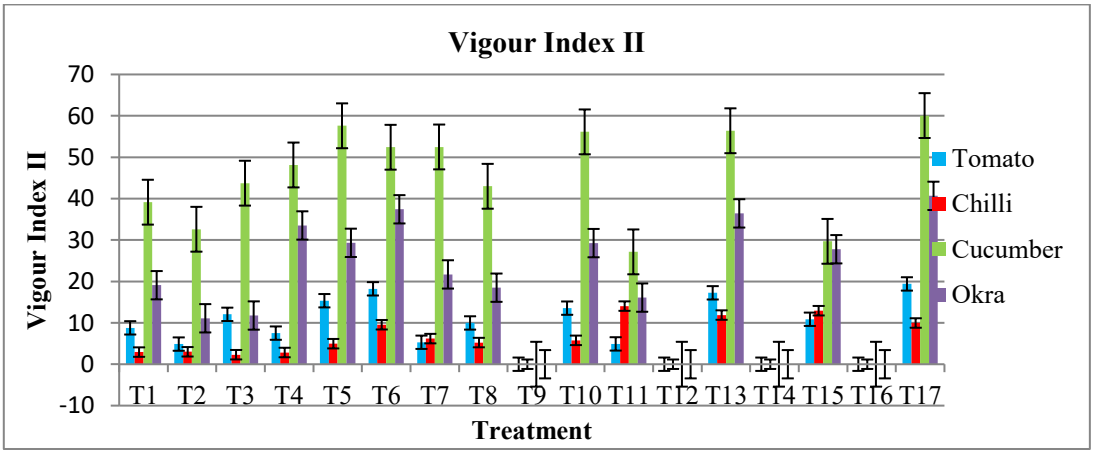


Figure 5.1.8. Effect of growing media on Vigour Index II

In tomato T_5 (soil and vermicompost - 1:1) & T_{15} (soil, cocopeat, vermiculite and perlite - 1:1:1:1) in chilli T_{11} (soil, cocopeat and vermicompost - 1:1:1) & T_8 (cocopeat and vermicompost - 1:1), in cucumber T_{10} (soil, cocopeat and cow dung - 1:1:1) and in okra T_4 (soil and cocopeat - 1:1) & T_{10} had higher total chlorophyll content among soil containing media. In tomato and okra soil-less media T_{13} (cocopeat, vermiculite and perlite - 1:1:1) and T_{17} (cocopeat, vermiculite and perlite - 1:1:1) respectively recorded highest total chlorophyll content. Among soil-less media, T_8 (cocopeat and vermicompost - 1:1) and T_2 (vermicompost alone) recorded higher total chlorophyll content in chilli. In cucumber T_3 (cow dung alone) had maximum chlorophyll content. The media comprising vermicompost recorded maximum total chlorophyll content which may be due to high nitrogen content in the medium. These

results were in accordance with the findings of Paul and Metzger (2005) who noted high chlorophyll content in pepper seedlings grown in vermicompost amended medium (Fig.5.1.9).

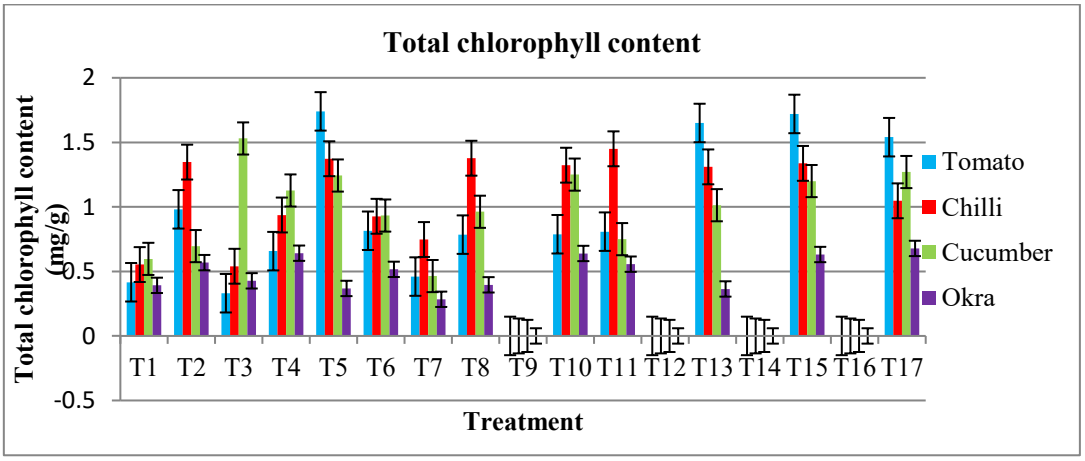


Figure 5.1.9. Effect of growing media on total chlorophyll content

T_1. Cocopeat	**T_2. Vermicompost**	**T_3. Dried powdered cow dung**
T_4. Soil: cocopeat (1:1)	**T_5. Soil: vermicompost (1:1)**	**T_6. Soil: dried powdered cow dung (1:1)**
T_7. Cocopeat: dried powdered cow dung (1:1)	**T_8. Cocopeat: vermicompost (1:1)**	**T_9. Cocopeat: neem cake (1:1)**
T_{10}. Soil: cocopeat: dried powdered cow dung (1:1:1)	**T_{11}. Soil: cocopeat: vermicompost (1:1:1)**	**T_{12}. Cocopeat: vermicompost: neem cake (1:1:1)**
T_{13}. Cocopeat: vermiculite: perlite (1:1:1)	**T_{14}. Soil: cocopeat: dried powdered cow dung: neem cake (1:1:1:1)**	**T_{15}. Soil: cocopeat: vermiculite: perlite (1:1:1:1)**
T_{16}. Cocopeat: neemcake: vermiculite: perlite (1:1:1:1)	**T_{17}. Cocopeat: vermiculite: perlite (3:1:1)**	

Characters *viz*., germination percentage, root length, number of leaves, collar diameter vigour index I & II were maximum for the media having 3 parts cocopeat mixed with 1 part vermiculite and 1 part perlite. The result obtained was comparable from studies of Singh *et al*. (2009).

5.1.4. Cost Analysis

Benefit cost ratio (100 m^2 per month) was calculated. Among soil-less media benefit cost ratio was higher for T_{17} and T_{13} comprising cocopeat, vermiculite and perlite in the ratio of 3:1:1 and 1:1:1 respectively. T_6 (soil and cow dung - 1:1) and T_{10} (soil, cocopeat and cow dung - 1:1:1) recorded higher BC ratio among soil containing media. These media had BC ratio more than one indicated that the investment was worthwhile (Table 4.10).

5.1.7. Ranking to select best growing media for pro-tray seedling production

The media were ranked based on an index calculated through principal component analysis (PCA) providing weightage based on loadings (Appendix III). The number of leaves, leaf area, collar diameter, vigour index I & II, and total chlorophyll content were used in the PCA. The results revealed that T_{17} having cocopeat, vermiculite and perlite in the ratio of 3:1:1 by volume ranked first in all the crops studied. It was followed by T_{13} & T_{10} in cucumber and okra, T_6 & T_{10} in tomato and T_{15} & T_{13} in chilli. Cocopeat when mixed with vermiculite and perlite in the ratio of 3:1:1 by volume had acceptable physicochemical properties which might result in the vigorous seedlings. These results were in accordance with Baillu *et al*. (2017).

5.1.8. Selection of best soil-less and soil containing medium based on benefit cost ratio

T_{17} (cocopeat: vermiculite: perlite - 3:1:1) was found to be the best soil-less media for all the four crops based on the benefit-cost ratio, followed by T_{13} (cocopeat: vermiculite: perlite - 1:1:1). Hence, T_{17} can be recommended as the ideal growing media for vegetable seedling production on a commercial scale. This medium also ranked best in terms of germination, growth parameters and vigour in all the four crops studied *viz*., tomato, chilli, cucumber and okra.

Among soil containing media, T_6 having soil and dried powdered cow dung in equal proportion and T_{10} having soil, cocopeat and dried cow dung exhibited higher benefit cost ratio and was found to be on par with T_{17} for most of the growth parameters. Farmers do not have easy access to vermiculite and perlite, and they are costly. In this context, soil and dried powdered cow dung in equal proportion and soil, cocopeat, cow dung (1:1:1) are found to be an alternate media comprising locally available inputs and is affordable by the farmers. Chilli can be grown profitably in the media T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1) and T_{11} (soil: cocopeat: vermicompost - 1:1:1). Similar results have not been reported so far.

5.2. Experiment II: Effect of pre-sowing seed invigoration on pro-tray seedling production

Inspite of selecting the best media in the first trial, crops like chilli and okra not attain 100% germination. Chili displayed wide variability in germination. Even in the best media it had germination only up to 92%. The present study is conducted with the purpose of overcoming this problem of low germination and to increase the growth parameters. Seed treatment can be done either with chemical compounds or bio-control agents. There are several reports showing the effect of seed treatment with chemicals and bio-agents treated individually. But studies on the effect of seed treatment with the combination of chemicals and bio-control agents are scanty. In this study, nine different treatments including direct seeding, soaking in water, treating with different concentrations KNO_3 and *Pseudomonas* individually and in combinations were evaluated for germination and seedling characters.

5.2.1. Impact of seed invigoration on growth parameters

In tomato, clilli, cucumber and okra, 100% germination was recorded in the treatment having a combination of 0.5% KNO_3 and 1% *Pseudomonas* (T7). In tomato, chilli and okra where the initial germination percentage was less than 100% (in initial germination test), treatment with KNO_3 was successful in increasing the germination to 100%. The germination percentage could be significantly improved compared to direct seeding and water soaking. Higher germination percentage was recorded in 0.5% KNO_3, 1% KNO_3 and 1% *Pseudomonas* treatments individually and in

combinations (Fig.5.2.1). Syaiful *et al.* (2021) had reported a serious germination problem in chilli. Low germination is a major concern with chilli; this barrier could overcome by treating the seeds with KNO_3. Improvement in germination percentage may be due to breaking of dormancy through the formation of nitric oxide. According to Lara *et al*. (2014), the advantages of KNO_3 priming were linked to the action of the enzyme *nitrate reductase* in the synthesis of nitric oxide, which promote rapid germination. So, it can be inferred that seed treatment with KNO_3 can ameliorate the problem of low germination. In tomato, cucumber and okra reduced germination at 2% KNO_3 might be due to sensitivity of these seeds to KNO_3 which cause some detrimental effects on seed germination. Similar findings were reported by Mushtaq *et al*. (2012) who reported a decrease in germination with higher concentration of KNO_3.

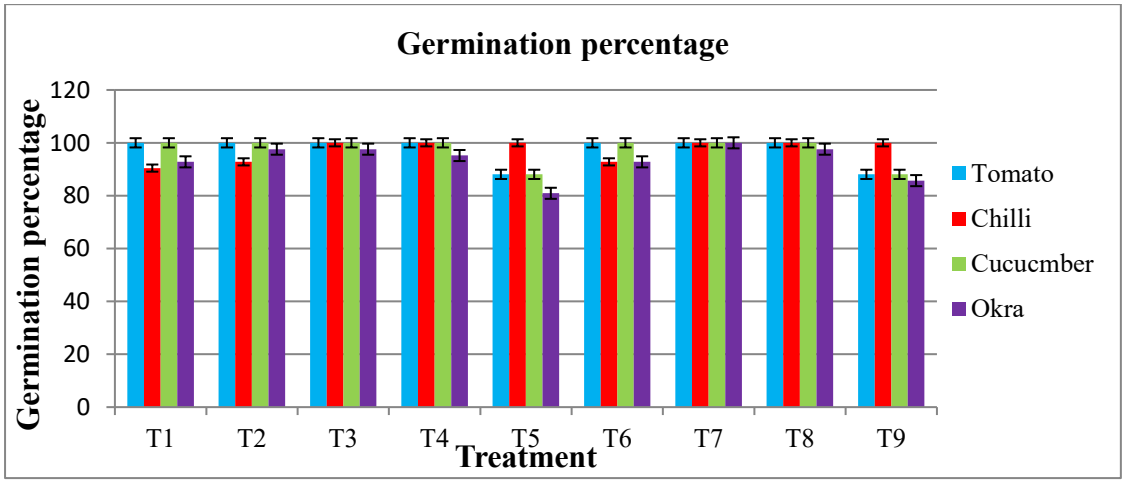


Figure 5.2.1. Effect of pre-sowing seed invigoration on germination percentage

Plant height of tomato, chilli, cucumber and okra was higher under treatment comprising 0.5% KNO_3, 1% KNO_3 and their combination with 1% *Pseudomonas* (Fig.5.2.2). Minimum plant height was under untreated control, water soaking (T_2), 2% KNO_3 (T_5) and 2% KNO_3 + 1% *Pseudomonas* (T_9) for all the crops. The increase in plant height is possibly due to more nitrogen and potassium content in seeds treated with KNO_3. These results were in accordance with Mushtaq *et al*. (2012) who reported good growth parameters in seeds treated with 0.25% to 0.5% KNO_3. While this result was in contrary with the findings of Anwar *et al*. (2020), who reported 5% KNO_3 as best treatment in cucumber.

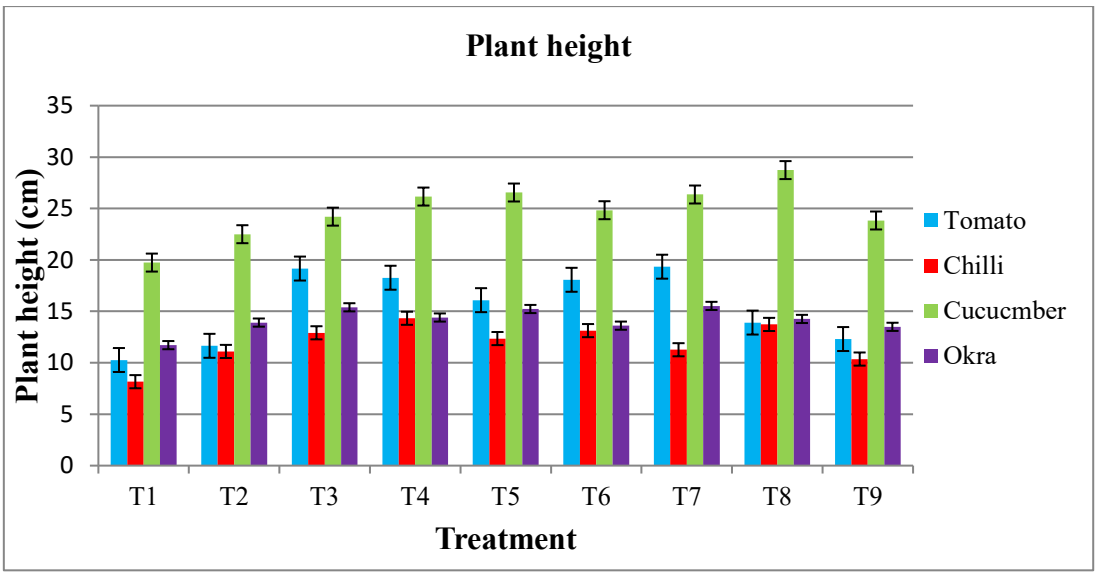


Figure 5.2.2. Effect of pre-sowing seed invigoration on plant height

In general root length was comparatively higher in T_4 (1% KNO3), T_5 (2% KNO3) and T_7 (0.5% KNO_3 and 1% *Pseudomonas*). Root length was much lower in T_1 (direct seeding) T_2 (water soaking) and T_9 (2% KNO3 + 1% *Pseudomonas*) whereas, in chilli higher root length was noted in T_2 (water soaking) and T_6 (1% *Pseudomonas*). Similar results were reported by Kulsumbi *et al*. (2020), who observed more root growth in spinach treated with 1% KNO_3 (Fig.5.2.3).

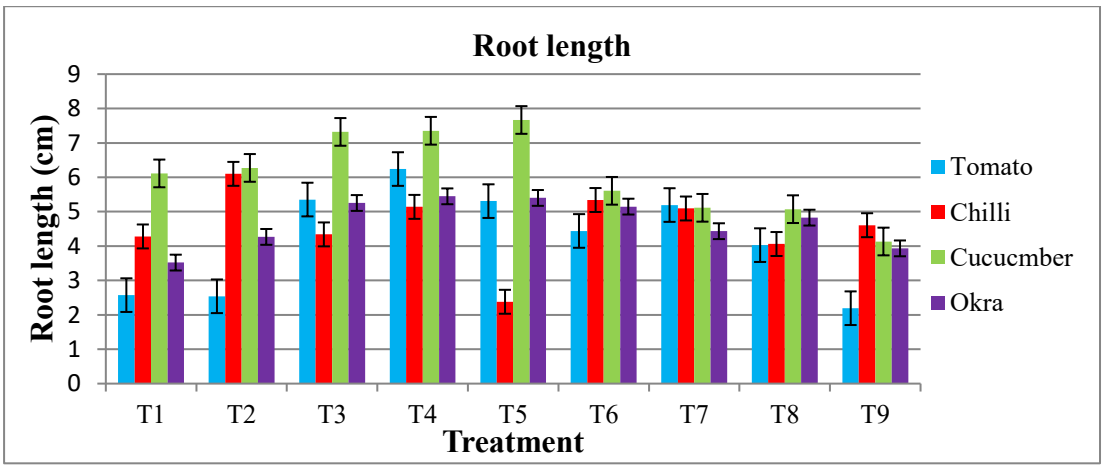


Figure 5.2.3. Effect of pre-sowing seed invigoration on root length

In tomato and chilli more number of leaves was recorded in T_3 (0.5% KNO_3) and T_7 (0.5% KNO_3 and 1% *Pseudomonas*). There was no significant difference in number of leaves of cucumber and okra (Fig.5.2.4). Leaf area was higher in the

treatments having 0.5% KNO_3, 1% KNO_3 and combination of these with 1% *Pseudomonas* (Fig. 5.2.5).

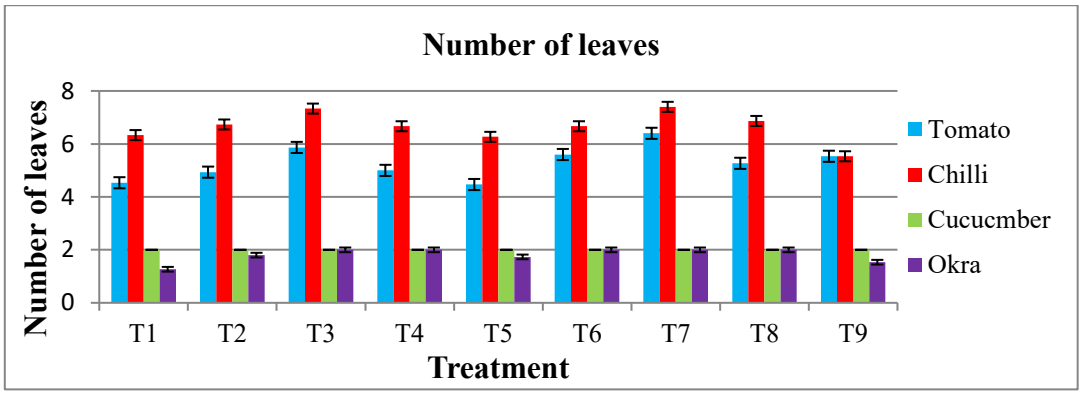


Figure 5.2.4. Effect of pre-sowing seed invigoration on number of leaves

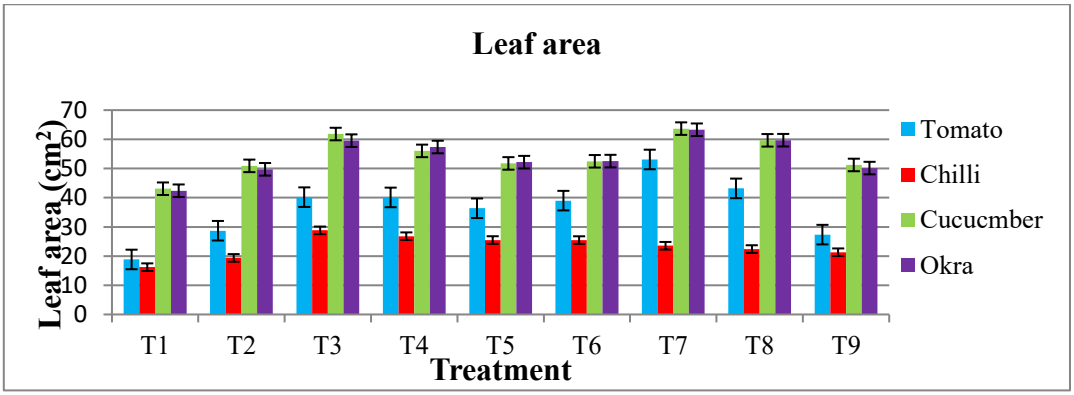


Figure 5.2.5. Effect of pre-sowing seed invigoration on leaf area

Collar diameter did not vary that much in all the four crops studied. But comparatively more collar diameter was observed in the treatments having 0.5% KNO_3, 1% KNO_3 alone and in combination with 1% *Pseudomonas* (Fig.5.2.6).

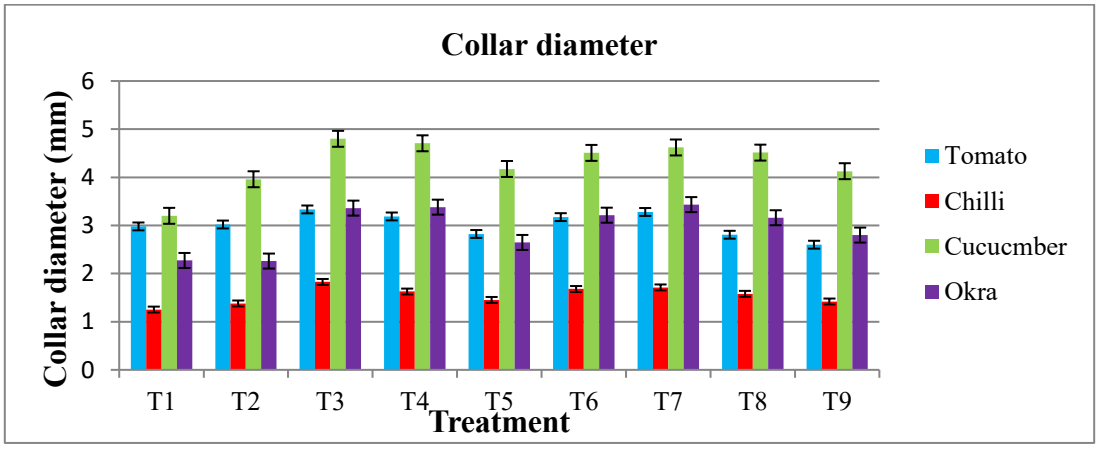


Figure 5.2.6. Effect of pre-sowing seed invigoration on collar diameter

In tomato, chilli, cucumber and okra, Vigour index I was higher in the treatment comprising 0.5% KNO_3, 1% KNO_3 and combination of these with 1% *Pseudomonas* (Fig.5.2.7). Vigour Index II was not significantly different in tomato. In chili and cucumber VI II was higher in T_2 (water soaking) and T_3 (0.5% KNO_3). Okra recorded maximum VI II in 1% *Pseudomonas* and in combination of 0.5% KNO_3 and 1% *Pseudomonas* (Fig.5.2.8). Tiwari *et al.* (2014) reported deterioration in vigour of pigeon pea seedlings treated with KNO_3 beyond 0.3%.

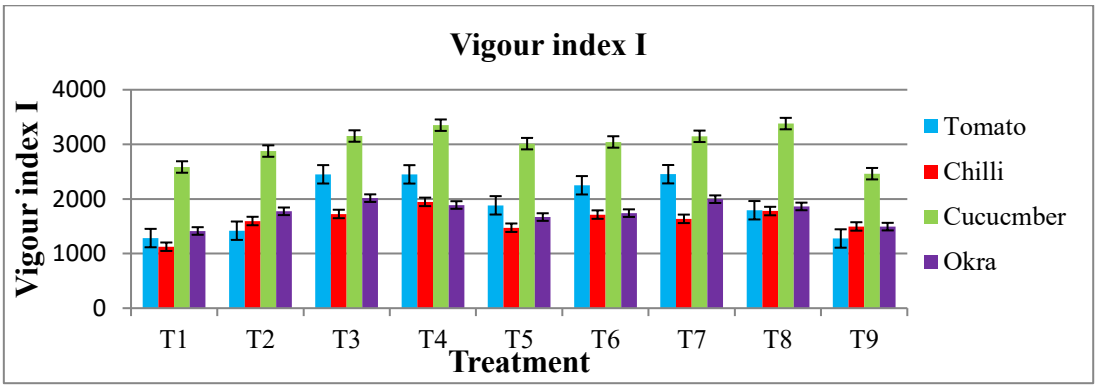


Figure 5.2.7. Effect of pre-sowing seed invigoration on vigour index

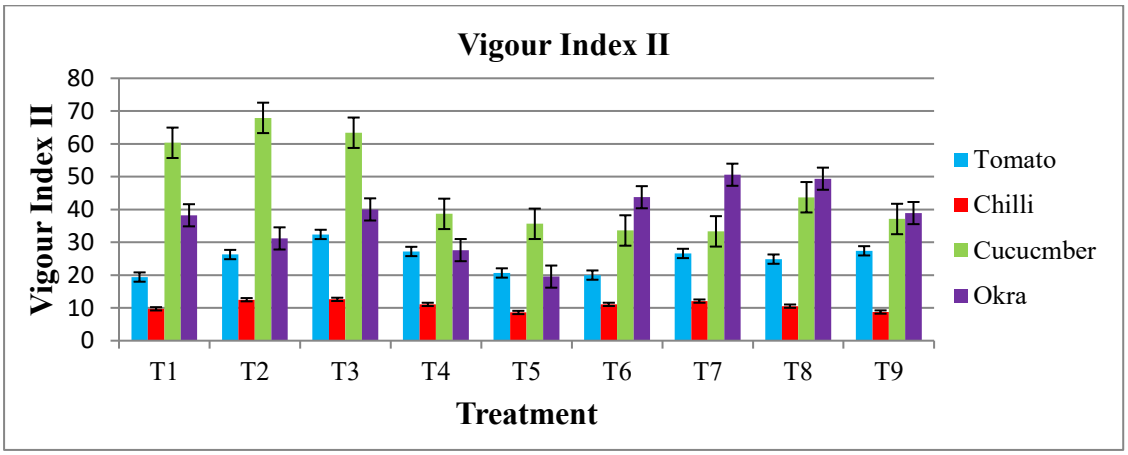


Figure 5.2.8. Effect of pre-sowing seed invigoration on Vigour Index II

In cucumber and okra chlorophyll content was found higher in treatments containing 0.5% & 1% KNO_3, 1% *Pseudomonas* and their combinations. In tomato and chilli treatments comprising water soaking, 0.5% and 1% KNO_3 recorded higher chlorophyll content (Fig.5.2.9). The higher initial growth parameters in okra and cucumber could be probably due to the stored materials present in the seeds.

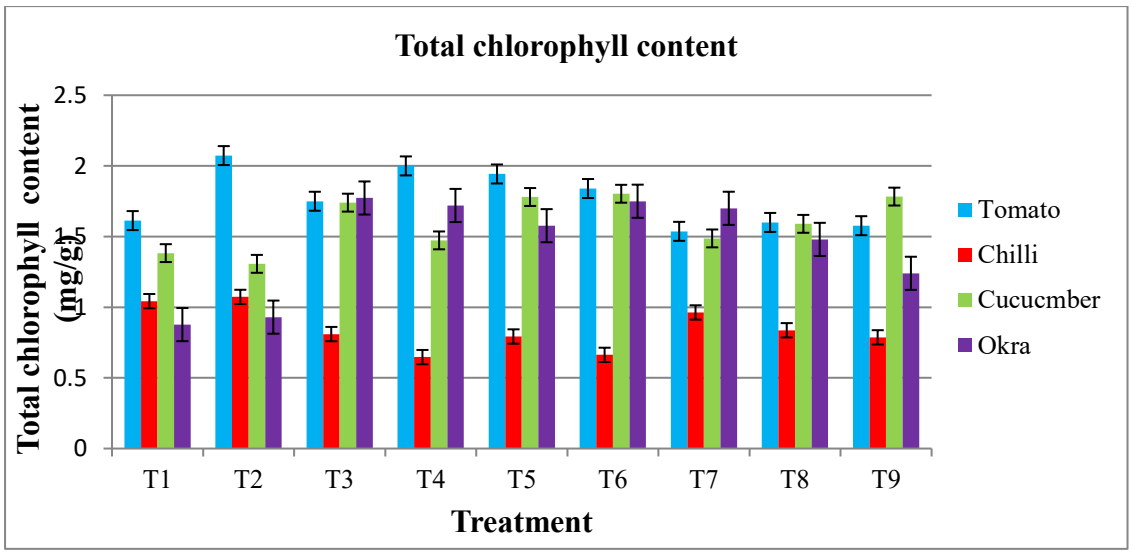


Figure 5.2.9. Effect of pre-sowing seed invigoration on total chlorophyll content

T_1: Control, T_2: Soaking in water, T_3: 0.5% KNO3, T_4: 1% KNO3, T_5: 2% KNO3, T_6: 1% *Pseudomonas*, T_7: 0.5% KNO3 + 1% *Pseudomonas*, T_8: 1% KNO3 + 1% *Pseudomonas*, T_9: 2% KNO3 + 1% *Pseudomonas*

5.2.2. Selection of best seed treatment for pro-tray seedling production

Ranking was done based on the index calculated to identify the best seed treatment. Principal component analysis was performed for the characters *viz*., leaf area, collar diameter, vigour index I & II, and total chlorophyll content. Loadings of principal components having Eigen value more than one was taken to calculate the index. Based on ranking, in tomato and okra 0.5% KNO_3 and 1% *Pseudomonas* (T_7) was found to be the efficient seed invigoration treatment. In cucumber and chilli 1% KNO_3 alone or in combination with *Pseudomonas* was found to be the best treatment for pre-sowing seed invigoration. The ranking revealed that 0.5% and 1% KNO_3 alone, as well as in combination with 1% *Pseudomonas*, performed effectively in all the four crops evaluated.

It can be inferred that seeds treated with 0.5% and 1% KNO_3 concentrations alone or in combination with 1% *Pseudomonas* yielded good growth parameters, while seeds treated at 2% KNO_3 concentrations was detrimental for seedling growth. The results were in accordance with the findings of Singh *et al*. (2014) who reported good growth parameters in KNO_3 treated cowpea. Apart from giving good vigour, the

combination of KNO_3 and *Pseudomonas* also confers resistance to soil-borne diseases. Paulitz *et al*. (1992) reported that seeds treated with antagonistic bacteria protect germinating embryos and seedlings from soil-borne diseases. This allows the production of healthy, vigorous transplants.

A combination of KNO_3 and *Pseudomonas* improved the growth parameters and might impart resistance to soil-borne diseases. Agar plate method showed that *Pseudomonas* survives in seeds treated with 0.5%, 1% and 2% KNO_3. Studies on the effect of seed invigoration with a combination of chemicals and bio-control agents are scanty. It is because of the presumption that chemicals are not compatible with biocontrol agents. But bacteria survive better in isotonic rather than hypotonic or hypertonic solutions.

Though, pests and diseases are not observed in the current trial, there are reports that *Pseudomonas* imparts resistance to damping off and other nursery diseases (Paulitz *et al*., 1992). Hence this experiment revealed that, pre-sowing seed invigoration with KNO_3 up to concentration of 2% and in combination with 1% *Pseudomonas* was highly effective in the improvement of germination and growth parameters of seedlings of tomato, chilli, cucumber and okra. This combination has the dual advantage of providing potassium and nitrogen and imparting resistance to diseases. KNO_3 contains 13.7% nitrate nitrogen and 46% potassium oxide. Prasad *et al*. (2016) reported that *pseudomonas* when treated with seeds can induce systemic resistance in plants. So, these treatments can be effectively be utilized for producing healthy and vigorous vegetable seedlings.

Seeds saved are equivalent to seeds produced. This simple technique of seed invogouration with 0.5 to 1 % KNO_3, 1% *Pseudomonas* and their combination is successful in overcoming pre-germination barriers in vegetable seeds and in increasing germination percentage up to almost 100 per cent.

5.3. Experiment III: Effect of biofertilizers on pro-tray seedling production

Biofertilizer treatment is highly effective to get good yield and growth parameters in vegetable crops. It should be treated during the initial stage of sowing. Otherwise, farmers have to do it in the field while planting which increases the manual labour. By adopting the method of adding biofertilizers in the pro-tray medium itself, it facilitates root zone inoculation. Once it is inoculated in the root, it will grow and get enriched in the main field when transplanted. So, in the present experiment, inoculation of biofertilizers alone and in combinations was done in pro-tray media itself to produce healthy seedlings.

5.3.1. Effect of biofertilizers on growth characters

In tomato, chilli, cucumber and okra highest germination was recorded in treatment T_6 having AMF, *Pseudomonas* and PGPR Mix-1 and in T_7 having AMF, *Trichoderma* and PGPR Mix-1 (Fig.5.3.1). Thus, indicating that the microbial consortium has an impact on seedling emergence and hence seedling growth. Desai *et al*. (2020) reported that tomato and capsicum seeds sown in media inoculated with AMF and PGPR had higher growth parameters.

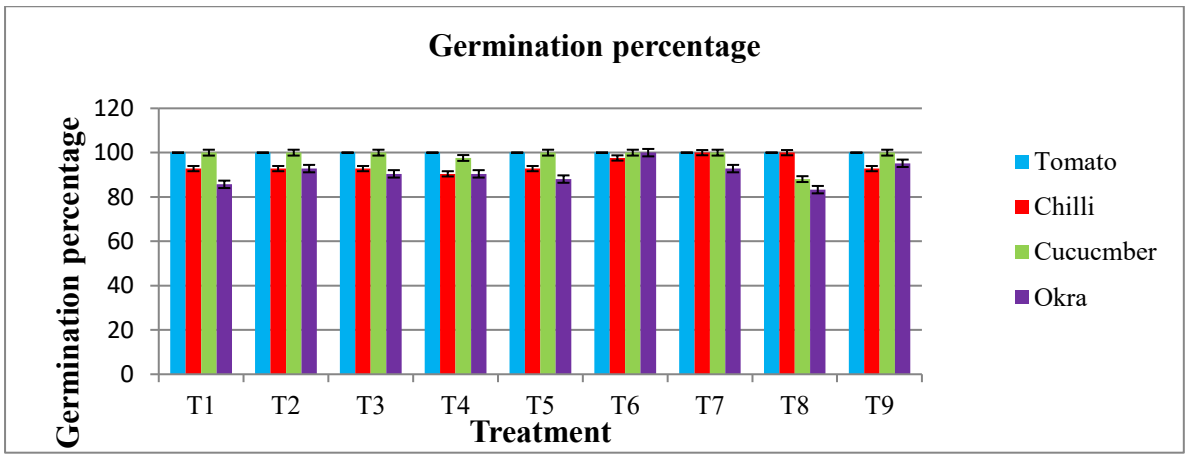


Figure 5.3.1. Effect of biofertilizers on germination percentage

In tomato, chilli, okra and cucumber maximum plant height was recorded in treatment combinations containing AMF and PGPR along with either *Trichoderma* or *Pseudomonas* (Fig.5.3.2). Co-inoculation of PGPR and AMF had a beneficial effect on growth parameters as reported by Vivas *et al*. (2003). Similarly, Jayashree and Jagadeesh (2017) reported an increase in plant height of tomato and chilli grown in the media inoculated with microbial consortium. It might be due to the production of

plant growth promoting substances which leads to enhanced cell division and hence, more seedling height.

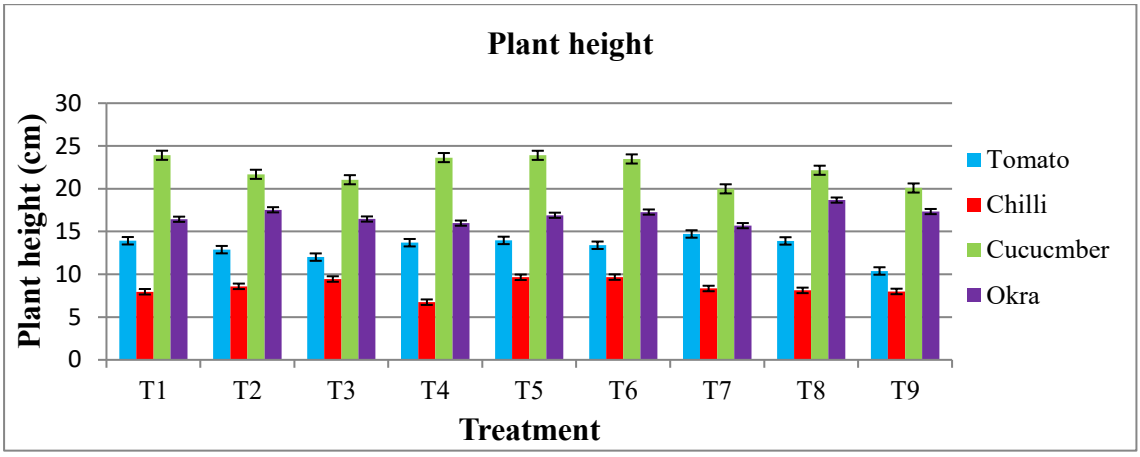


Figure 5.3.2. Effect of biofertilizers on plant height

In tomato, chilli, cucumber and okra maximum root length was obtained in media inoculated with AMF, PGPR and *Pseudomonas* or *Trichoderma* (Fig.5.3.3). Mwangi *et al*. (2011) also reported good growth parameters in tomato sown in medium treated with *Trichoderma* and AMF individually and in combination.

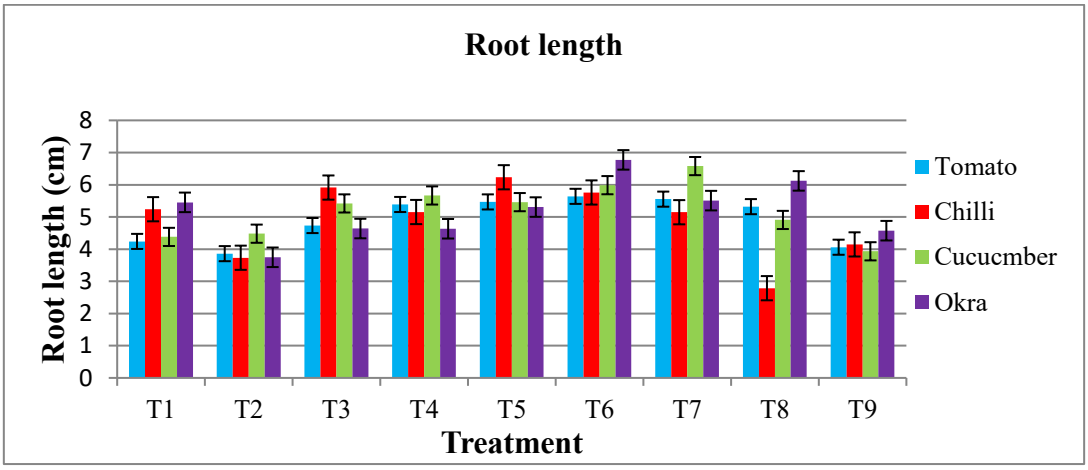


Figure 5.3.3. Effect of biofertilizers on root length

Media inoculated with AMF + PGPR Mix-1 recorded greater number of leaves in tomato and chilli. There were no much variations in number of leaves of cucumber and okra between treatments (Fig.5.3.4).

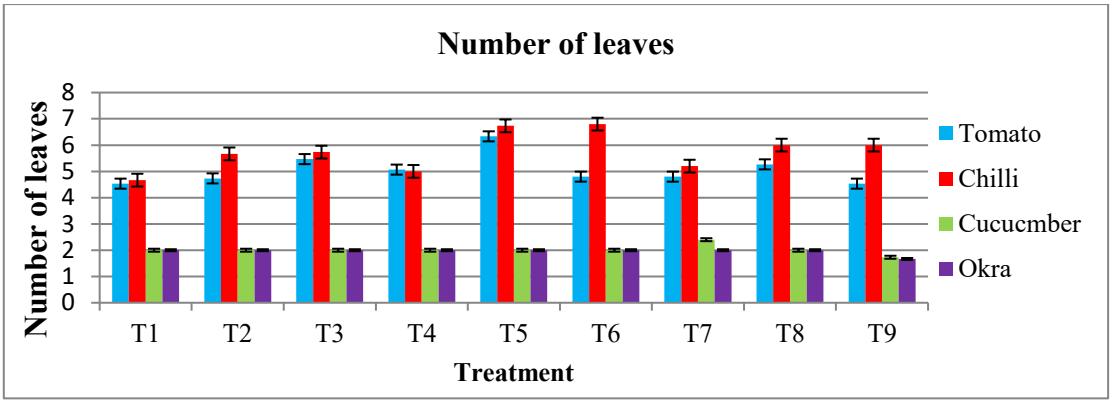


Figure 5.3.4. Effect of biofertilizers on number of leaves

In tomato and okra leaf area was highest in AMF and PGPR Mix-1 containing medium. Chilli and cucumber exhibited maximum leaf area under T_3 where the media was inoculated with *Trichoderma* (Fig.5.3.5). Similar results were reported by Desai *et al*. (2020).

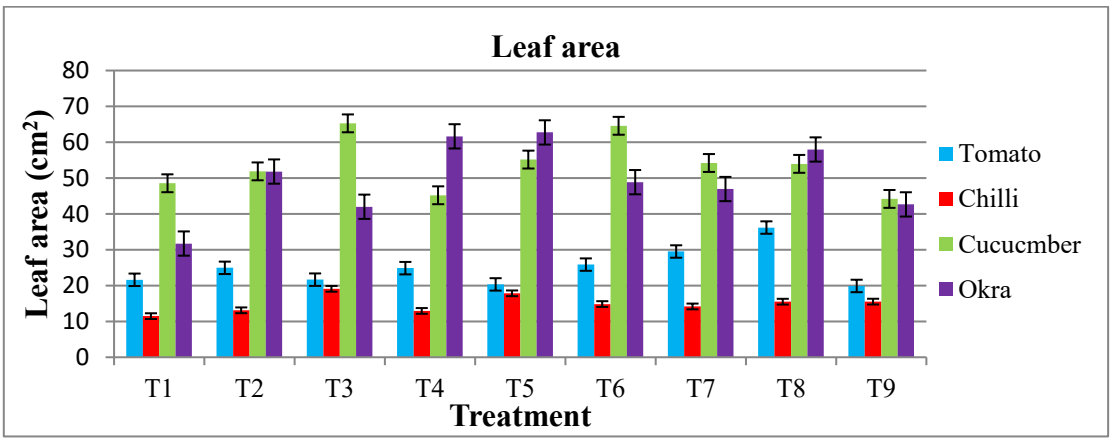


Figure 5.3.5. Effect of biofertilizers on leaf area

There was no much variation in collar diameter between treatments in all the crops studied (Fig.5.3.6). Comparatively higher collar diameter was noted in medium comprising AMF and PGPR Mix-1. Similar trend in collar diameter was also reported by Desai *et al.* (2020) in tomato and capsicum seeds sown in AMF and PGPR inoculated media. Higher stem girth in this study could be attributed to the synthesis of plant growth promoting chemicals, which are known to promote cell division as reported by Jayashree and Jagadeesh (2017). Seedlings with a larger girth have been shown to be more resistant to transplant shock.

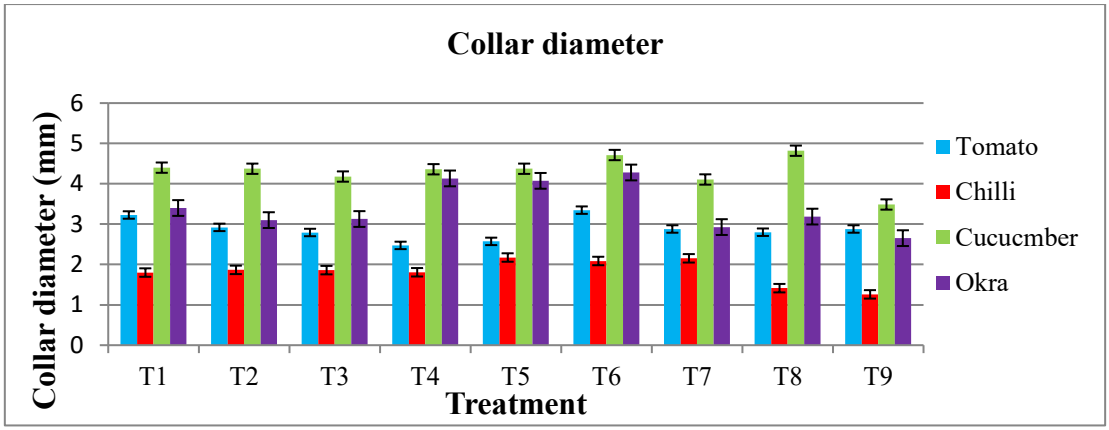


Figure 5.3.6. Effect of biofertilizers on collar diameter

Tomato, chilli, cucumber and okra exhibited maximum vigour index-1 under treatment having AMF and PGPR Mix-1 along with either *Trichoderma* or *Pseudomonas* (Fig.5.3.7). Similar results were reported by Vivas *et al*. (2003). In tomato and okra vigour index-2 was found to be higher under treatment having *Trichoderma* spp. In cucumber maximum VI II was recorded in T_1 (PGPR Mix-1). In chilli T_7 (AMF, *Trichoderma* and PGPR Mix-1) had maximum VI II (Fig.5.3.8). Behera *et al*. (2019) reported that inoculation of AMF and PGPR in combination in pro-trays is beneficial for raising vigorously growing tomato seedlings.

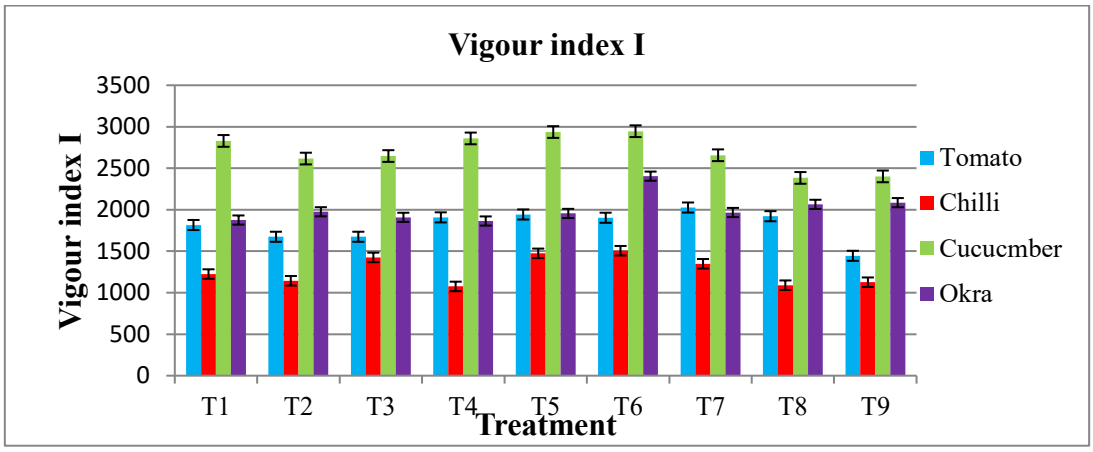


Figure 5.3.7. Effect of biofertilizers on Vigour index I

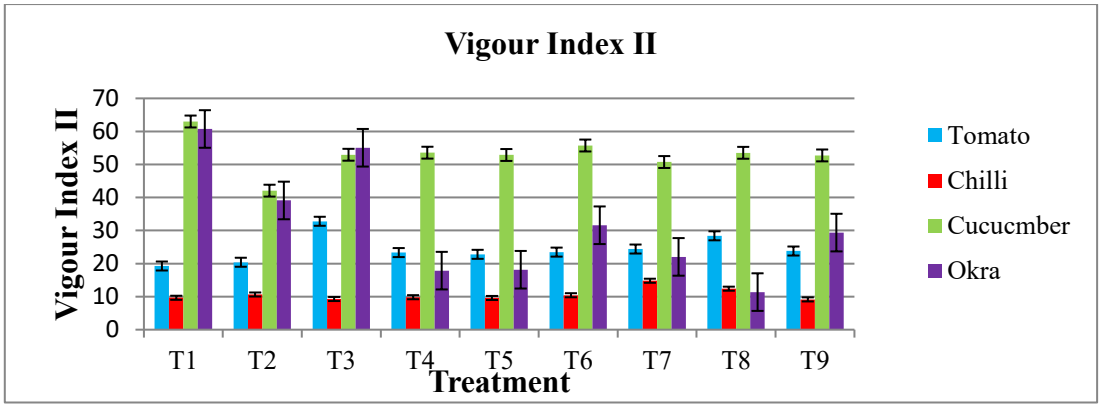


Figure 5.3.8. Effect of biofertilizers on Vigour Index II

Chlorophyll content was found maximum for AMF inoculated media in tomato, chilli and cucumber. While in okra it was higher for the control (Fig.5.3.9). The tomato, chilli, cucumber and okra seedlings inoculated with biofertilizers showed significantly improved growth parameters as compared to uninoculated seedlings. Okra and cucumber have higher initial growth parameters, which could be attributable to stored materials in the cotyledons.

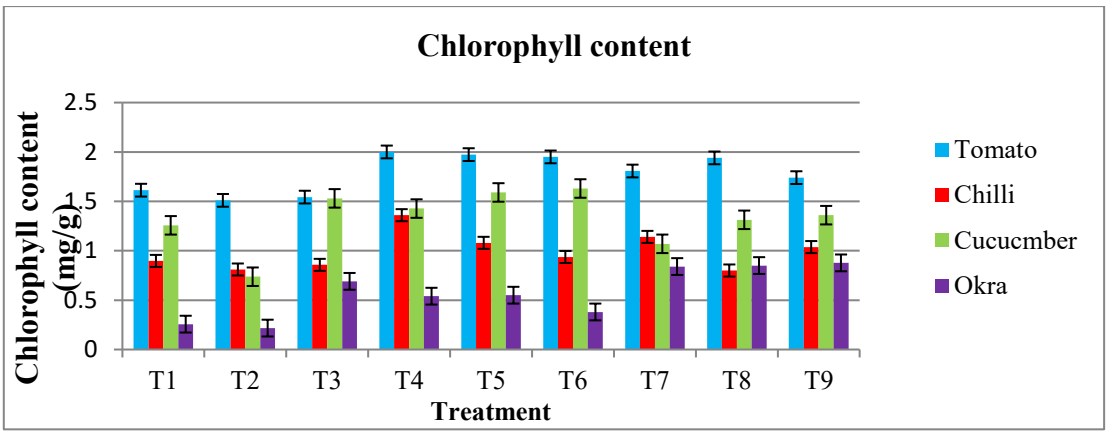


Figure 5.3.9. Effect of biofertilizers on chlorophyll content

T_1: 2% PGPR Mix-1, T_2: 2% *Pseudomonas flourescens*, T_3: 2% *Trichoderma asperellum*, T_4: AMF, T_5: 2% PGPR Mix-1 + AMF, T_6: 2% PGPR Mix-1 + 2% *Pseudomonas* + AMF, T_7: 2% PGPR Mix-1 + 2% *Trichoderma* + AMF, T_8: 2% KNO3, T_9: Control

5.3.2. Ranking to select the effective biofertilizer for pro-tray seedling production

Ranking based on the index was used to determine the effective biofertilizers among all the treatment combinations. Number of leaves, leaf area, collar diameter, vigour index I & II, and total chlorophyll content were all subjected to principal

component analysis. An index was calculated using loadings of principal components with Eigen value greater than one. In all of the crops studied, a combination of AMF, PGPR Mix-1 and *pseudomonas* consistently provided better growth parameters, hence ranked higher. In tomato combination of AMF, *Trichoderma* and PGPR Mix-1 was also promising. As a result, co-inoculation was found to be more effective than inoculation with either AMF or PGPR alone. These results were in consistence with findings of Vivas *et al*. (2003). It is known that when two or three organisms are infected together, they perform better than single inoculations, probably due to their synergistic interaction as reported by Jayashree and Jagadeesh (2017).

Higher growth parameters like plant height, root length, leaf area, collar diameter, Vigour index I and VI II are comparatively higher in the treatment containing PGPR and AMF along with either *Pseudomonas* or *Trichoderma*. Increased growth characters in the media inoculated with a combination of AMF and PGPR may be due to improved nutrient absorption. This might be due to the activity of PGPR, which alters the morphology of roots through the production of phytohormones, resulting in an increase in root surface area. Desai *et al*. (2020) proved that dual inoculation of AMF and PGPR promotes nutrient uptake and plant growth when compared to inoculation with any of them alone. From these results it can be inferred that co-inoculation of biofertilizers in the pro-tray media can be recommended to raise healthy, actively growing seedlings that will perform better when transplanted in the field with reduced fertilizer application.

When biofertilizers are inoculated in the pro-tray medium, it serves as an inoculum in the root zone and when transplanted it will proliferate in the field conditions. So, the impact of treating seedlings with biofertilizer will be realized only if the yield and growth parameters are recorded in the field conditions. Hence, inoculation with biofertilizers can be recommended during pro-tray seedling production of vegetables to ensure the availability of nutrients and thereby promoting organic vegetable production.

5.4. Pest and diseases

There was no disease and pest incidence in the first two trials which was conducted during the period of March to May 2021. Incidence of *Alternaria* leaf spot was observed in tomato in the third experiment which was conducted during the

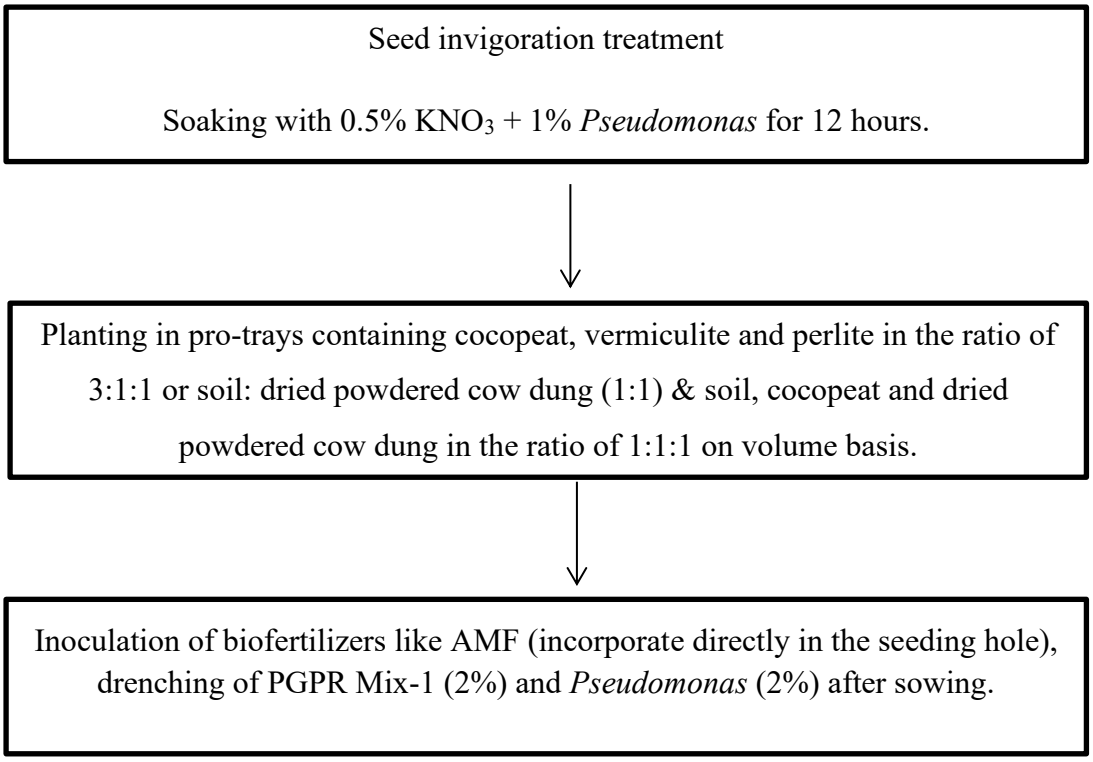
period of July to August 2021. The reason for incidence of leaf spot may be attributed to the higher relative humidity during the trial. Results showed that treatment combinations in which *Pseudomonas* was included; incidence of *Alternaria* leaf spot was not observed. Hence, it can be inferred that treatment with *Pseudomonas* will reduce the incidence of disease in tomato seedling production as reported by Prasad *et al.* (2016).

Future prospects of the study

Apart from this study, there is a need to optimize the fertilizer dose for either increasing or reducing the growth rate of seedlings in order to adjust production as per demand. The neem cake used in the present study was adulterated, so it exhibited a very high EC value. So, there was no germination in the media amended with neem cake. The effect of neem cake which is having low EC as a growing media component can also be studied. In the case of pre-sowing seed invigoration, the duration of soaking seeds in the respective solution can be standardised so as to check if treatment for a lesser duration is effective. There is also a need to extend these results to all vegetable varieties released by Kerala Agricultural University especially those which show irregularity in germination.

Based on the insights obtained from the above three trials, standard operational protocol for seedling production of tomato, chilli, cucumber and okra is generated for use by farmers.

5.5. SOP for seedling production of tomato, chilli, cucumber and okra



Summary

6. SUMMARY

The most critical requirement for every vegetable crop to reach its full output potential is healthy seedlings. As a result, large-scale seedling production has evolved into a profession and a commercial activity. In the past, farmers used to produce seedlings in nursery beds at a reasonable cost. However, due to some drawbacks in traditional nurseries, such as poor germination, higher pest and disease incidence, poor field establishment, and so on, many progressive farmers and agriculture entrepreneurs have shifted their focus to commercial seedling production using seedling trays or pro-trays. In this background, the current study, titled "Standardisation of operational procedures for pro-tray seedling production of vegetables," was conducted with the objective of standardising the best growing media, pre-sowing seed invigoration, and evaluating the effect of biofertilizers on pro-tray seedling production of vegetables.

The present study was carried out at the Department of Vegetable Science, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur during the period of 2020 - 2021. The study was carried out as three experiments. The first experiment was standardisation of growing media for pro-tray seedling production. The experimental material consisted of seventeen different growing media. The seeds of tomato var. Anagha, chilli var. Anugraha, cucumber var. Heera and okra var. Salkeerthi were sown in these media in a Completely Randomized Design with three replications. The seedlings were evaluated for different growth parameters at the stage of commercial sale (30 DAS in tomato and chilli and 15 DAS in okra and cucumber). Significant effect of treatments on growth parameters could be observed in all the four crops studied.

In tomato, chilli, cucumber and okra, T_{17} comprising cocopeat, vermiculite and perlite in the ratio of 3:1:1 (on volume basis) recorded higher germination percentage. There was no germination in the media comprising neem cake *viz*., T_9, T_{12}, T_{14}, and T_{16} due to its high EC value caused by adulteration. In tomato, chilli, cucumber and okra soil-less media in which highest germination was recorded is T_{17}. While media containing soil in which highest germination was recorded include T_5,

T_6, and T_{10}. In chilli among soil containing media T_{15} and T_{11} recorded higher germination percentage compared to other media combinations.

Soil-less medium T_{17} recorded the maximum plant height in all the four crops studied. In tomato, cucumber and okra, T_5, T_6 and T_{10} were the soil containing media which exhibited relatively higher plant height. While in chilli, T_6 and T_{10} recorded higher plant height. Characters *viz*., root length, number of leaves, leaf area, vigour index I and vigour index II were relatively higher in T_{17} (cocopeat: vermiculite: perlite - 3:1:1) and T_{13} (cocopeat: vermiculite: perlite - 1:1:1).

In order to select best media ranking was done based on an index derived through principal component analysis. The results showed that T_{17} having cocopeat: vermiculite: perlite in the ratio of 3:1:1 by volume ranked first in all the four crops studied. It was followed by T_{13} (cocopeat vermiculite, perlite - 1:1:1) & T_{10} (soil, cocopeat, cow dung - 1:1:1) in cucumber and okra, T_6 (soil: cow dung - 1:1) & T_{10} in tomato, and T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1) & T_{13} in chilli. In terms of benefit cost ratio also T_{17} exhibited maximum BC ratio among soil-less media. So, T_{17} comprising cocopeat, vermiculite and perlite (3:1:1) can be recommended as the ideal growing media for producing vegetable seedlings and grafts on a commercial scale. This media ranked best in terms of germination and growth parameters in all the crops studied. Farmers do not have easy access to vermiculite and perlite, and they are expensive. In this context soil, cocopeat and cow dung (1:1:1) or soil and cow dung in equal proportion are found to be an alternative media comprising locally available inputs and is affordable by the farmers. In chilli T_{15} (soil: cocopeat: vermiculite: perlite - 1:1:1:1) and T_{11} (soil: cocopeat: perlite - 1:1:1) were also found promising.

Despite using the best media in the first trial, crops like chilli and okra did not germinate completely. In chilli germination was up to 92% even in the best media. The second experiment was done with the goal of solving the low germination problem and increasing the growth parameters. The second trial was standardisation of pre-sowing seed invigoration and biopriming treatments for pro-tray seedling production. The study comprised of nine treatments including direct seeding, water

soaking, different concentrations of KNO_3, *Pseudomonas* individually and in combination. A combination of KNO_3 and *Pseudomonas* was included in the study to assess its compatibility.

The germination percentage could be significantly improved to almost 100% compared to direct seeding and water soaking, especially in chili and okra. Higher germination percentage was noted in 0.5% KNO_3, 1% KNO_3 and 1% *Pseudomonas* treatments individually and in combinations. Plant height of tomato, chilli, cucumber and okra was higher under treatment comprising 0.5%, 1% KNO_3 and their combination with 1% *Pseudomonas*. Minimum plant height was recorded under control, water soaking, and treatment comprising 2% KNO_3.

In tomato and chilli, More number of leaves were noted in T_3 (0.5% KNO_3) and T_7 (0.5% KNO_3 and 1% *Pseudomonas*). Leaf area was higher in the treatment comprising 0.5% KNO_3, 1% KNO_3 and combination of these with 1% *Pseudomonas*.

Ranking revealed that combination of 0.5% KNO_3 and 1% *Pseudomonas* (T_7) was the most efficient seed invigoration treatment in tomato and okra. In cucumber and chilli, 1% KNO_3 alone or in combination with *Pseudomonas* was found to be the best treatment for pre-sowing seed invigoration. As a result 0.5% and 1% KNO_3 alone, as well as in combination with 1% *Pseudomonas*, performed superior in all the four crops evaluated. Apart from giving good vigour, a combination of KNO_3 and *Pseudomonas* imparts resistance to soil-borne diseases and in turn produces healthy, vigorous transplants.

Third experiment comprised of nine treatments in which different biofertilizers *viz*., PGPR Mix-1, *Pseudomonas fluorescens, Trichoderma asperellum* and arbuscular mycorrhizal fungi were inoculated in the media individually and in combination. In tomato, chilli, cucumber and okra highest germination was recorded in T_6 comprising AMF, *Pseudomonas* and PGPR Mix-1 and T_7 having AMF, *Trichoderma* and PGPR Mix-1.

Tomato, chilli, okra and cucumber recorded relatively higher plant height and root length in treatment combinations containing AMF and PGPR along with either

Trichoderma or *Pseudomonas*. In tomato and okra leaf area was higher in media containing AMF and PGPR Mix-1. Cucumber and chilli exhibited maximum leaf area in the treatment comprising *Trichoderma* alone (T_3).

Vigour index I was relatively higher in the treatment having AMF and PGPR Mix-1 along with either *Trichoderma or Pseudomonas*. In tomato and okra vigour index II was found to be higher under treatment comprising *Trichoderma* alone. In cucumber higher VI II was noted in medium inoculated with PGPR Mix-1 (T_1). In chilli, T_7 (AMF, *Trichoderma* and PGPR Mix-1) had maximum VI II. Chlorophyll content was higher in AMF inoculated media in tomato, chilli and cucumber. While in okra total chlorophyll was higher under control. The tomato, chilli, cucumber and okra seedlings inoculated with biofertilizers showed significantly improved growth parameters as compared to uninoculated seedlings.

In all the crops studied, a combination of AMF, PGPR Mix-1 and *Pseudomonas* consistently provided good growth parameters and hence was ranked higher. In tomato, a combination of AMF, *Trichoderma* and PGPR Mix-1 was also promising. Higher growth parameters like plant height, root length, leaf area, collar girth, vigour index I and vigour index II were comparatively higher in the treatment containing PGPR and AMF along with either *Pseudomonas* or *Trichoderma*.

When biofertilizers are inoculated in the pro-tray media, they act as inoculum in the root zone and will multiply in the field conditions when transplanted. As a result, the impact of applying biofertilizers to seedlings will only be realised if yield and growth parameters are recorded in the field conditions. As a result, biofertilizer inoculation during pro-tray seedling production of vegetables may be recommended to assure nutrient availability and thereby to promote organic vegetable production.

Based on the findings of the above three studies, a standard operational protocol for seedling production of tomato, chilli, cucumber and okra is generated for use by farmers. The best media obtained include cocopeat: vermiculite: perlite (3:1:1), soil: dried cow dung (1:1) and soil: cocopeat: dried cow dung (1:1:1). A combination of 0.5% KNO_3 and 1% *Pseudomonas* was the best seed invigoration treatment.

Among different biofertilizers evaluated the combination of AMF, PGPR Mix-1 and *Pseudomonas* was found to be the best.

References

REFERENCES

Abnavi, M. S. and Ghobadi, M. 2012. The effects of source of priming and post-priming storage duration on seed germination and seedling growth characteristics in wheat (*Triticum aestivem* L.). *J. Agric. Sci.* 4(9): 256.

Agarwal, P., Saha, S. and Hariprasad, P. 2021. Agro-industrial-residues as potting media: physicochemical and biological characters and their influence on plant growth. *Biomass convers. Biorefin.* 1: 1-24.

Ala, V., Usha, K. E. and Hiremath, R. 2021. Conceptual efficacy study on effect of seed treatment with organic liquid formulations on germination and seedling vigour in oriental pickling melon in Trissur, Kerala. *J. Pharm. Innov*. 10(5): 222-225.

Alam, M. K., Rahim, M. A., Rahman, M. H. and Jahiruddin, M. 2014. Effects of organic fertilizers on the seed germination and seedling vigour of tomato. *Bldg. Org. Br.* 1: 49-52.

Ali, M., Javed, T., Mauro, R. P., Shabbir, R., Afzal, I. and Yousef, A. F. 2020. Effect of seed priming with potassium nitrate on the performance of tomato. *Agric.* 10(11): 498-500.

Al-Karaki, G. N. 2017. Effects of mycorrhizal fungi inoculation on green pepper yield and mineral uptake under irrigation with saline water. *Adv. Plants Agric. Res*. 6(5): 231-233.

Ananthi, M., Selvaraju, D and Sundaralingam, K. 2019. Performance of bioprimed chilli seed under moisture stress condition. *Curr. J. Appl. Sci. Tech.* 34(3): 1-7.

Angadi, V., Rai, P. K. and Bara, B. M. 2017. Effect of organic manures and biofertilizers on plant growth, seed yield and seedling characteristics in tomato (*Lycopersicon esculentum* Mill.). *J. Pharmacogn. Phytochem.* 6(3): 807-810.

Anwar, A., Xianchang, Y. U. and Yansu, L. I. 2020. Seed priming as a promising technique to improve growth, chlorophyll, photosynthesis and nutrient contents in cucumber seedlings. *Not. Bot. Horti. Agrobot. Cluj. Napoca*. 48(1): 116-127.

Arenas, M., Vavrina, C. S., Cornell, J. A., Hanlon, E. A. and Hochmuth, G. J. 2002. Coir as an alternative to peat in media for tomato transplant production. *Hort. Sci.* 37(2): 309-312.

Ashoka, N., Ravi, Y., Lingamurthy, K. R., Kuamr, B. R. and Anupama, G. 2019. A study on seedling demand and economic analysis of chilli nurseries in Karnataka. *J. Crop Weed*. 15(2): 120-125.

Atif, M. J., Jellani, G., Malik, M. H. A., Saleem, N., Ullah, H., Khan, M. Z and Ikram, S. 2016. Different growing media effect the germination and growth of tomato seedlings. *Sci. Tech. Dev*. 35(3): 123-127.

Atiyeh, R. M., Subler, S., Edwards, C. A. and Metzger, J. 1999. Earthworms in agro-ecosystems and land use - Growth of tomato plants in horticultural potting media amended with vermicompost. *Pedobiologia*. 43(6): 724-728.

Baki, A. A. and Anderson, J. D. 1973. Vigor determination in soybean seed by multiple criteria. *Crop Sci.* 13(6): 630-633.

Balliu, A., Sallaku, G. and Nasto, T. 2017. Nursery management practices influence the quality of vegetable seedlings. *Italus Hort.* 24(3): 39-52.

Behera, A. D., Nachu, N. S., Ashwin, R. and Bagyaraj, D. J. 2019. Influence of AM fungus *G. mosseae* and plant growth promoting rhizobacteria (PGPR) on growth of tomato seedlings raised in pro trays. *J. Soil Biol. Ecol*. 39: 53-63.

Bharathi, C. S., Mohan, B. and Alagudurai, S. 2014. Raising of hybrid vegetable seedlings under protrays. *J. Krishi Vigyan*, 2(2): 64-68.

Bi, Y., Qiu, L., Zhakypbek, Y., Jiang, B., Cai, Y. and Sun, H. 2018. Combination of plastic film mulching and AMF inoculation promotes maize growth, yield and

water use efficiency in the semiarid region of Northwest China. *Agric. Water Manag.* 201: 278-286.

Bidabadi, S. S. and Mehralian, M. 2020. Arbuscular mycorrhizal fungi inoculation to enhance chilling stress tolerance of watermelon. *Gesunde Pflanzen*. 72(2): 171-179.

Calvo, P., Nelson, L. and Kloepper, J. W. 2014. Agricultural uses of plant biostimulants. *Plant and soil*. 383(1): 3-41.

Chatterjee, R and Mal, D. 2016. Influence of nursery technique and growing media on seedling growth and field performance of cabbage (*Brassica oleraceae* var. *capitata* L.). *J. Environ. Agric. Sci*. 9: 15-20.

Chrysargyris, A., Saridakis, C. and Tzortzakis, N. 2013. Use of municipal solid waste compost as growing medium component for melon seedlings production. *J. Plant Biol. Soil Health*. 2(1): 1-5.

Constantino, M., Gomez-Alvarez, R., Álvarez-Solis, J. D., Geissen, V., Huerta, E. and Barba, E. 2008. Effect of inoculation with rhizobacteria and arbuscular mycorrhizal fungi on growth and yield of *Capsicum chinense* Jacquin. *J. Agric. Rural Dev. Trop. Subtrop.* 109(2): 169-180.

Desai, S., Bagyaraj, D. J. and Ashwin, R. 2020. Inoculation with microbial consortium promotes growth of tomato and capsicum seedlings raised in pro trays. *Proc. Natl. Acad. Sci.* 90(1): 21-28.

Farooq, M. S., Basra, M. A., Saleem, S. M. A., Nafees, B. A. and Chishti, S.A. 2005. Enhancement of tomato seed germination and seedling vigor by osmopriming. *Pak. J. Agri. Sci*. 42: 3-4.

Gama, P. B., Wani, L. B., Marcelo-dRagga, P. W. and Misaka, B. C. 2015. Effect of soil media on growth of tomato seedlings (*Solanum lycopersicum* L) under nursery (greenhouse) conditions. *Int. J. Agric. Res.* 3(10): 432-439.

Gholamnejad, S., Arouiee, H. and Nemati, S. H. 2012. Effect of different ratios of coco peat and vermicompost as a cultural media on seed emergence and some qualitative and quantitative characteristics of sweet pepper (*Capsicum annuum* L.) Transplants. *J. Hortic. Sci.*, *25*(4): 369-375.

Golezani, G. K. and Esmaeilpour, B. 2008. The effect of salt priming on the performance of differentially matured cucumber (*Cucumis sativus*) seeds. *Not. Bot. Horti. Agrobot. Cluj. Napoca*. 36(2): 67-70.

Golubkina, N., Krivenkov, L., Sekara, A., Vasileva, V., Tallarita, A. and Caruso, G. 2020. Prospects of arbuscular mycorrhizal fungi utilization in production of *Allium* plants. *Plants*. 9(2): 279.

Gopinath, P. P, Parsad, R, Joseph, B, Adarsh, V. S. 2020. GRAPES: General Rshiny Based Analysis Platform Empowered by Statistics. Available: https://www.kaugrapes.com/home. version 1.0.0

Goswami, D., Thakker, J. N. and Dhandhukia, P. C. 2016. Portraying mechanics of plant growth promoting rhizobacteria (PGPR): A review. *Cogent Food Agric. 2*(1): 1-19.

Gruda, N. and Schnitzler, W. H. 2004. Suitability of wood fiber substrate for production of vegetable transplants: Physical properties of wood fiber substrates. *Sci. Hortic. 100*(1-4): 309-322.

Hanegave, A. S., Ravi, H., Nadaf, H. L., Biradarpatil, N. K. and Uppar, D. S. 2011. Effect of seed priming on seed quality of maize (*Zea mays* L.). *Karnataka J. Agric. Sci. 24*(2): 237-238.

Hashemimajd, K., Kalbasi, M., Golchin, A., Knicker, H., Shariatmadari, H. and Rezaei-Nejad, Y. 2006. Use of vermicomposts produced from various solid wastes as potting media. *Eur. J. Hortic. Sci. 71*(1): 21-29.

Hosseini, M. H., Alavipoor, E. and Delshad, M. 2017. Evaluation of different growing media for tomato seedlings to optimize production and water use. *Iran Agric. Res.* 36(2): 61-70.

Ievinsh, G. 2011. Vermicompost treatment differentially affects seed germination, seedling growth and physiological status of vegetable crop species. *Plant grow. reg.* 65(1): 169-181.

Ilahi, W. F. F. and Ahmad, D. 2017. A study on the physical and hydraulic characteristics of cocopeat perlite mixture as a growing media in containerized plant production. *Sains Malays.* 46(6): 975-980.

Islam, M. T. and Faruq, A. N. 2008. Effect of selected soil amendments on seed germination, seedling growth and control of damping-off of chilli seedlings. *J. Sher-e-Bangla Agric. Univ. 2*(2): 12-16.

Jackson, M. L. 1958. Soil Chemical Analysis. Prentice Hall of India Private Ltd., New Delhi, 498 p.

Jayashree, C. and Jagadeesh, K. S. 2017. Testing the effect of the microbial consortium on growth of vegetable seedlings in a farmer's nursery. *Int. J. Curr. Microbiol. Appl. Sci*. 6(2): 1636-1639.

Kandemir, D., Oze, H., Ozkaraman, F., Uzun, S. 2013. The effect of different seed sowing media on the quality of cucumber seedlings. *Eur. J. Plant Sci. Biotech*. 7(1): 66-69.

Karthika, C. and Vanangamudi, K. 2013. Biopriming of maize hybrid COH (M) 5 seed with liquid biofertilizers for enhanced germination and vigour. *Afr. J. Agric. Res. 8*(25): 3310-3317.

Kerala Agricultural University 2016. *Package of Practices Recommendations: Crops* 15th edition. Kerala Agricultural University, Thrissur. 392 p.

Koening and Johnson, 1942. Colorimetric determination of phosphorus in biological material. *Ind. Eng. Chem. Anal*. 14(2): 155-156.

Kulsumbi, A. K., Sangeeta, I. M., Shakuntala, S. N., Vasudevan and Kisan, B. 2020. Study on the effect of seed priming on physiological and biochemical changes

in seed quality of spinach (*Spinacia oleraceae* L.). *Res. J. Pharmacogn. Phytochem*. 12(2): 65-70.

Lara, T. S., Lira, J. M. S., Rodrigues, A. C., Rakocevic, M and Alvarenga, A. A. 2014. Potassium nitrate priming affects the activity of nitrate reductase and antioxidant enzymes in tomato germination. *J. Agric. Sci*. 6(2): 72-80.

Lin, L. J., Luther, G. C. and Hanson, P. 2015. Raising healthy tomato seedlings. *AVRDC–World Veg. Cent. Publ.* 15(795): 1-20.

Mariyappillai, A. and Arumugam, G. 2021. Physico-chemical and hydrological properties of soilless substrates. *J. Environ. Biol.* 42(3): 700-704.

Mathowa, T., Tshegofatso, N., Mojeremane, W., Matsuane, C., Legwaila, G. M. and Oagile, O. 2016. Effect of commercial growing media on emergence, growth and development of tomato seedlings. *Int. J. Plant Soil Sci.* 9(1): 83-91.

Mirabi, E. and Hasanabadi, M. 2012. Effect of seed priming on some characteristic of seedling and seed vigor of tomato (*Lycopersicon esculentum*). *J. Adv. Lab. Res. Biol*. 3(3): 237-240.

Moeinzadeh, A., Sharif-Zadeh, F., Ahmadzadeh, M. and Tajabadi, F. 2010. Biopriming of sunflower (*'Helianthus annuus'* L.) seed with *'Pseudomonas fluorescens'* for improvement of seed invigoration and seedling growth. *Aust. J. Crop Sci.* 4(7): 564-570.

Mohana K., Velavan C., Palanichamy N. V., Ganeshan K. 2021. Enonomics analysis and market potential of commercial vegetable seedling nurseries in Tamil Nadu. *Int. J. Agric. Sci.* 13(1): 10612-10625.

Mota, L. C., Meeteren, U. V and Blok, C. 2007. Comparison of the physical properties of vermicompost from paper mill sludge and green compost as substitutes for peat-based potting media. In: *International Symposium on Growing Media;* 02 September, 2007*,* pp. 227-234.

Musa, M., Singh, A. and Aliyu, L. A. 2014. Influence of priming duration on the performance of Amaranths (*Amaranthus cruentus* L.) in Sokoto semiarid zone of Nigeria. *Int. J. Agron.* 2014: 1-15.

Mushtaq, S., Hafiz, I. A., Hasan, S. Z. U., Arif, M., Shehzad, M. A., Rafique, R., Rasheed, M., Ali, M. and Iqbal, M. S. 2012. Evaluation of seed priming on germination of *Gladiolus alatus*. *Afr. J. Biotech.* 11(52): 11520-11523.

Mwangi, M. W., Monda, E. O., Okoth, S. A. and Jefwa, J. M. 2011. Inoculation of tomato seedlings with *Trichoderma harzianum* and arbuscular mycorrhizal fungi and their effect on growth and control of wilt in tomato seedlings. *Braz. J. Microbiol.* 42: 508-513.

Navitha, D., Keerthanapriya, S., Venudevan, B., Geetha, R. and Arumugam Pillai, M. 2019. Optimizing duration of hydro priming for seed quality enhancement in basil (*Ocimum basilicum* L.). *J. Pharmacogn. Phytochem.* 8(6): 1149-1151.

Nawaz, A., Amjad, M., Khan, S. M., Afzal, I., Ahmed, T., Iqbal, Q. and Iqbal, J. 2013. Tomato seed invigoration with cytokinins. *J. Anim. Plant Sci.* 23(1): 121-128.

Newman, S. E., Brown, W. M. and Ozbay, N. 2002, August. The effect of the *Trichoderma harzianum* strains on the growth of tomato seedlings. In: *XXVI International Horticultural Congress: Managing Soil-Borne Pathogens: A Sound Rhizosphere to Improve Productivity;* 11 August 2002, pp. 131-135.

Noguera, P., Abad, M., Noguera, V., Puchades, R and Maquieira, A. 2000. Coconut coir waste, a new and viable ecologically friendly peat substitute. Acta Hortic. 517: 279-286.

Oseni, T. O., Shongwe, N. S. and Masarirambi, M. T. 2010. Effect of arbuscular mycorrhiza (AM) inoculation on the performance of tomato nursery seedlings in vermiculite. *Int. J. Agric. Biol.* 12(5): 789-792.

Ozbay, N. and Newman, S. E. 2004. Biological control with *Trichoderma* spp. with emphasis on T. *harzianum*. *Pak. J. Bio.l Sci.* 7(4): 478-484.

Pandiyaraj, P. 2017. Modern nursery raising systems in vegetables. *Int. J. Agric. Sci.* 9(52): 4882-4892.

Paramanandham, J., Ross, P. R., Vaidehi, J. and Abbiramy, K. S. 2013. Influence of sequential washing on the pH and electrical conductivity of graded coir pith. *Int. J. Pure Appl. Zool.* 1(3): 231-34.

Patil, K. R., Adivappar, N., Chinnappa, B. and Manjunatha, G. R. 2017. Economic analysis of commercial tomato nurseries. *J. Crop Weed*. 13(1): 137-141.

Paul, L. C. and Metzger, J. D. 2005. Impact of vermicompost on vegetable transplant quality. *Hort. Sci.* 40(7): 2020-2023.

Paulitz, T. C., Anas, O. and Fernando, D. G. 1992. Biological control of *Pythium* damping-off by seed-treatment with *Pseudomonas putida*: Relationship with ethanol production by pea and soybean seeds. *Biocontrol Sci. Technol.* 2(3): 193-201.

Piper, C. S. 1942. *Soil and Plant analysis*. Hans Publishers, Mumbai, India, 450p.

Piri, M., Mahdieh, M. B., Olfati, J. A. and Peyvast, G. 2009. Germination and seedling development of cucumber are enhanced by priming at low temperature. *Int. J. Veg. Sci.* 15(3): 285-292.

Prasad, S. R., Kamble, U. R., Sripathy, K. V., Bhaskar, K. U. and Singh, D. P. 2016. *Microbial inoculants in sustainable agricultural productivity*. Springer, New Delhi, pp. 211-228.

Rahimi, Z., Aboutalebi, A. and Hasanzadeh, H. 2013. Effect of various culture media on tomato transplant production. *Int. Res. J. Appl. Basic Sci.* 4(2): 326-328.

Rai, A. K and Behera, S. 2019. Response of seed biopriming on chilli (*Capsicum annum* L.). *J. Pharmacogn. Phytochem*. 8(1): 900-903.

Raj, C. M and Sundareswaran. 2016. Standardisation of concentration of bio-agents for enhanced seedling growth of tomato cv. PKM- 1. *Int. J. Agric. Sci. Res.* 6(6): 38-398.

Ramadani, S., Nasto, T., Sahiti, B. and Murati, G. 2012. Influence of different substrates on the height of the stalk, root length, number of leaves and leaf surface on pepper seedlings (*Capsicum annum*). In: *International Symposium for Agriculture and Food, XXXVII Faculty-Economy Meeting, IV Macedonian Symposium for Viticulture and Wine Production, VII Symposium for Vegetables and Flower Production, Skopje, Macedonia,* pp. 424-430.

Raviv, M. Y. Chen, and Y. Inbar. 1986. The use of peat and composts as growing media for container-grown plants. In: Chen, Y and Avnimelech, Y (eds.), *The role of organic matter in modern agriculture*, Springer, New Delhi, pp. 257-287.

Rekani, O. A., Ameen, H. A. and Ahmed, S. M. 2016. Effect of different potting mixes on germination and vegetative growth of sweet pepper plant (*Capsicum annum* L.) under greenhouse conditions. *Sci. J. Univ. Zakho*. 4(2): 187-193.

Sadasivam, S. and Manickam, A. 1996. Biochemical methods for agricultural science, Willey Publishers, pp. 10-11.

Sarl, Q. 2012. EPAGMA Project-final report-comparative life cycle assessment of horticultural growing media based on peat and other growing media constituents. *Parc. Scientifique. de l'EPFL Batiment D*.

Seymen, M., Erdinc, C., Kurtar, E. S., Kal, U., Sensoy, S. and Turkmen, O. 2021. *Microbiome Stimulants for Crops*. Woodhead Publishing, Sawston, pp. 193-237.

Shakuntala, N., Sai, N. N., Ashwin, R. and Bagyaraj, D. 2019. Influence of plant growth promoting rhizobacteria on growth of tomato (*Lycoperiscon esculentum* Mill.) raised in pro-trays. *J. Soil Biol. Ecol*. 39: 32-38

Singh, A., Dahiru, R., Musa, M. and Sani, H. B. 2014. Effect of Osmopriming duration on germination, emergence, and early growth of cowpea (*Vigna unguiculata* (L.) Walp.) in the Sudan Savanna of Nigeria. *Int. J. Agron.* 2014: 1-5.

Singh, B., Tomar, B. S. and Hasan, M. 2009. Plug-tray nursery raising technology for off-season cucurbits cultivation. In: *IV International Symposium on Cucurbits;* 21 September 2009, pp. 279-282.

Sivakumar, T., Ambika, S. and Balakrishnan, K. 2017. Biopriming of rice seed with Phosphobacteria for enhanced germination and vigour. *Int. J. Rice*. 54(3): 346-349.

Spehia, R. S., Singh, S. K., Devi, M., Chauhan, N., Singh, S., Sharma, D. and Sharma, J. C. 2019. Standardisation of growing media and its effects on nutrient uptake. *Ann. Agri. Bio. Res.* 24(1): 71-75.

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

Sun, Z., Song, J., Xin, X., Xie, X., Zhao, B. 2018. Arbuscular mycorrhizal fungal proteins 14-3-3- are involved in arbuscule formation and responses to abiotic stresses during AM symbiosis. *Front. Microbiol.* 5: 9–19.

Syaiful, S. A., Haring, F., Syawlia, R. R., Padjung, R., Mantja, K. and Farid, M. 2021. July. Improvement on the quality of chilli (*Capsicum annuum* L.) seedlings through seed immersion in Supergib solution. *IOP Conf. Ser.: Earth Environ. Sci*. 807(4): 042051.

Tiwari, T. N., Kamal, D., Singh, R. K and Prasad, S. R. 2014. Relative efficacy of seed priming with potassium nitrate and tap water in relation to germination, invigoration, growth, nitrate assimilation and yield of pigeon pea (*Cajanus cajan* L.). *Ann. Agric. Res*. 35(2): 164-170.

Truong, H. D., Wang, C. H. and Kien, T. T. 2017. Study on effects of different medium compositions on growth and seedling quality of two tomato varieties under greenhouse conditions. *Commun. Soil Sci. Plant Anal.* 48(14): 1701-1709.

Venkatasubramanian, A. and Umarani, R. 2007. Evaluation of seed priming methods to improve seed performance of tomato (*Lycoperison esculentum*), egg plant

(*Solanum melongena*) and chilli (*Capsicum annum*). *Seed Sci. technol.* 35(2): 487-493.

Vivas, A., Marulanda, A., Ruiz, J. M., Barea, J. M. and Azcon, R. 2003. Influence of a *Bacillus* sp. on physiological activities of two arbuscular mycorrhizal fungi and on plant responses to PEG-induced drought stress. *Mycorrhiza*. 13(5): 249-256.

Vivek, R and Duraisamy, V. M. 2017. Study of growth parameters and germination on tomato seedlings with different growing media. *Int. J. Agric. Sci. Res*. 7(3): 461-470.

Wu, M., Yan, Y., Wang, Y., Mao, Q., Fu, Y., Peng, X., Yang, Z., Ren, J., Liu, A., Chen, S. and Ahammed, G. J. 2021. Arbuscular mycorrhizal fungi for vegetable (VT) enhance resistance to *Rhizoctonia solani* in watermelon by alleviating oxidative stress. *Biol. Control*. 152: 104433.

Yadav, K. S. and Bajpay, A. 2019. Nursery pro-trays and its importance in horticulture. *Int. J. Floriculture Sci. Landscaping*. 1(2): 27-28.

Appendices

Appendix I

Abbreviations

%	Percentage
^{0}C	Degree Celsius
@	At the rate of
AMF	Arbuscular Mycorrhizal Fungi
cc	Cubic centimetre
cm	Centimetre
cm^2	Square centimetre
DAS	Days after sowing
EC	Electrical Conductivity
G	Gram
g/cm^3	Gram per cubic centimetre
g/l	Gram per litre
KAU	Kerala Agricultural University
Kg	Kilo gram
LSD	Least Significant Difference
M	Metre
Mm	Millimetre
m^2	Square metre
mg/g	Milligram per gram
MSL	Mean Sea Level
mS/cm	Millisiemens per centimetre
nm	Nanometre
PCA	Principal Component Analysis
PGPR	Plant Growth Promoting Rhizobacteria
pH	Potential of hydrogen
ppm	Parts per million
POP	Package of practices
rpm	Revolutions per minute
UV	Ultraviolet
VI I	Vigour index I
VI II	Vigour index II

Appendix II

Light intensity data during the study

Days	Experiment 1 & 2 (March - May)	Days	Experiment 3 (July - August)
	Light intensity (Lux)		Light intensity (Lux)
1 - 7	2350	1 - 7	648.66
8 - 14	1958	8 - 14	651.43
15 - 21	1605	15 - 21	535
21 - 27	1785	21 - 27	707.43
28 - 32	2000	28 - 32	663.29

Appendix III

Principal components of growth parameters - Effect of growing medium

Variables	Components			
	Tomato	**Chilli**	**Cucumber**	**Okra**
Number of leaves	0.423	0.413	0.415	0.405
leaf area	0.389	0.423	0.411	0.418
Collar girth	0.425	0.416	0.407	0.411
Vigour index I	0.426	0.422	0.412	0.413
Vigour Index II	0.421	0.380	0.414	0.401
Total chlorophyll	0.362	0.393	0.391	0.401
Eigen Value	4.99	5.27	5.37	5.35
Percentage of variance	83.19	87.83	89.51	89.15

Appendix IV

Principal components of growth parameters - Effect of seed treatment

Variables	Components						
	Tomato		Chilli		Cucumber		Okra
	PC 1	PC2	PC1	PC2	PC 1	PC 2	PC1
Leaf area	0.525	-0.238	0.515	-0.165	0.528	-0.254	0.506
Collar girth	0.513	0.238	0.513	0.171	0.572	-0.064	0.504
Vigour index I	0.593	0.068	0.498	0.064	0.476	-0.388	0.469
Vigour Index II	0.327	-0.264	0.257	0.771	-0.315	-0.563	0.232
Total chlorophyll	0.055	0.901	-0.397	0.588	0.261	0.681	0.465
Eigen Value	2.61	1.10	3.26	1.27	2.85	1.32	3.61
Percentage of variance	52.20	22.02	65.18	25.49	56.89	26.39	72.12

Appendix V

Principal components of growth parameters - Effect of biofertilizers

Variables	Components									
	Tomato			Chilli		Cucumber		Okra		
	PC 1	PC 2	PC 3	PC 1	PC 2	PC 1	PC 2	PC 1	PC 2	PC 3
Number of leaves	0.47	-0.42	0.18	0.515	-0.256	0.116	-0.622	-0.29	0.486	0.314
Leaf area	0.316	0.476	-0.543	0.501	-0.274	0.419	-0.32	-0.614	-0.151	0.211
Collar girth	-0.393	0.475	-0.135	0.347	0.626	0.406	-0.365	-0.492	0.368	-0.207
Vigour index I	0.473	0.429	0.14	0.584	0.252	0.495	-0.062	-0.163	-0.085	-0.888
Vigour Index II	0.236	-0.364	-0.742	-0.085	0.457	0.4	0.435	0.519	0.427	-0.053
Total chlorophyll	0.496	0.234	0.29	-0.127	0.443	0.491	0.43	0.009	-0.645	0.15
Eigen Value	2.37	1.52	1.07	2.38	1.54	2.21	1.60	2.22	1.95	1.09
Percentage of variance	39.55	25.32	17.80	39.62	25.67	36.83	26.65	36.95	32.57	18.31

STANDARDISATION OF OPERATIONAL PROCEDURES FOR PRO-TRAY SEEDLING PRODUCTION OF VEGETABLES

By

Arya S.

(2019-12-045)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

(VEGETABLE SCIENCE)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA, THRISSUR- 680656

KERALA, INDIA

2021

ABSTRACT

Healthy seedlings are the most important prerequisite for any vegetable crop to reach its full output potential. As a result, large-scale seedling production is becoming a profession and a commercial activity. Farmers used to generate seedlings at a reasonable cost in nursery beds in the past. However, due to some drawbacks like poor germination, higher pest and disease incidence, poor field establishment *etc.* in traditional nurseries, many progressive farmers and agriculture entrepreneurs have turned their attention to the commercial production of quality seedlings utilising seedling trays or pro-trays. In this background, the present study entitled 'Standardisation of operational procedures for pro-tray seedling production of vegetables' was undertaken with the objective of standardising best growing media, pre-sowing seed invigoration, and evaluating the effect of biofertilizer on pro-tray seedling production of vegetables.

The present study was carried out at the Department of Vegetable Science, College of Agriculture, Vellanikkara as three experiments during 2020-21. All three experiments were conducted in a Completely Randomized Design with three replications. In the first experiment seeds of tomato var. Anagha, chilli var. Anugraha, cucumber var. Heera, and okra var. Salkeerthi collected from the Department of Vegetable Science were sown in seventeen different media that were initially analysed for various physicochemical properties. The growth parameters of the seedlings raised in the poly house were assessed at the stage of commercial sale of each crop i.e., 15 days after sowing (DAS) in cucumber and okra and 30 DAS in chilli and tomato. The results showed that T_{13} (cocopeat: vermiculite: perlite - 1:1:1) and T_{17} recorded comparatively minimum bulk density, maximum water holding capacity and porosity which are desirable physical properties for good seedling growth. T_{17} (coir pith compost: vermiculite: perlite - 3:1:1) was found to be the best soil-less media for all four crops based on growth parameters and cost analysis. Among soil containing media T_6 having soil and dried powdered cow dung in equal proportion and T_{10} having soil, cocopeat and dried cow dung exhibited a higher benefit cost ratio and was found to be on par with T_{17} for most of the growth parameters. Farmers do not have easy access to vermiculite and perlite, and they are costly. In this context,

soil, cocopeat and dried powdered cow dung in equal proportion is found to be an alternate media comprising locally available inputs and affordable by the farmers.

The best media from the first experiment was chosen for further trials. The second trial comprised of nine different seed treatments including various concentrations of KNO_3 and *Pseudomonas*. Pre sowing seed invigoration with 0.5% KNO_3 in combination with 1% *Pseudomonas* was found to be highly effective in improving germination and growth parameters *viz*., germination percentage, plant height, root length, vigour index I & II and chlorophyll content of seedlings of tomato, chilli, cucumber and okra. This combination has the dual advantage of providing potassium and nitrogen to the seedlings and imparting resistance from diseases especially damping off. So, these treatments can be effectively utilized for producing healthy and vigorous vegetable seedlings.

The third experiment included nine treatments in which different biofertilizers *viz*., PGPR Mix-1, *Pseudomonas fluorescense, Trichoderma asperellum* and arbuscular mycorrhizal fungi were inoculated in the media individually and in combination. Evaluation of the effect of biofertilizers showed that higher growth parameters like plant height, root length, leaf area, collar girth, vigour index I and vigour index II are comparatively higher in the treatment containing PGPR, AMF and along with either *Pseudomonas* or *Trichoderma.*

In the above three experiments the best treatments were identified by ranking based on an index derived from principal component analysis. The characters *viz*., number of leaves, leaf area, collar girth, vigour index I & II and total chlorophyll content was used for performing PCA. The loadings of principal component having Eigen value more than one was taken as weightage. Using weightage, an index was derived and the treatments having higher index was ranked higher. The best media obtained include cocopeat: vermiculite: perlite (3:1:1) and soil: cocopeat: cow dung (1:1:1). A combination of 0.5% KNO_3 and 1% *Pseudomonas* was the best seed invigoration treatment. Among different biofertilizers evaluated the combination of AMF, PGPR Mix-1 and *Pseudomonas* was found to be the best. Based on the insights

of the above three trials, standard operational protocol for seedling production of tomato, chilli, cucumber and okra is generated for use by farmers.