DEVELOPMENT OF AN EFFECTIVE ORGANIC LIQUID MANURE FOR VEGETABLE CROPS

by

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DECLARATION

I hereby declare that this thesis entitled **“Development of an effective organic liquid manure for vegetable crops”** is a bonafide record of research 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.

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Asha V. Pillai

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LIST OF ABBREVIATIONS

%	-	Per cent
@	-	At the rate of
^0C	-	Degree selcious
AS	-	Azospirillum
AZ	-	Azotobacter
B:C	-	Benefit cost ratio
CD	-	Critical difference
cm	-	Centi meter
CRD	-	Completely randomised design
DAS	-	Days after soaking
DAS	-	Days after sowing
DAS	-	Days after storage
DMSO	-	Di methyl sulphoxide
dSm^{-1}	-	Deci siemen per metre
EC	-	Electrical conductivity
et al	-	And others
g $tissue^{-1}$	-	Gram per tissue
ha^{-1}	-	Per hactre
IAA	-	Indole acetic acid
IBA	-	Indole butyric acid
ie	-	That is
K	-	Potassium
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hactre
kg^{-1}	-	Per kilogram
m	-	Metre

mg 100 g^{-1}	-	Milligram per hundred gram
ml $plant^{-1}$	-	Milli litre per plant
N	-	Nitrogen
NS	-	Not significant
OD	-	Optical density
P	-	Phosphorous
PGPR	-	Plant growth promoting rhizobacteria
POP	-	Package of practices
RBD	-	Randomised block design
Rs	-	Rupees
t ha^{-1}	-	Tonne per hactre
v/v	-	Volume by volume
via	-	Through
viz	-	Namely

Introduction

1. INTRODUCTION

Organic manures play a key role in sustaining crop growth and productivity and the same is mainly applied through soil. Among the organic manures groundnut cake, vermicompost, neem cake, poultry manure and compost are considered to be viable choice in crop production owing to their high nutrient content. Their soil application either alone or in combination was found beneficial in enhancing the productivity of vegetables. The feasibility of developing an organic foliar formulation using these manures has not much intervened.

Use of foliar formulations is gaining importance in crop production owing to its quick response in plant growth. Foliar feeding of nutrients is a viable supplement to conventional soil application and it entails the application *via* spraying of nutrients to plant leaves and stems and their absorption through those sites. Foliar feeding has proved to be the fastest way of curing nutrient deficiencies and boosting plant performances at specific physiological stages. With plants competing with weeds, foliar spraying focuses the nutrient application on the target plants.

Foliar feeding has been used to supplement major and minor nutrients, plant hormones, stimulants, and other beneficial substances. Use of water soluble chemical fertilizers as foliar applicants is much investigated. Application of organic liquid extracts is a potential fertilization strategy in developed countries. It is effective for fast growing plants by providing an extra boost in growth especially during the peak growth phase (Ismail, 1997).

Besides nutrients, organic liquid manures contain several beneficial microbes which help to increase yield, impart resistance to diseases and insect pests, improve drought tolerance and enhance crop quality. Organic liquid fertilization is considered as a viable means for enhancing crop production both in conventional and modern production system.

The beneficial effects of micro organisms in promoting crop growth and yield have been reported by several workers. Among the rhizopshere microorganisms, plant growth promoting rhizobacteria (PGPR) has been considered important in sustainable agriculture due to their plant growth promotional ability (Mallesh, 2008). Moreover, PGPR could improve the nutrient content of plant and can also act as a bio pesticide.

The demand for high quality and safe food is increasing day by day. Among the food components, vegetables have a vital role in our diet. The unscientific use of chemicals in vegetable cultivation can lead to serious health hazards. Use of heavy dose of fertilisers for topdressing can affect the nutrient content and keeping quality of vegetables. The high cost of chemical fertilizers also limits their application in vegetable cultivation. As the cultivation of vegetables in homesteads and terrace is gaining popularity, there is a need for an organic phytotonic to substitute chemical fertilizers.

Though several commercial organic foliar formulations are available, their low nutrient content necessitates several sprayings which limit their use in field conditions. The feasibility of developing an organic formulation with high nutrient content is a felt need in vegetable cultivation especially in organic farming. With this background the present investigation was proposed to develop a safe organic phytotonic with about 2 % nitrogen, to evaluate its influence on growth and yield of vegetables , to assess the economics of using liquid manures and also to assess the shelf life of organic liquid manures.

Review of literature

2. REVIEW OF LITERATURE

Unscientific use of chemicals in agriculture leads to several health hazards and environmental problems. To protect our crops and the environment we have to follow sustainable and eco-friendly agriculture, which minimizes the use of harmful and energy intensive inputs and adopts use of organic manures and bio fertilizers. Among the several methods of eco friendly agriculture, liquid nutrition occupies an important position. Foliar nutrition with organic compounds in vegetables is especially important as they provide quality foods, which are very important for providing health security to people. The available literature relating to liquid nutrition is reviewed here under.

2.1 ORGANIC LIQUID MANURES

India has vast potential of organic resources and the extract prepared from these resources can be effectively utilized to sustain yield, improve physical, chemical and biological properties of soil and to maintain soil health.

Commonly used liquid manures are compost tea, vermiwash, biogas slurry and cow's urine along with the extracts of oil cakes like groundnut cake, poultry manure and neem cake. Several studies were conducted on the nutrient content of common organic liquid manures. Biogas slurry, the common by product of biogas has a nutrient content of 0.5-1.0 % N; 0.5-0.8 % P and 0.6-1.5 % K (Dhobighat *et al*., 1991). The nutrient content of cow's urine was reported to be 0.9-1.2% N, 0.2-0.5% P and 0.5-1% K (Bertram, 1999). Vermiwash contains 0.5% N, 0.39% P and 0.46% K (Jasmine, 1999). Compost tea is rich in soluble nutrients, but the tea collected during early stages of composting may contain pathogens (Diver, 2002). As per the reports of Ingham (2003), the nutrient content of compost tea is 0.5-0.75% N, 0.25-0.5% P and 0.5-0.75% K.

2.1.1 Organic liquid manures on soil properties

Tisdale and Oades (1982) reported that organic amendments like vermicompost and vermiwash promote humification, increased microbial activity and enzyme production, which, in turn bring about the aggregate stability of soil particles, resulting in better aeration. According to Haynes (1986), vermiwash has the property of binding mineral particles like calcium, magnesium and potassium in the form of colloids of humus and clay, facilitating stable aggregates of soil particles for desired porosity to sustain plant growth.

Scheuerell (2002) noticed the beneficial effect of compost tea as a source of nutrients for both plant and microbial uptake. The microbial functions of compost tea included mineralization of plant nutrients, fixation of nitrogen and competition with disease causing microbes and degradation of toxic pesticides.

Sayre (2003) opined that compost tea as one of the liquid manures that enhanced nutrient status of the soil.

Coconut leaf vermiwash application increased the crop production capacities of soil by enhancing the organic carbon content in the soil and also improved the physical, chemical and biological properties of the soil (Gopal *et al*., 2010).

Jeevamrut, a promising liquid manure could act as a good soil tonic which enhanced the soil physical, chemical and biological properties (Palekar, 2006). Vasanthkumar (2006) reported that soil application of jeevamrut at very low rate act as a tonic to soil besides improving soil health.

Ryan (2007) observed the beneficial effect of compost tea on improvement of soil structure and health . He also reported that the nutrient status of the soil was improved by the application of compost tea. Mohan and Srinivasan (2008) observed that organic promoters like panchagavya and EM solution could improve the nutrient status of the soil.

Sreenivasa *et al.,* (2009) reported that the nitrogen fixation and P solubilisation capacity of the soil could be increased by the inoculation of bacterial isolates from beejamrutha.

Thus, liquid manures, owing to their ability to facilitate slow release of nutrients, enhancement of soil microbial activity, improvement of soil aggregation, soil properties and soil health.

2.1.2 Organic liquid manures on growth of crops

Ismail (1995) reported that vermiwash was very effective for foliar application in nurseries, lawns and orchids for obtaining maximum growth. He also observed in 1997 that this collection of excretory and secretory products of earthworms, along with major and micronutrients enhanced the growth of plants.

Jasmine (1999) noticed that soil application of vermiwash @12.5 % concentration enhanced tomato growth. The positive effect of vermiwash on crop growth was also reported by Buckerfield *et al.,* (1999) who observed that weekly foliar applications of vermiwash increased radish growth.

Lalitha *et al.,* (2000) reported that soil application of organic inputs like vermicompost in combination with vermiwash resulted in better growth of plants by slow release of nutrients. They also noticed that vermiwash provided additional growth promoters like gibberellin, cytokinin and auxins along with major nutrients resulting in improved growth of plants.

Ramesh and Thirumurugan (2001) noticed that vermiwash used for seed pelleting and foliar nutrition resulted in better growth of soybean. The growth of paddy was also increased with the foliar application of vermiwash (Thangavel *et al*., 2003).

Vermiwash contains enzymes and secretions of earthworms which can stimulate the growth of crops. Apart from organic acids it also contains a rich source of soluble plant nutrients stimulating crop growth (Shivasubramanian and Ganeshkumar, 2004).

Shivasubramanian and Ganeshkumar (2004) opined that the growth of marigold was significantly increased by the application of vermiwash diluted with water (1:2 ratio).

Field experiments conducted at Kerala Agricultural University revealed that soil and foliar application of vermiwash @ 50 ml plant^{-1} provided maximum growth in bhindi (Nishana, 2005). It was also observed that soil application of neemcake (0.5 t ha^{-1}) and foliar nutrition of vermiwash (1:1 dilution) increased crop vigour in chilli (George, 2006).

Prabhu (2006) reported the presence of large number of beneficial microorganisms in vermiwash that helped to increase the growth of the plants. He also reported that vermiwash improved the germination percentage and seedling vigour of cowpea and paddy seeds.

The spinach and onion growth was significantly higher in plot treated with vermiwash @ 1:5 v/v and 1:10 v/v in water respectively (Abdullah, 2008).

Lalitha and Ansari (2008) noticed that vermiwash and vermicompost are enriched in certain metabolites and vitamins that belongs to the B group or pro vitamin D which helped to enhance plant growth in bhindi.

Foliar nutrition with vermiwash from coconut leaf improved growth of bhindi, nodulation of cowpea and germination of paddy seeds (Gopal *et al*., 2010).

Experiments conducted by Abdulla and Sukhraj (2010) revealed that combined application of vermicompost and vermiwash was beneficial in improving the growth and yield of bhindi.

Ingham (2003) reported that compost tea contained soluble nutrients that enhanced crop growth when applied as foliar spray. Sayre (2003) and Ryan (2007) also observed that the health and growth of crops was improved by foliar application of compost tea.

According to Mohan and Srinivasan (2008), organic promoters like panchagavya and EM solution enhanced the yield of brinjal. Combined application of liquid manures like beejamrut, jeevamrut and panchagavya recorded significantly higher growth in chilli (Chandrakala, 2008)

The liquid extract of seaweeds popularly known as seaweed liquid fertilizers could be used as foliar spray for inducing faster growth in cereal crops, vegetables, fruits, orchards and horticultural plants (Metha *et al*., 1967). Kannan and Tamilselvan (1990) observed that soil application of seaweed liquid fertilizer of *Enteromorpha clathrata* and *Hypneamus ciformis* increased the growth characteristics of green gram, black gram and rice.

Effective Microorganisms (EM) is a mixture of live cultures of microorganisms isolated from fertile soils in nature and useful for crop production. EM preparations generally contain *Lactobacillus*, photosynthetic bacteria, yeasts and other beneficial microorganisms which increase the crop growth (Yamada *et al*., 2003).

According to Palekar (2006), beejamruth is a source of nutrients used for seed or seedling treatment to increase the germination capacity of seed and growth of seedlings. Several beneficial bacteria are also present in beejamruth and inoculation of these bacterial isolates resulted in improvement in seed germination, seedling length and seed vigour in soybean (Sreenivasa *et al*., 2009). The experiment conducted by Gore (2009) revealed that use of a combination of beejamruth, jeevamruth and panchagavya at 75 and 160 days after sowing of tomato increased the enzymatic activities, plant growth, root length and N, P and K concentration.

Sangeetha and Thevanathan (2010) reported that nodule formation in pulses was the highest in soil amended with low levels of seaweed based panchagavya (panchagavya : soil in 1: 100 ratio)

Application of plant growth promoting rhizobacteria (PGPR) to the foliage or the floral parts of apple increased growth of the plant (Lutfi *et al;* 2007). Mallesh (2008) opined that amongst the rhizopshere microorganisms, PGPR has been considered important in sustainable agriculture due to their plant growth promotional ability. PGPR @ 2% seed inoculation significantly enhanced seed germination and seedling vigour of maize (Gholami *et al.,* 2009). They also reported that inoculation of maize seeds with different bacterial strains in both sterile and non-sterile soil significantly increased plant height, 100 seed weight, number of seed per ear, leaf and shoot dry weight and leaf surface area.

On perusal of the research work cited above, it could be inferred that liquid manures could enhance plant growth as evident by increased seedgermination, seedling growth, root length, plant height, seedling vigour etc.

2.1.3 Organic liquid manures on yield of crops

Buckerfield *et al.,* (1999) observed that weekly applications of vermiwash increased radish yield by 7.3 %. Yield improvement in tomato by soil application of vermiwash @12.5 % concentration was reported by Jasmine (1999). Studies by Lozek and Gracova (1999) revealed that application of vermisol increased yield by 7.3 % in chilli.

Application of organic inputs like vermicompost in combination with vermiwash resulted in better yield of crops by slow release of nutrients for absorption and supplementation of gibberellins, cytokinins and auxins (Lalitha *et al.,* 2000).

Jasmine *et al.*, (2003) opined that the yield of tomato was significantly increased by the application of vermiwash. Vermiwash at 50 % cocentration along with full NPK applied plots produced maximum number of seeds per fruit. The highest fruit yield of 18.35 t ha^{-1} was recorded by the same treatment.

According to Thangavel *et al*., (2003) the yield of paddy was improved by foliar application of vermiwash. Studies conducted by Shivasubramanian and Ganeshkumar (2004) revealed that the enzymes present in the vermiwash and secretions of earthworms stimulated the yield of crops. He also noticed enhanced productivity of marigold by the application of vermiwash.

Nishana (2005) reported that soil and foliar application of vermiwash @ 50 ml $plant^{-1}$ registered maximum yield in bhindi. The combined use of neem cake (0.5 t ha^{-1}) as soil application and foliar application of vermiwash (1:1 ratio) increased the crop vigour and fruit yield of chilli (George, 2006).

Foliar application of vermiwash (1:1 dilution) significantly increased dry chilli yield (George *et al.,* 2007). Abdullah (2008) observed that the yield of spinach and onion were significantly enhanced by foliar nutrition of vermiwash at 1:5 v/v and 1:10 v/v in water respectively. Lalitha and Ansari (2008) noticed that use of vermiwash enhanced the yield of bhindi.

Use of vermiwash from coconut leaf vermicompost improved the yield of bhindi (Gopal *et al*., 2010).

Use of seaweed liquid fertilizers as foliar spray induced higher yield in cereal crops, vegetables, fruits, orchards and horticultural plants (Metha *et al*., 1967). Dahiya and Vasudevan (1986) reported that application of biogas slurry was beneficial in replacing half of the fertilizer nitrogen and to produce better yield in vegetables. The soil application of seaweed liquid fertilizer of *Enteromorpha clathrata* and *Hypneamus ciformis* increased the yield of green gram, black gram and rice (Kannan and Tamilselvan, 1990). Kungkaew *et al*., (2004) observed that bio gas slurry along with chemical fertilizers in 1:1 ratio was effective in improving the crop yields of sweet corn, tomato and strawberry.

Ingham (2003) observed that compost tea contained soluble nutrients that enhanced crop yield. The beneficial organisms present in the EM solution increased the yield of crops (Yamada *et al*., 2003). Sayre (2010) reported that application of compost tea at fort nightly interval increased the marketable yield of potato by 18 to 19 %.

Chandrakala (2008) reported that the combined application of beejamrut, jeevamrut and panchagavya increased yield and drymatter production in chilli. The yield of brinjal could be increased by 33 % by the application of organic promoters like panchagavya and EM solution (Mohan and Srinivasan, 2008). Gore (2009) observed that application of a combination of beejamruth, jeevamruth and panchagavya (1:1:2 ratio) at 75 DAS and 160 DAS increased tomato yield.

The effectiveness of floral and foliar application of PGPR on yield improvement of apple was reported by Lutfi *et al*., (2007).

From the above reviews it is clear that liquid manures as foliar sprays could increase the yield of crops in several ways - by supplying a part of nitrogen requirement, providing soluble nutrients at correct time, increasing the pigment content in the plant and producing more dry matter.

2.1.4 Organic liquid manures on quality of fruits and vegetables

Adams (1986) reported that vermiwash application had a positive effect in bringing colour to tomato fruits, due to the presence of nitrogen and other micronutrients which enhanced the synthesis of lycopene. Whapham *et al*., (1993) observed that the application of seaweed liquid fertilizer of *Ascophyllum nodosum* increased the chlorophyll levels of cucumber cotyledons and tomato plants.

Studies by Lozek and Gracova (1999) revealed that application of vermiwash resulted in decrease in fruit nitrate content in chilli by 15 %. Zaller (2006) reported that foliar applications of vermicompost leachate improved lycopene content in tomatoes.

Modified formulations of panchagavya was found to enhance the biological efficiency of the crop plants and the quality of fruits and vegetables (Natarajan, 2002).

Shivamurthy and Pate (2006) noticed the effectiveness of cow's urine for seed treatment in enhancing the chlorophyll a and chlorophyll b content thereby contributing to yield improvement in wheat.

Ryan (2007) opined that the quality of crop produce could be improved by the application of compost tea.

According to Mohan and Srinivasan (2008) foliar application of organic promoters like panchagavya and EM solution increased quality of fruits .

Gore (2009) reported that use of beejamruth + jeevamruth + panchagavya at 75 DAS and 160 DAS as foliar spray increased the lycopene content in tomato.

In short, organic liquid manures increased quality of fruits and vegetables by reducing the toxicity of poisonous chemicals.

2.1.5 Organic liquid manures on pest and disease resistance

Weltzien (1992) reported the effectiveness of compost tea as surface spray for the control of foliar diseases of plants. Compost tea could reduce the severity of diseases like powdery mildew and downy mildew of grape, grey mould of strawberries and late blight of potato (Elad and Shtienberg, 1994); butter cup infestation and tomato blight (Touart, 2000).

Scheuerell and Mahaffee (2002) observed that compost tea as foliar spray reduced the incidence of pests and diseases in crops by competition with disease causing microbes and degradation of toxic pesticides.

The effectiveness of compost tea in controlling the bacterial spot of tomato was reported by (Al-Dahmani *et al*., 2003).

According to Sayre (2003), compost tea had the capacity to manage many pests and diseases of crop plants. Ingham (2003) opined that the plant exudates, both from roots and leaves, enhanced the disease - suppressive bacteria and fungi that occur in aerobic compost tea. Scheuerell (2003) noticed that non aerated compost tea preparation takes longer time for fermentation. This enabled accumulation of antibiotics in the non aerated compost tea which activate natural plant defence responses thereby help in disease suppression.

Verngrubinger (2005) observed that compost tea was helpful to fight off diseases by inoculating plants with beneficial micro organisms. The application of compost tea for reducing the incidence of foliar diseases was also reported by Linda (2007). Ryan (2007) opined that compost tea improved the drought tolerating capacity of the plants and suppressed pests and diseases.

An improvement in pest and disease resistance due to the application of EM in vegetables was noticed by Tuat and Trinh (2002).

Giradi *et al*., (2003) reported a significant reduction in pest population and leaf curl index in chilli treated with vermiwash (soil drench 30 days after transplanting and foliar sprays at 60 and 75 days after transplanting). The efficiency of vermiwash in imparting resistance to many pest and diseases was also reported by Shivasubramanian and Ganeshkumar (2004). Subasashri (2004) observed the suitability of vermiwash as an effective bio pesticide in many vegetable crops. Prabhu (2006) inferred vermiwash as a good bio control agent that protects the plant from a number of infestations. He also observed that foliar applications of vermiwash improved pest and disease resistance in tomato by suppressing *Phytophthora* disease.

Complete suppression of mycelial growth of *Sclerotiana sclerotiorum* in cucumber was possible by the addition of different herbal plant extracts with fresh cow's urine and cowdung (Basak *et al.,* 2002).

Solaiappan (2002) reported that the bacteria present in panchagavya acted as biocontrol agent. Sreenivasa *et al.,* (2009) noticed similar results and reported that the beneficial microorganisms of beejamrut protected the crop from harmful soil-borne and seed-borne pathogens.

Increased productivity and disease resistance in plants was observed by using a modified formulation of panchagavya - panchagavya amended seaweed extract (Sangeetha and Thevanathan, 2010).

The efficiency of PGPR as a biopesticide was examined by Nakkeeran *et al.,* (2005). They reported that use of PGPR for seed treatment, bio-priming, seedling dip, soil application, foliar spray, fruit spray, sucker treatment and sett treatment were better for the management of pest and diseases of crop plants, in addition to plant growth promotion. Bahadur *et al.,*(2007) observed that foliar application of PGPR increased anti fungal compounds in pea (*Pisum sativum*) against powdery mildew pathogen *Erysiphe pisi.*

Mallesh (2008) reported that PGPR have emerged as the biggest group of beneficial soil microorganisms, involved in the control of a number of plant diseases and pests by virtue of their ability to synthesize a wide range of antagonistic secondary metabolites. Reddy *et al*., (2011) noticed that application of PGPR suppressed the sheath blight disease caused by *Rhizactonia solani* in rice.

The observation depicted above revealed that liquid manures have a great potential as a good bio control agent by producing certain antibiotics and beneficial micro organisms.

2.1.6 Liquid manures on the production of growth promoting hormones

Seaweed liquid extract contained growth promoting hormones like auxins (IAA and IBA), cytokinins, gibberellins, trace elements, vitamins, amino acids, antibiotics and micronutrients for achieving higher agricultural production (Booth,1965).

Beejamruth contains several growth hormones which promote the growth of plants (Palekar, 2006).

According to Sreenivasa *et al.,* (2009) the bacterial isolates from beejamruth were capable of the production of the growth promoters like IAA and GA. Vermiwash was identified as a bio-liquid rich in nutrients and plant growth hormones (Gopal *et al*., 2010).

The liquid manure facilitate the production of growth hormones like IAA, IBA, cytikinins, gibberellins and also have the capacity to produce certain vitamins, trace elements, amino acids, antibiotics, enzymes and micronutrients required for plant growth.

2.1.7 Liquid manures on nutrient content of plants

Palekar (2006) revealed that availability and uptake of nutrients by crops was increased by the application of jeevamrut.

Gopal *et al*., (2010) inferred that the nutrient content of plant was increased by the application of coconut leaf vermiwash. Similar observation was also made by Lutfi *et al*., (2007) who observed an increase in nutrient content of apple by floral and foliar application of PGPR.

2.1.8 Liquid manures and microbial activity.

Ingham (2005) reported that the compost tea contained populations of several beneficial microorganisms and also the well made compost tea will be dominated by beneficial bacteria or fungi. He also observed that greater the amount of soluble material in the compost tea, the more food resources would be there for the growth of beneficial bacteria and fungi, and microbial activity will be improved.

According to Palekar (2006) the enormous amount of microbes present in jeevamrut enhanced microbial activity in soil. Ryan (2007) also opined compost tea as one of the liquid manure for enhancing microbial activity of soil.

Studies conducted by Sreenivasa *et al.,*(2009) revealed that the beneficial micro organisms in beejamruth enhanced the microbial activity of the soil.

Gopal *et al*., (2010) reported that application of coconut leaf vermiwash increased the population of soil microorganisms, particularly plant beneficial ones, and their activities facilitated increased uptake of the nutrients.

The microbial activity of soil could be improved by the application of liquid manures due to the enormous amount of beneficial microbes (bacteria and fungi) present in it.

2. 2 FOLIAR APPLICATION OF UREA ON VEGETABLES

Foliar fertilization of urea is common in vegetables to correct nutrient deficiencies at any growth stage of crops. It also enhances the efficiency of applied nutrient by 90 %. A concentration of 1-2 % is recommended for foliar application of urea in vegetables.

The beneficial effects of foliar urea applications @ 1% concentration in increasing the yield and improving crop quality were reported in many vegetables such as cabbage, onion, cucumber, squash (Padem and Yildirim, 1996). Kolota and Osinska (2001) reported that supplementary foliar fertilization of urea @ 0.5% during crop growth improved the mineral status of plants and increased yield in field vegetables.

According to Renata *et al.,* (2005), foliar application of urea @1% concentration significantly lowered concentration of nitrates and increased soluble sugar content in broccoli. Moreover, the foliar application of urea increased the ascorbic acid content in broccoli heads.

Yildirim *et al.,* (2007) observed that foliar applications of urea, especially @ 0.8 and 1.0 % concentration resulted in larger and heavier broccoli heads. They also noticed that soil nitrogen fertilization and foliar urea applications increased the content of almost all nutrients in leaves and heads of broccoli.

In general N supplementation through foliar fertilization of urea improves crop growth, yield and quality of vegetables by enhancing the nutrient uptake.

Materials and methods

3. MATERIALS AND METHODS

The present investigation entitled "Development of an effective organic liquid manure for vegetable crops" was carried out at College of Agriculture, Vellayani during 2010–2012. The main objective of the study was to develop a safe organic phytotonic with about 2 per cent nitrogen, to evaluate its shelf life and to study its influence on growth and yield of vegetables and to assess the economics of using liquid manures. The investigation was carried out in three phases.

(1) Preparation of composite liquid manures.

(2) Assessing the shelf life of composite liquid manures.

(3) Crop response study to evaluate the efficacy of promising liquid manures on the growth and yield of vegetables.

Part I

3.1 PREPARATION OF COMPOSITE LIQUID MANURES

Organic liquid manures and extracts of various manures were analysed for nutrient content for the preparation of composite liquid manure. The study was conducted under laboratory conditions during January 2011 to November 2011. The organic sources having comparatively higher N content *viz;* groundnut cake , vermicompost, neem cake, poultry manure, cowdung and cow's urine were selected for composite liquid manure preparation.

3.1.1 Characterization of selected organic manures

Good quality organic manures available in the market were collected and analysed for major nutrients. The sources having higher nutrient contents were selected for the preparation of liquid manures.

3.1.1.1 Standardisation of liquid manures.

Standardisation study was carried out in several steps as presented below.

i. ***Characterisation of organic liquid manures and liquid extracts of selected organic manures***: Common liquid manures like cow's urine and vermiwash along with two commercial liquid manure formulations namely *Biosix* (manufactured by

Biosix Peptides India Private Limited, Ernakulam) and *Nutrich Z* (manufactured by Neuscire Biolab, Coimbatore) were also analysed for the nutrient content.

The selected organic manures *viz;* groundnut cake, neem cake, poultry manure, cowdung and vermicompost were mixed with water in 1:5 ratio (one part organic manure and five part water) and kept in water for 15 (Schruerell *et al*., 2002) and 30 days. The extract collected was analysed for major nutrients.

ii. Characterisation of vermiwash of selected organic combinations :

Portable vermicompost units were set up and vermicompost was prepared using kitchen waste and organic sources in different combinations as detailed below.

T_1 – Kitchen waste (2kg) + cowdung (0.5kg)

T_2 – Kitchen waste (2kg) + poultry manure(0.5kg)

T_3– Kitchen waste (2kg) + neem cake (0.5kg)

T_4– Kitchen waste (2kg) +groundnut cake(0.5kg)

T_5– Kitchen waste (2kg) + cowdung (0.25kg)+ poultry manure (0.25kg)

T_6– Kitchen waste (2kg) + cowdung (0.25kg)+ neem cake (0.25kg)

T_7– Kitchen waste (2kg) + cowdung (0.25kg)+ groundnut cake (0.25kg)

T_8– Kitchen waste (2kg) + neem cake (0.25kg)+ groundnut cake (0.25kg)

T_9– Kitchen waste (2kg) + poultry manure (0.25kg)+ groundnut cake (0.25kg)

T_{10}– Kitchen waste (2kg) + neem cake (0.25kg)+ poultry manure (0.25kg)

The vermiwash collected was analysed for major nutrients.

iii. Characterisation of liquid extracts of composite organic manures: This involved preparation of composite organic manures and collection and analysis of the extract from these composite manures. Six composite organic manures were selected for this study. Composite organic manures were prepared by mixing different proportion of various sources and these composite manures were mixed with five times water and the liquid extract was collected after seven and 15 days. The nutrient content of the organic liquid manures were analysed. The six composite manures tried were

T_1 - Groundnut cake + neem cake (1:1)

T_2 – Groundnut cake + vermi compost (1:1)

Plate 1. Vermiwash collection from portable vermicompost unit

T_3 - Groundnut cake + neem cake+vermi compost (1:0.5:0.5)

T_4 - Groundnut cake + poultry manure (1:1)

T_5 - Groundnut cake + poultry manure + vermi compost (1:0.5:0.5)

T_6 - Groundnut cake + neem cake +poultry manure (1:0.5:0.5)

The composite organic liquid manures analysing higher nitrogen content were selected for further study.

The physical and chemical characteristics of organic liquid manures *viz*; odour, colour. pH, EC, nitrogen, phosphorous and potassium contents were analysed by using standard analytical methods for organic liquid manures as given in Table 1.

Table 1. Analytical method used for the physico-chemical characterisation of liquid manures

Sl No.	Estimated characters	Method	Reference
I	Physical parameters		
a.	Odour	Sensory evaluation	
b.	Colour	Visual evaluation	
II	Chemical parameters		
a.	Soil reaction	pH meter with glass electrode	Jackson,1973
b.	EC(dSm^{-1})	Conductivity meter	Jackson,1973
c.	Total N(%)	Microkjeldhal method	Jackson,1973
d.	Total P(%)	Vanado molybdo phospho yellow colour method	Bray and Kurtz,1945
e.	Total K(%)	Flame photometer method	Jackson,1973

Part II

3.2 SHELF LIFE STUDY

Shelf life study of the selected three organic liquid manures was conducted to assess the keeping quality.

3.2.1 Shelf life study with pH adjustment: The selected liquid extracts were subjected to shelf life study after bringing the pH to slightly acidic condition (6-6.5) by the addition of lime.

Technical programme

Design - CRD

Treatment combinations - 24

Replications - 2

Treatments

a. Liquid manures (3)

Extracts of following composite manures

L_1 – Ground nut cake +poultry manure (1:1)

L_2 - Ground nut cake + poultry manure +vermi compost (1:0.5:0.5)

L_3 - Ground nut cake +neem cake+ poultry manure (1:0.5:0.5)

b. Containers (2)

C_1 - Plastic container

C_2 - Earthern pot

c. Storage (2)

S1- Open condition

S2 - Refrigerated condition

d. Bio inoculants (2)

B_1- With PGPR mix 1 and 2 at 2% concentration

B_2- Without PGPR

3.2.2 Shelf life study with pH adjustment and autoclaving

Selected liquid manures were subjected to autoclaving at 121^0C, 15 lbs for

Plate 2. Shelf life study of liquid manures

Plate 3. Mould growth incidence in liquid manures on storage

Plate 4. Autoclaved liquid manures kept for shelf life study

20 minutes after pH adjustment to 6- 6.5. PGPR mix 1 and 2 @ 2% were added to the liquid manures after autoclaving and subjected to shelf life study both in open and refrigerated condition.

3.2.3 Sampling

Sampling was done at fortnightly interval for two months and again at three months during storage.

Part III

3.3 CROP RESPONSE STUDY

Field experiments were conducted using amaranthus and bhindi as test crops to study the efficiency of selected organic liquid manures on crops growth and yield.

3.3.1 Experimental site

The experiment was carried out at Instructional Farm attached to College of Agriculture, Vellayani. The site is situated at 80^0 30'N latitude and 76^0 54' E longitude and at an altitude of 29 m above mean sea level.

3.3.2 Soil

Soil of the experimental site is laterite red loam belonging to the order oxisol of Vellayani series.

3.3.3 Weather conditions

Weekly averages of maximum and minimum temperature, relative humidity and rainfall received during the cropping period collected from the observatory of College of Agriculture, Vellayani are given in Appendix I. The average maximum temperature recorded during the cropping period was 30.46^{o}C and a total of 972.83 mm rainfall was received.

3.3.4 Materials

3.3.4.1 Crops and varieties

Amaranthus variety Arun and the local variety of bhindi (Aanakkomban) were selected for the study.

3.3.4.2 Planting material

Seeds of amaranthus variety Arun was obtained from the Department of Oleiriculture, College of Agriculture, Vellayani and seeds of bhindi was collected

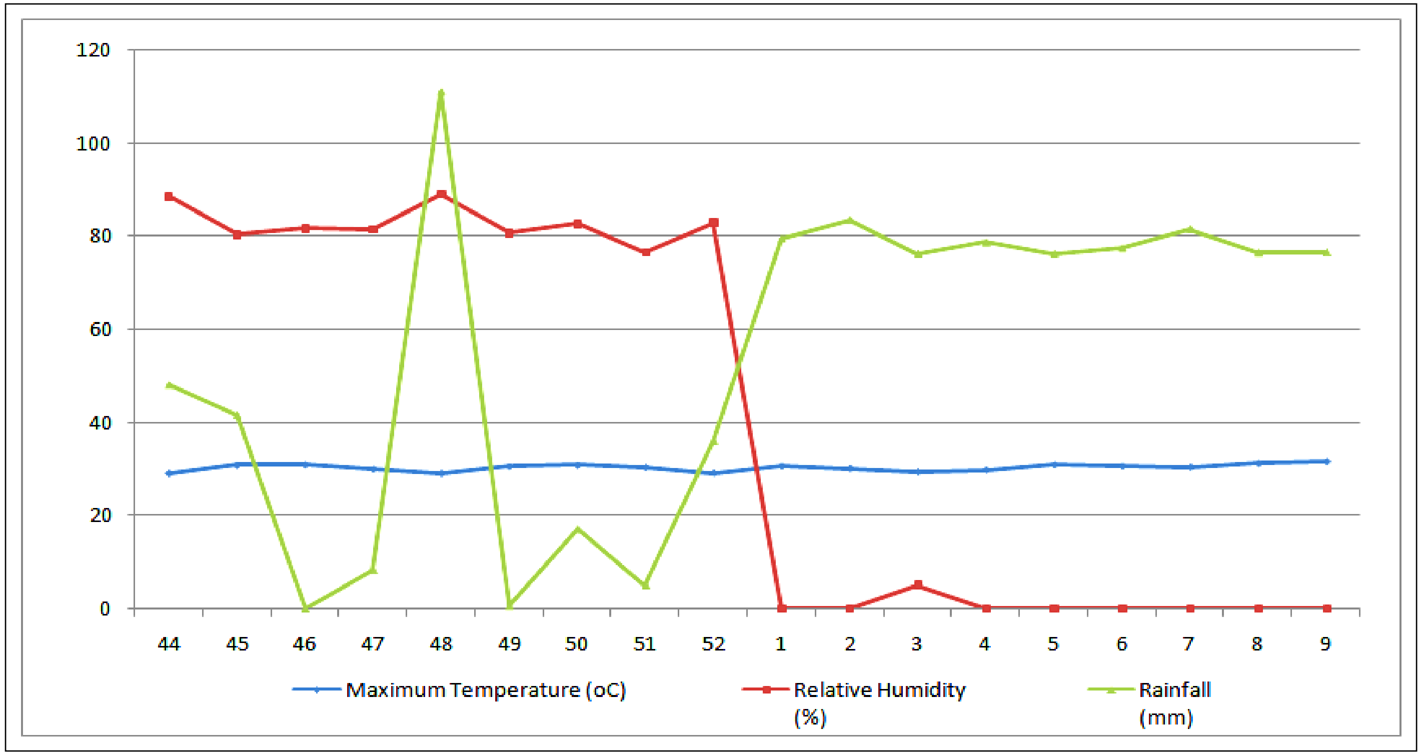


Fig. 1. Weather parameter during the cropping period (November 2011 to February 2012

from the District Agricultural Farm, Peringammala, Thiruvananthapuram.

3.3.4.3 Manures and Fertilizers

Basal application of organic manures to test crops was done with farmyard manure as per the recommendation of Kerala Agricultural University (50 t ha^{-1} for amaranthus and 12 t ha^{-1} for bhindi). N, P and K were supplied through urea (46 %N), rajphos 20 % P) and muriate of potash (60 % K) respectively. Top dressing of nitrogen was adopted as foliar nutrition as per treatments except T_6.

Methods

3.3.5 Field experiment

3.3.5.1 Season

The experiment was conducted during November 2011 to January 2012. The properties of the soil analysed and the methods adopted are presented in Table 2.

Table 2. Chemical properties of the soil at the experimental site

Sl no	Parameter	Content	Rating	Methods adopted
1	Soil reaction	5.4	Strongly acidic	pH meter with glass electrode (Jackson, 1973)
2	Available N (kg ha^{-1})	224.00	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
3	Available P (kg ha^{-1})	10.4	Medium	Bray colorimeter method (Jackson, 1973)
4	Available K (kg ha^{-1})	108.65	Low	Neutral normal ammonium acetate method (Jackson, 1973)
5	Organic carbon(%)	1.57	High	Chromic acid wet digestion method (Walkley and Black, 1934)

Separate experiments were conducted for amaranthus and bhindi with the following technical programme.

Design - RBD

Treatments - Foliar nutrition (6)

T_1 – Selected liquid manure 1

T_2 – Selected liquid manure 2

T_3 – Selected liquid manure 3

T_4 – Urea 2%

T_5 – Commercial formulation (*Nutrich - Z*)

T_6 – Control (POP recommendation of respective crops)

Replications 4

Gross plot size 3.0×2.4 m (bhindi)

2.4×2.1 m (amaranthus)

Net plot size 1.2× 1.3 m (amaranthus)

1.8×1.8m (bhindi)

The layout plan of the experimental field (amaranthus and bhindi) is given in Fig.2

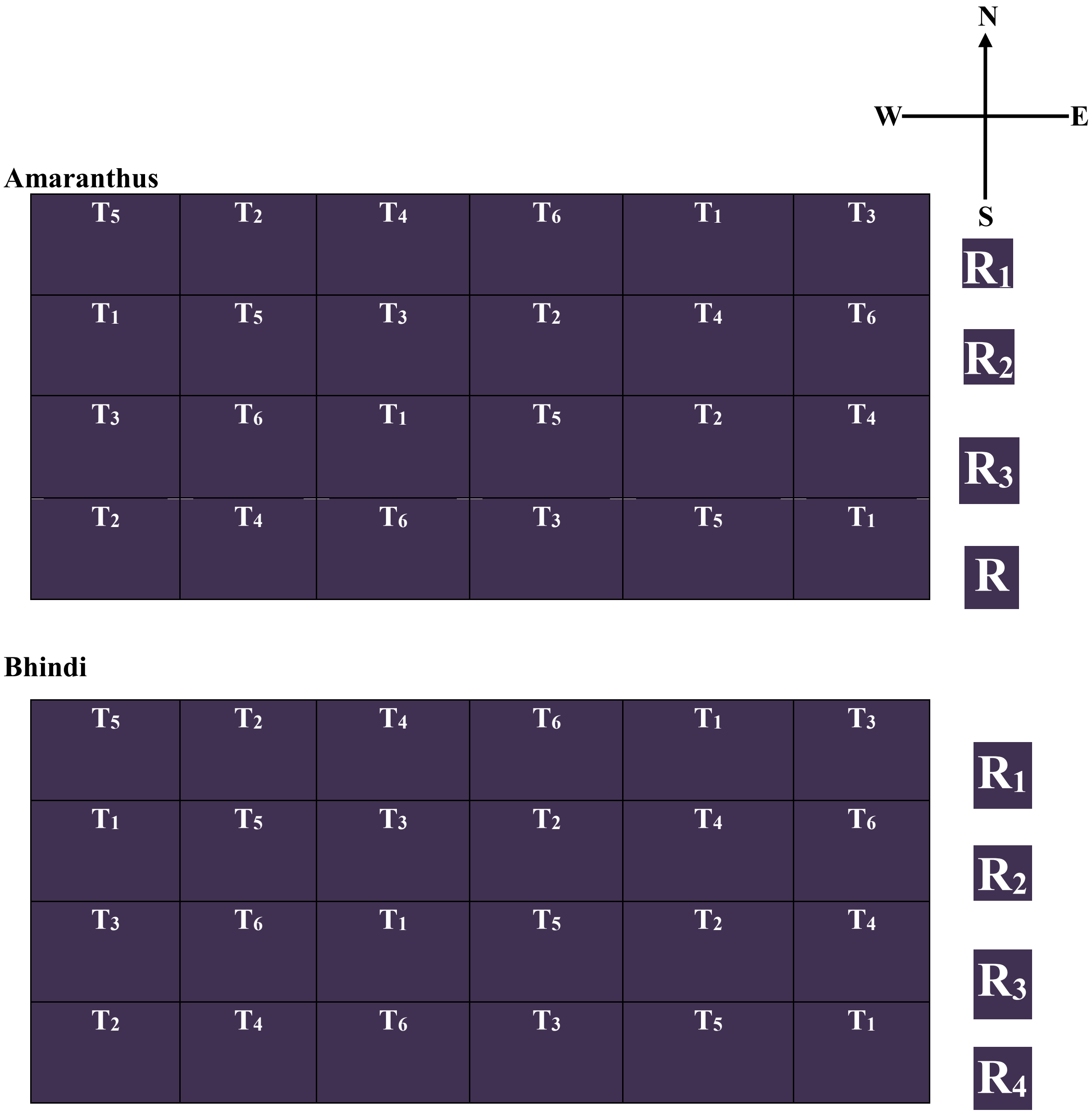


Fig 2. Layout plan of the field experiment

3.3.5.2 Details of cultivation

3.3.5.2.1 Nursery

The nursery area was well prepared and amaranthus seedlings were raised. Sowing was done on 19th November 2011. Need based irrigation was practiced in nursery.

3.3.5.2.2 Transplanting

Twenty days old amaranthus seedlings were transplanted in the main field on 9th December 2011.

Bhindi seeds were sown in well prepared plots, on 8th December 2011 @ three seeds per pit at a spacing of 60× 30 cm.

3.3.5.2.3 Manures and fertilizers

In addition to organic manures, 50:50:50 kg ha^{-1} N: P_2O_5: K_2O applied as basal for amaranthus and further nutrient requirement was met through foliar nutrition. Foliar nutrition was given ten days after transplanting of amaranthus and subsequent sprays were given on the regrowth after each cut. The recommendation of chemical fertilizers for bhindi is 110:35:70 kg NPK ha^{-1}. Of this half N, full P and half K was applied as basal and half K was applied at flowering. The remaining N requirement was met by foliar nutrition at 10 days interval. The selected liquid manures *viz*; T_1, T_2 and T_3 were mixed with PGPR mix 2 @ 2% prior to spraying.

3.3.5.2.4 After cultivation

Plant population was maintained uniformly by gap filling/resowing and thinning wherever necessary. Regular irrigation and weeding were carried out both in amaranthus and bhindi.

3.3.5.2.5 Plant protection

Leaf blight was observed in amaranthus and was managed by spraying Dithane M-45 at 0.30% concentration.

Yellow vein mosaic disease was observed in bhindi towards the later stages and to control the vectors Dimethoate was sprayed at 0.15 % concentration.

3.3.5.2.6 Harvesting

First harvest of amaranthus was taken at 20 days after transplanting and subsequent harvests at 10 - 15 days interval and total four harvests were taken.

In bhindi first harvest was done at 45 days after planting. Subsequent harvests were made in two to three days interval and a total of six economic harvests were obtained.

3.3.5.3 Observations

3.3.5.3.1 Part I

3.3.5.3.1.1 Nutrient content of selected organic manures : The NPK content of selected organic manures was estimated as per the procedure given in Table 1 and was expressed as percentage.

3.3.5.3.1.2. Nutrient content of liquid extracts of selected organic manures : The NPK content of liquid extracts of selected organic manures was also estimated (Table 1) and expressed as percentage.

3.3.5.3.1.3. Nutrient content of vermiwash : The NPK content of vermiwash was estimated (Table 1) and presented as percentage.

3.3.5.3.1.4. Nutrient content of extracts of composite organic manures : Same procedure was followed for the estimation of nutrient content.

3.3.5.3.2 Part II

3.3.5.4.2.1 Observations on mould growth : The number of days taken for appearance of mould growth on the liquid manures kept for shelf life study was noted and expressed in days.

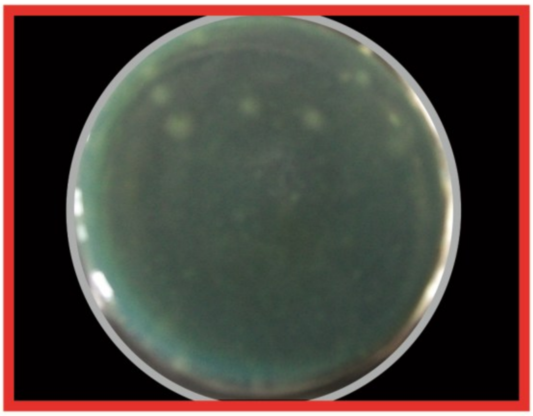
3.3.5.3.2.2 Nutrient analysis

Available nitrogen (Microkjeldhal method), available phosphorous (Vanado - molybdo phosphor yellow colour method) and available potassium (Flame photometer method) of the liquid manures kept for shelf life study were analysed at 7, 15 and 30 days after storage (DAS) and expressed as %.

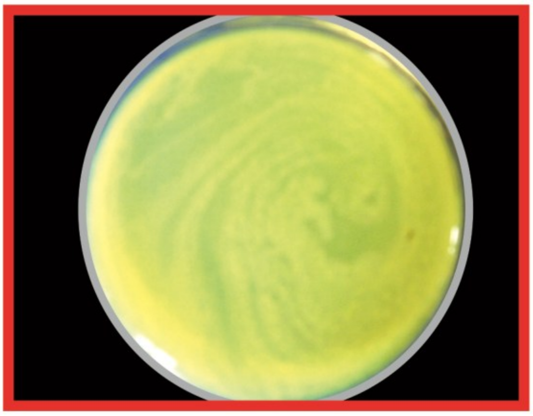
3.3.5.3.2.3 Microbial study

Microbial population (nitrogen fixers, phosphorous and potassium solubilizers) of selected composite liquid manures were analysed by serial dilution

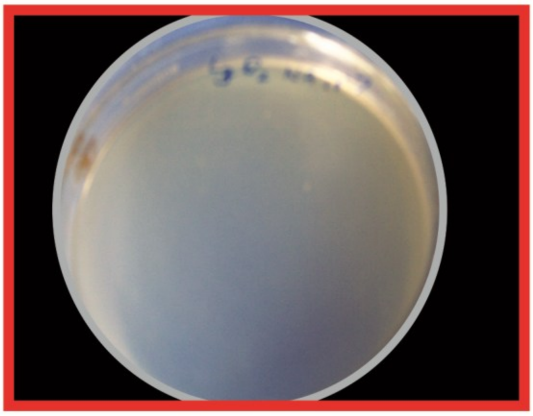
Azotobacter



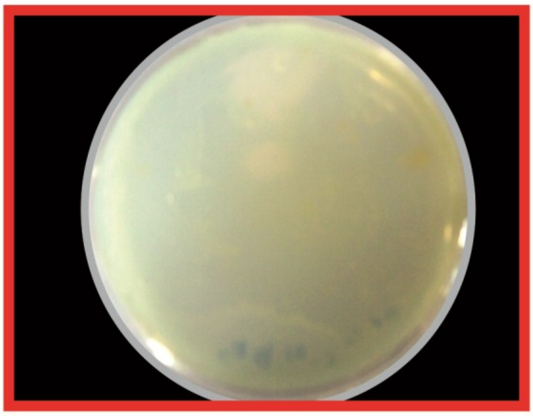
Azospirillum



Pseudomonas



K Solubilisers



P Solubilisers

Plate 5. Microbial colonies in liquid manures

and plate technique using appropriate medium. For azospirillum – Nitrogen free bromothymol blue medium (Dobereiner *et al.,* 1976), azotobacter- Jensen's medium (Jensen, 1942), P solubilisers – Pikovskay's medium (Sundara and Sinha, 1963) and K solubilisers- Nutrient agar medium (Anthoni *et al.,* 2000) were used at 10^{-7} dilution. Microbial observation was also carried out at 7, 15 and 30 DAS.

3.3.5.3.3 Part III

3.3.5.3.3.1 Selection of observational plants

Five observational plants were selected randomly from the net plot, each for amaranthus and bhindi for recording biometric observations.

3.3.5.3.3.2 Growth characters

3.3.5.3.3.2.1 Plant height

Height of amaranthus was measured from base to the growing tip of observational plants prior to each harvest and the mean values were computed and expressed in cm.

Height of bhindi was measured from base to the growing tip at 30 days interval and given as cm.

3.3.5.3.3.2.2 Number of leaves

Total number of leaves of amaranthus was counted in the observational plants prior to each harvest and the mean values were computed.

In bhindi total leaf count was recorded at 30 days interval

3.3.5.3.3.2.3 Total dry matter production

Dry matter production at harvest was recorded in both the crops by recording the fresh weight and oven dry weight of the plant. For recording the oven dry weight the fresh samples were first shade dried and then oven dried at 60^0 C to a constant weight. The dry weight of the biomass was recorded as the total dry matter production and expressed in kg ha^{-1}.

3.3.5.4 Yield and yield attributes

3.3.5.4.1 Number of fruits per plant

Total number of fruits of bhindi was counted from the observational plants

Plate 6. Layout plan of field experiment

Plate 7. General view of the experimental field

Plate 8. General view of amaranthus field

Plate 9. General view of bhindi field

of each treatment and the mean values were computed.

3.3.5.4.2 Weight of fruits per plant

Total weight of fruits of bhindi was recorded from the observational plants of each treatment and the mean values were computed and expressed as g plant.$^{-1}$

3.3.5.4.3 Yield

Weight of amaranthus at each harvest was recorded from the net plot and the total yield was calculated and expressed in t ha^{-1}

In bhindi weight of the fruits in each harvest was recorded from the net plot and the total yield was calculated and expressed in t ha^{-1}

3.3.5.5 Crop quality attributes

3.3.5.5.1 Vitamin C content

Vitamin C content of amaranthus prior to first harvest was estimated by titrimetric method (Sadasivam and Manickam, 1996) and expressed in mg100 g^{-1} fresh leaf sample.

3.3.5.5.2 Chlorophyll content

The chlorophyll content of bhindi was estimated at the beginning of flowering by the DMSO (Di Methyl Sulphoxide) method (Reddy *et al.,*1990). The amount of pigment was calculated using the formula given below and expressed in mg chlorophyll g tissue.$^{-1}$

$$\text{Total chlorophyll} = [20.2\ (\text{OD at } 645) + 8.01\ (\text{OD at } 663)] \times \frac{V}{W \times 1000}$$

Where W is the weight of leaf sample and V is made up volume of the extract

3.3.5.6 Phyllosphere observation

Microbial population was estimated from the leaf samples of both crops two days after application of liquid manures. Microbial population (nitrogen fixers, phosphorous and potassium solubilizers) was analysed as per the method specified in 3.3.5.3.2.3 by serial dilution and plate technique using appropriate medium.

3.3.5.7 Soil analysis

A composite soil sample was collected from the experimental site before the experiment and samples were collected from individual plots after the experiment. These soil samples were processed and N, P, K and organic carbon content were analysed as per the method given in Table 2

3.3.5.8 Economics of cultivation

Economics of cultivation of amaranthus and bhindi as influenced by foliar nutrition was worked out considering the total expenditure and total income of the crops. The B:C ratio was calculated as follows

Benefit : Cost ratio = Gross income/ Cost of cultivation

Profit = Gross income – cost of cultivation

3.3.5.9 Statistical analysis

Data generated from the field investigation were analysed by applying the analysis of variance technique and significance was tested by F test (Snedecor and Cochran, 1975). Where the effects were found to be significant, CD values were calculated by using standard technique.

Results

4. RESULTS

An investigation was conducted to assess the feasibility of developing an effective organic liquid manure for foliar nutrition in vegetables. The study was undertaken in three parts and the results obtained are presented in this chapter

Part I

4.1. PREPARATION OF LIQUID MANURES

4.1.1. Characterisation of selected organic manures

The selected organic manures like groundnut cake, neem cake, poultry manure vermicompost and fresh cowdung were analysed for the nutrient content and the results are presented in Table 3

The results revealed that groundnut cake registered the highest N content of 6.18 % followed by neem cake (3.42 %). Poultry manure had the highest P content (0.90 %) followed by cowdung (0.76 %) and groundnut cake (0.68 %). K content was maximum in poultry manure (2.14 %) followed by groundnut cake (1.21 %)

4.1.2 Standardisation of liquid manures

4.1.2.1 Characterisation of organic liquid manures and liquid extracts of selected organic manures

Nutrient content of organic liquid manures *viz*; cow's urine, vermiwash and two commercial formulations namely *Biosix* and *Nutrich - Z* along with the extracts of selected organic manures collected after 15 and 30 DAS were analysed for N, P, K content and data furnished in Table 3.

The data revealed that among organic liquid manures, the commercial formulation *Nutrich - Z* registered maximum nitrogen content (0.32 %) followed by vermiwash (0.30 %). The highest P and K content were also recorded by *Nutrich- Z.*

Table 3. Nutrient content of selected organic manures, liquid manures and extracts of selected organic nanures (%)

Organic sources	N		P		K	
Groundnut cake	6.18		0.68		1.21	
Neem cake	3.42		0.32		0.56	
Vermicompost	1.43		0.43		0.96	
Poultry manure	1.43		0.90		2.14	
Cowdung (fresh)	1.20		0.76		0.98	
Liquid manures						
Cow's urine	0.27		0.006		0.29	
Vermiwash	0.30		0.040		0.36	
Biosix	0.12		0.007		0.23	
Nutrich – Z	0.32		0.008		0.32	
Organic manure extracts	15 DAS			30 DAS		
	N	P	K	N	P	K
Groundnut cake	0.22	0.004	0.31	0.33	0.006	0.20
Neem cake	0.12	0.016	0.32	0.18	0.015	0.30
Poultry manure	0.02	0.003	0.27	0.08	0.004	0.30
Compost	0.02	0.010	0.28	0.03	0.009	0.30
Cowdung	0.01	0.007	0.03	0.02	0.008	0.04
Vermicompost	0.01	0.004	0.26	0.02	0.005	0.24

DAS - Days after soaking

The nutrient content of extracts of selected organic manures analysed 15 DAS revealed that maximum N content was in groundnut cake extract (0.22 %) followed by neem cake extract (0.12 %). The highest P content was recorded in neem cake extract (0.016 %) followed by compost extract (0.01 %). Maximum K content was observed in neem cake extract (0.32 %) followed by groundnut cake extract (0.31 %).

The N content of extracts of all organic manures registered higher values at 30 DAS and the content ranged from 0.02 % to 0.33 %. P content also increased except in neem cake and compost extract and the content ranged from 0.004 % to 0.015 %. K content ranged from 0.20 to 0.30 %. The K content reduced for groundnut cake, neem cake and vermicompost extracts at 30 DAS while the content slightly increased for poultry manure, compost and cowdung extract.

4.1.2.2 Characterisation of vermiwash of selected organic combinations

The nutrient content of the vermiwash collected from combinations of kitchen waste and organic manures is presented in Table 4. In general, the N content ranged from 0.2 % to 0.4 %, maximum N content (0.4 %) recorded in T_9 (kitchen waste + poultry manure+ groundnut cake) and T_1 (kitchen waste + cowdung). N content was the lowest (0.2 %) in T_3, T_4, T_5, T_6 and T_7.

P content ranged from 0.02 to 0.07 %. Highest P content was registered in T_7 (kitchen waste + cowdung + groundnut cake) and the lowest in T_2, T_5 and T_{10}. K content ranged from 0.15 to 0.16 % and the maximum K content being recorded in T_2, T_3, T_5 and T_7 (0.16 %).

4.1.2.3 Characterisation of liquid extracts of composite organic manures

Six composite organic manures were prepared by mixing organic manures with high N content sources namely groundnutcake, neem cake, vermicompost, and poultry manure in different proportions. The nutrient content of the extracts of composite manures collected seven days after soaking were analysed and data furnished in Table 4. In earlier study (presented 4.1.2.1) the nutrient content of extracts of organic manures showed an increase in N content with increase in soaking period from 15 to 30 days. But the extracts had foul smell and the management became difficult. Hence for this study the soaking period was limited to seven days.

The data presented in Table 4 revealed that T_6 (groundnut cake + neem cake + poultry manure in 1:0.5:0.5 ratio) recorded the highest N content of 0.62 % followed by T_5 (0.50 %) and T_4 (0.45 %). The treatments T_3 (groundnut cake + neem cake + vermicompost in 1:0.5:0.5 ratio) and T_5 (groundnut cake + vermicompost + poultry manure in 1:0.5:0.5 ratio) registered maximum P content (0.08 %). Maximum K content was recorded in T_5 and T_6 (0.17 %).

Based on N and K contents three promising combinations *viz;* T_4, T_5, and T_6 were selected for further study. The organic liquid manures T_4, T_5, and T_6 were renamed as L_1, L_2 and L_3.

4.1.3 Nutrient content of selected organic liquid manures with PGPR

The nutrient content of three selected liquid manures were assessed after the addition of PGPR mix 1 and 2 @ 2 % concentration and the data are presented in Table 5.

The data revealed that N content of all organic liquid manures increased with addition of PGPR mix 1 and 2. The maximum N content was recorded in L_3 (0.78 %) followed by L_2 and L_1. The P content was the highest observed in L_2 (0.09 %) followed by L_1 and L_3. Compared to L_1, L_2 and L_3 recorded a slightly higher K content (0.17 %).

4.1.4 Physico chemical characters of selected liquid manures

Data presented in Table 6 shows the physico chemical characters of organic liquid manures. The colour of the organic liquid m anures varied from light yellow to dark brown. The manures emits foul odour due to fermentation. The pH was the highest in L_1 (5.71) followed by L_2 (5.50) and L_3 (5.47). L_1 was

Table 4. Nutrient content of vermiwash of selected organic combinations and extracts of composite organic manures 7 DAS (%)

Treatments	N	P	K
T_1	0.40	0.05	0.15
T_2	0.30	0.02	0.16
T_3	0.20	0.03	0.16
T_4	0.20	0.04	0.15
T_5	0.20	0.02	0.16
T_6	0.20	0.05	0.15
T_7	0.20	0.07	0.16
T_8	0.30	0.04	0.15
T_9	0.40	0.06	0.10
T_{10}	0.30	0.02	0.15
Extracts of composite organic manures 7 DAS			
T_1	0.32	0.03	0.15
T_2	0.29	0.06	0.15
T_3	0.26	0.08	0.16
T_4	0.45	0.04	0.15
T_5	0.50	0.08	0.17
T_6	0.62	0.02	0.17

DAS - Days after soaking

Table 5. Nutrient content of selected organic liquid manures with PGPR addition (%)

Treatments	N	P	K
L_1	0.56	0.07	0.16
L_2	0.64	0.09	0.17
L_3	0.78	0.07	0.17

Table 6. Physico chemical characters of liquid manures

Treatments	Colour	Odour	pH	EC (dSm^{-1})
L_1	Light yellow	Foul odour	5.71	7.6
L_2	Dark brown	Foul odour	5.50	6.7
L_3	Light orange	Foul odour	5.47	9.2

medium acidic, L_2 and L_3 were strongly acidic. L_3 registered the highest EC (9.2 dSm^{-1}) and was followed by L_1 (7.6 dSm^{-1}) and L_2 (6.7 dSm^{-1}).

Part II

4.2 SHELF LIFE STUDY

4.2.1 Shelf life study without autoclaving

Shelf life study was conducted after pH adjustment. The selected liquid manures were kept in plastic and earthen vessels both in open and refrigerated conditions with PGPR and without PGPR addition.

4.2.1.1 Observation on mould growth on storage

The data on mould growth during storage is presented in Table 7. Mould growth was first observed after three days of storage in the plastic bottles and earthen vessels kept in open condition. In the refrigerated condition mould growth was observed after seven days of storage.

4.2.1.2 Nutrient analysis of liquid manures

Nitrogen content of selected liquid manures kept in plastic bottles and earthen vessels were assessed in open and refrigerated condition, with and without PGPR addition at 7, 15 and 30 days of storage. The results presented in Table 8 revealed that the containers, PGPR addition and storage condition had no influence on the N content estimated at different intervals. However, a slight increase in N content was observed with PGPR addition. In all cases the N content decreased with increase in storage time.

The results presented in Table 9 showed that the different treatments did not influence the P content of selected liquid manures. In general the P content declined with increase in storage time.

The K content of selected liquid manures estimated at different intervals of storage (Table 10) revealed no significant variation due to treatments. No change

*Table 7. Days for initiation of mould growth of liquid manures on storage

Treatments	Open condition (days)				Refrigerated condition (days)			
	Plastic		Earthen		Plastic		Earthen	
	With PGPR	Without PGPR	With PGPR	Without PGPR	With PGPR	Without PGPR	With PGPR	Without PGPR
L_1	3	3	3	3	7	7	7	7
L_2	3	3	3	3	7	7	7	7
L_3	3	3	3	3	7	7	7	7

*not analysed statistically

Table 8. Nitrogen content of liquid manures on storage (%)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	0.16	0.15	0.21	0.20	0.16	0.15	0.24	0.22
L_2	0.11	0.11	0.19	0.18	0.11	0.10	0.21	0.19
L_3	0.18	0.16	0.24	0.22	0.18	0.16	0.25	0.22
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	0.13	0.13	0.18	0.16	0.13	0.12	0.19	0.18
L_2	0.10	0.10	0.14	0.13	0.11	0.11	0.18	0.16
L_3	0.16	0.13	0.19	0.18	0.16	0.15	0.19	0.18
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	0.11	0.11	0.11	0.11	0.11	0.11	0.13	0.11
L_2	0.11	0.10	0.11	0.10	0.10	0.11	0.11	0.10
L_3	0.12	0.11	0.13	0.11	0.11	0.15	0.13	0.11
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

DAS - Days after storage

Table 9. Phosphorous content of liquid manures on storage (%)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	0.01	0.01	0.04	0.04	0.02	0.02	0.04	0.04
L_2	0.04	0.04	0.04	0.04	0.05	0.05	0.08	0.08
L_3	0.01	0.01	0.04	0.04	0.03	0.03	0.07	0.07
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
L_2	0.02	0.02	0.02	0.02	0.05	0.05	0.05	0.05
L_3	0.01	0.01	0.04	0.04	0.03	0.03	0.04	0.04
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
L_2	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04
L_3	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

DAS - Days after storage

Table 10. Potassium content of liquid manures on storage (%)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	0.10	0.10	0.11	0.11	0.13	0.13	0.15	0.15
L_2	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12
L_3	0.10	0.10	0.13	0.13	0.12	0.12	0.16	0.16
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	0.10	0.10	0.11	0.11	0.11	0.11	0.13	0.13
L_2	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12
L_3	0.10	0.10	0.11	0.11	0.11	0.11	0.13	0.13
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	0.10	0.10	0.10	0.10	0.11	0.11	0.12	0.12
L_2	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11
L_3	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

DAS - Days after storage

in K content was observed in storage in open. Though refrigerated storage maintained the K content to higher levels than open, the variation was found to be insignificant.

4.2.1.3 Microbial population analysis

The microbial population of liquid manures with and without PGPR addition prior to storage is presented in Table 11. PGPR addition enhanced the microbial population of all liquid manures under study.

The population of microorganisms *viz; Azotobacter, Azospirillum, Pseudomonas, P solubilisers* and *K solubilisers* estimated at different periods of storage are presented in Table 12 to 16. The results showed no significant variation due to treatments on the microbial population of liquid manures. In general, the microbial population showed a decreasing trend on storage. The population of all microbes were comparatively higher in treatments with PGPR addition and kept under refrigerated condition.

4.2.2 Shelf life study after autoclaving

Storage of liquid manures in open and refrigerated condition in different containers had no effect on shelf life and the liquid manures had foul odour and severe mould infestation. Hence, liquid manures were subjected to autoclaving. Autoclaving removed the foul smell of the manures.

4.2.2.1 Nutrient analysis

The nutrient content of liquid manures after autoclaving are presented on Table 17. The results revealed that autoclaving did not bring any change in N, P and K content of liquid manures.

The nutrient content of liquid manures at different periods of storage was assessed with and without PGPR addition both under open and refrigerated condition and presented in Table 18. The results revealed that the N content varied with storage periods. PGPR addition and method of storage significantly enhanced N content of all liquid manures. At 15 DAS, L_3 with PGPR addition registered the highest N content of 0.90 % under refrigerated condition. The liquid manures kept both under open and refrigerated condition without PGPR addition showed a significant decline in N content on storage. The initial N content without PGPR addition (0.45, 0.50 and 0.62 % of L_1, L_2 and L_3) was reduced to 0.33, 0.38 and 0.51 % respectively. With PGPR addition, the N content enhanced on storage up to 60 DAS and a significant reduction was observed on 90 DAS both under open and refrigerated condition. Among the liquid manures, L_3 registered the highest N content with PGPR addition.

The P content of liquid manures (Table 18) analysed at different storage periods revealed that maximum P content was maintained by L_2 with and without PGPR addition up to 30 DAS. Storage of liquid manure reduced the P content. Though refrigerated storage of PGPR added liquid manures decreased with increase in storage time, the decrease was more pronounced under open storage. From the initial value of 0.07 % P (with PGPR addition) for L_1 the value was reduced to 0.03 % at 15 DAS and the content was retained up to 45 DAS. Subsequently the content was reduced to 0.02 %. In the case of L_2 and L_3 the P content with PGPR addition was maintained to 0.07 % up to 45 DAS in a refrigerator and decreased subsequently.

The K content of liquid manures was estimated at 15, 30, 45, 60 and 90 DAS and results presented in Table 18. For all liquid manures addition of PGPR enhanced the K content. The treatment L_3 registered the highest K content with PGPR addition and refrigerated storage at 15, 30 and 45 DAS. The variation between open and refrigerated storage was found to be insignificant for L_2 at 15, 30 and 45 DAS. Though a slight reduction from the initial K content was observed at 15 DAS, the content was maintained up to 60 DAS and a decline was observed at 90 DAS.

Table 11. Microbial population of liquid manures prior to storage (× 10^7)

Treatments	L_1		L_2		L_3	
	Without PGPR	With PGPR	Without PGPR	With PGPR	Without PGPR	With PGPR
Azotobacter	7	19	6	16	6	6
Azospirillum	6	25	7	49	5	60
Pseudomonas	8	118	8	131	8	114
P solubilisers	5	6	6	8	6	9
K solubilisers	8	13	7	16	7	21

Table 12. Population of *Azotobacter* in liquid manures on storage (× 10^7)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	3.50	3.00	15.50	14.50	4.50	3.50	19.50	18.50
L_2	2.50	2.00	12.50	11.50	3.50	2.50	16.50	15.50
L_3	2.50	2.00	12.50	12.00	3.50	2.50	19.50	18.50
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	2.50	2.00	7.50	6.50	2.50	2.00	13.50	13.00
L_2	2.50	2.00	6.00	5.50	3.50	2.50	10.50	10.00
L_3	2.50	2.00	12.00	11.00	3.50	2.50	16.50	16.00
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	0.00	0.00	5.50	4.50	1.50	0.50	6.00	5.00
L_2	1.00	1.00	5.00	4.00	2.00	1.50	7.50	6.50
L_3	1.00	1.00	8.00	7.50	2.50	1.50	13.50	11.50
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

DAS - Days after storage

Table 13. Population of *Azospirillum* in liquid manures on storage (× 10^7)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	2.50	2.00	21.50	20.50	2.50	2.00	27.50	26.50
L_2	2.50	1.50	45.50	44.50	2.50	1.50	53.50	52.50
L_3	2.50	2.00	57.00	56.50	2.50	1.50	62.50	61.50
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	2.50	1.50	17.00	16.00	2.00	2.50	21.00	20.00
L_2	1.50	0.50	32.50	31.50	1.50	0.50	43.00	41.00
L_3	1.00	1.50	29.00	29.50	2.50	1.50	40.00	39.00
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	2.50	1.50	8.50	8.00	1.50	1.00	13.00	12.00
L_2	1.50	0.50	18.00	17.00	1.50	0.50	23.50	23.00
L_3	1.00	1.50	15.50	14.50	2.00	1.50	20.50	20.00
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 14. Population of *Pseudomonas* in liquid manures on storage (× 10^7)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	4.50	3.50	112.50	110.50	5.50	4.50	120.00	118.00
L_2	5.00	4.50	126.00	124.00	5.00	4.50	126.00	124.00
L_3	5.00	4.50	108.50	106.50	4.50	4.00	126.00	124.00
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	2.50	2.00	84.00	83.00	3.50	2.50	86.00	84.00
L_2	4.00	3.00	85.50	84.50	3.50	2.50	86.00	84.00
L_3	3.50	2.50	74.00	72.00	3.50	2.50	84.50	82.50
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	2.50	1.50	32.00	30.00	2.50	1.50	36.00	34.00
L_2	1.50	0.50	21.50	20.50	2.00	1.00	22.00	20.00
L_3	2.50	1.50	20.50	19.00	2.50	1.50	21.00	20.00
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

DAS - Days after storage

Table 15. Population of *P solubilisers* in liquid manures on storage (× 10^7)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	2.50	1.50	3.00	2.00	2.50	1.00	4.50	3.50
L_2	3.00	2.00	4.50	3.50	3.50	2.00	7.50	6.50
L_3	3.50	2.50	5.50	4.50	3.00	2.00	9.50	8.50
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	2.50	1.50	1.50	1.00	2.50	1.50	3.50	3.00
L_2	1.50	0.50	2.50	2.00	1.50	0.50	7.50	6.50
L_3	2.50	1.50	4.50	3.50	2.50	1.50	8.00	7.50
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	2.00	1.00	1.50	0.50	2.50	1.50	2.50	2.00
L_2	1.50	0.50	2.50	1.50	1.50	0.50	5.00	4.50
L_3	2.00	1.00	3.50	2.50	2.50	1.50	3.50	3.00
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 16. Population of *K solubilisers* in liquid manures on storage (× 10^7)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen	Plastic	Earthen
7 DAS								
L_1	4.50	3.50	9.50	8.50	5.50	4.50	13.50	12.50
L_2	4.00	3.50	12.50	11.50	4.50	3.50	15.50	14.50
L_3	4.50	3.50	18.50	16.50	4.50	3.50	27.50	25.50
CD	NS	NS	NS	NS	NS	NS	NS	NS
15 DAS								
L_1	2.50	2.00	6.50	4.50	2.50	2.00	10.50	9.50
L_2	1.50	1.00	7.50	6.50	1.50	1.00	13.50	12.50
L_3	3.50	2.50	9.50	8.50	2.50	2.00	14.00	12. 50
CD	NS	NS	NS	NS	NS	NS	NS	NS
30 DAS								
L_1	1.50	0.50	3.50	2.50	1.50	0.50	3.50	3.00
L_2	1.50	0.50	4.50	3.50	1.50	0.50	4.50	4.00
L_3	2.50	1.50	4.50	3.50	1.50	1.00	6.50	5.50
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

DAS - Days after storage

Table 17. Nutrient content of liquid manures after autoclaving (%)

Treatments	N	P	K
T_4	0.45	0.03	0.15
T_5	0.50	0.07	0.17
T_6	0.62	0.01	0.17

Table 18. N, P, K content of liquid manures at different periods of storage after autoclaving

Treatments	Open condition						Refrigerated condition					
	Without PGPR			With PGPR			Without PGPR			With PGPR		
	N	P	K	N	P	K	N	P	K	N	P	K
15 DAS												
L_1	0.43	0.01	0.10	0.68	0.02	0.10	0.44	0.03	0.13	0.68	0.03	0.13
L_2	0.51	0.04	0.10	0.73	0.04	0.15	0.51	0.05	0.11	0.75	0.07	0.15
L_3	0.61	0.02	0.11	0.87	0.03	0.13	0.62	0.05	0.15	0.90	0.07	0.16
CD (0.05%)	0.027	0.009	0.016	0.027	0.009	0.016	0.027	0.009	0.016	0.027	0.009	0.016
30 DAS												
L_1	0.42	0.01	0.10	0.73	0.02	0.10	0.42	0.02	0.13	0.73	0.03	0.13
L_2	0.48	0.04	0.10	0.79	0.03	0.15	0.49	0.06	0.11	0.80	0.07	0.15
L_3	0.58	0.02	0.11	0.90	0.02	0.13	0.58	0.05	0.14	0.90	0.07	0.16
CD (0.05%)	0.021	0.012	0.047	0.021	0.012	0.047	0.021	0.012	0.047	0.021	0.012	0.047
45 DAS												
L_1	0.37	0.01	0.10	0.82	0.01	0.10	0.38	0.02	0.13	0.83	0.03	0.13
L_2	0.43	0.03	0.10	0.85	0.02	0.15	0.44	0.05	0.11	0.84	0.07	0.15
L_3	0.56	0.02	0.11	0.97	0.02	0.11	0.57	0.04	0.12	0.97	0.07	0.16
CD (0.05%)	0.031	0.011	0.048	0.031	0.011	0.048	0.031	0.011	0.048	0.031	0.011	0.048
60 DAS												
L_1	0.35	0.01	0.10	0.89	0.01	0.10	0.35	0.02	0.11	0.91	0.02	0.12
L_2	0.40	0.02	0.10	0.92	0.02	0.15	0.41	0.04	0.11	0.92	0.03	0.15
L_3	0.53	0.02	0.10	0.98	0.02	0.11	0.53	0.03	0.11	0.99	0.05	0.16
CD (0.05%)	0.024	0.156	0.057	0.024	0.156	0.057	0.024	0.156	0.057	0.024	0.156	0.057
90 DAS												
L_1	0.33	0.01	0.09	0.87	0.01	0.09	0.32	0.01	0.10	0.89	0.02	0.11
L_2	0.38	0.01	0.09	0.89	0.01	0.12	0.38	0.04	0.09	0.90	0.03	0.12
L_3	0.51	0.01	0.09	0.96	0.01	0.10	0.53	0.02	0.11	0.97	0.04	0.15
CD (0.05%)	0.023	0.007	0.001	0.023	0.007	0.001	0.023	0.007	0.001	0.023	0.007	0.001

4.2.2.2 Microbial population analysis

The microbial population of liquid manures were assessed after autoclaving with and without PGPR addition prior to storage and results are presented in Table 19. In all liquid manures PGPR addition enhanced the count of *Azotobacter, Azospirillum, Pseudomonas, P solubilisers* and *K solubilisers.*

The microbial population of liquid manures after autoclaving was assessed at different periods of storage and the data are presented in Tables 20 to 22. The population of *Azotobacter* (Table 20) estimated at different periods of storage was significantly influenced by the treatments. PGPR addition enhanced the population of *Azotobacter*. The initial population of *Azotobacter* was maintained in all liquid manures up to 15 DAS in refrigerated storage and the population declined subsequently. Though L_2 registered the highest population of *Azotobacter* with PGPR addition, the population declined at 30, 45, and 90 days of storage and was found to be significantly lower than L_3 at 60 and 90 days of storage. The reduction in *Azotobacter* population over different storage periods was more significant in open storage.

The results presented in Table 20 revealed that the *Azospirillum* population in different liquid manures at different storage periods significantly reduced with increase in storage time. PGPR addition enhanced the population. The population in general was more under refrigerated condition. With increase in storage period the population of *Azospirillum* was reduced.

The *Pseudomonas* population (Table 21) estimated at different periods of storage showed significant variation due to treatments. PGPR addition significantly increased the population of *Pseudomonas* and the difference between open and refrigerated storage was found to be insignificant. Among the liquid manures, L_2 registered the highest population at 15 DAS while the population was more in L_3 at 30, 45, 60 and 90 DAS.

The population of *P solubilisers* (Table 22) also varied with treatments. PGPR addition significantly enhanced the population of *P solubilisers* in all liquid

Table 19. Microbial population of liquid manures prior to storage after autoclaving ($\times 10^7$)

Microbial population						
	L_1		L_2		L_3	
Microbes	Without PGPR	With PGPR	Without PGPR	With PGPR	Without PGPR	With PGPR
Azotobacter	2.00	11.50	1.50	10.50	2.50	9.50
Azospirillum	1.50	20.00	0.50	40.50	1.50	30.50
Pseudomonas	2.50	84.00	2.50	89.50	3.00	84.50
P solubilisers	1.00	5.00	0.50	4.50	1.50	5.50
K solubilisers	2.00	9.00	1.50	10.50	2.00	14.00

Table 20. Population of *Azotobacter* and *Azospirillum* in liquid manures at different periods of storage after autoclaving ($\times 10^7$)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
15 DAS	AZ	AS	AZ	AS	AZ	AS	AZ	AS
L_1	2.00	1.50	9.50	18.50	2.00	2.00	11.50	21.50
L_2	1.50	0.50	8.50	38.00	1.50	0.50	18.50	41.50
L_3	2.50	1.50	7.50	28.00	2.50	1.50	11.00	33.00
CD (0.05%)	2.555	1.989	2.555	1.989	2.555	1.989	2.555	1.989
30 DAS								
L_1	0.50	0.50	3.00	4.50	0.50	1.50	4.50	8.50
L_2	0.50	0.50	3.50	11.50	1.50	0.50	3.50	14.00
L_3	1.00	1.50	2.00	13.50	1.50	1.50	5.00	14.00
CD (0.05%)	1.779	1.664	1.779	1.664	1.779	1.664	1.779	1.664
45 DAS								
L_1	0.00	0.50	2.50	3.50	0.50	1.00	3.50	6.50
L_2	0.00	0.50	2.00	8.00	0.50	0.50	3.50	11.50
L_3	0.00	1.50	2.00	11.00	1.50	1.50	5.00	13.00
CD (0.05%)	1.664	1.989	1.664	1.989	1.664	1.989	1.664	1.989
60 DAS								
L_1	0.00	0.50	2.00	3.50	0.50	1.00	2.50	4.50
L_2	0.00	0.50	2.00	4.50	0.50	0.50	2.50	7.50
L_3	0.00	1.50	2.00	9.00	1.50	1.50	4.00	10.50
CD (0.05%)	1.603	1.406	1.603	1.406	1.603	1.406	1.603	1.406
90 DAS								
L1	0.00	0.00	1.00	2.00	0.00	1.00	1.50	3.00
L2	0.00	0.00	1.00	3.50	0.00	0.50	1.50	6.00
L3	0.00	1.00	1.50	7.00	1.00	1.00	3.00	7.50
CD (0.05%)	0.832	0.770	0.832	0.770	0.832	0.770	0.832	0.770

DAS - Days after storage

AZ - *Azotobacter*

AS - *Azospirillum*

Table 21. Population of *Pseudomonas* in liquid manures at different periods of storage after autoclaving ($\times 10^7$)

Treatments	Open condition		Refrigerated condition	
	Without PGPR	With PGPR	Without PGPR	With PGPR
15 DAS				
L_1	2.50	82.00	2.50	83.50
L_2	2.50	87.50	2.50	87.50
L_3	3.00	82.50	2.50	84.50
CD (0.05%)	2.882	2.882	2.882	2.882
30 DAS				
L_1	1.50	12.50	1.50	13.50
L_2	0.50	18.50	2.00	17.00
L_3	1.50	20.00	2.00	20.00
CD (0.05%)	1.938	1.938	1.938	1.938
45 DAS				
L_1	0.50	7.50	1.00	8.00
L_2	0.50	9.50	1.00	10.00
L_3	1.50	11.50	1.50	12.00
CD (0.05%)	2.476	2.476	2.476	2.476
60 DAS				
L_1	0.50	5.50	1.00	6.50
L_2	0.50	7.50	1.00	8.50
L_3	1.50	9.50	1.00	9.50
CD (0.05%)	1.334	1.334	1.334	1.334
90 DAS				
L_1	0.00	4.00	0.00	3.50
L_2	0.00	6.50	0.00	4.50
L_3	1.00	7.50	1.00	7.50
CD (0.05%)	0.994	0.994	0.994	0.994

DAS - Days after storage

manures. The treatment L_3 registered the highest population at different storage periods and refrigerated storage was found to be superior to open storage. With increase in storage period, the population of *P solubilisers* decreased and the value reached zero at 60 DAS for L_2 without PGPR addition. The population of *P solubilisers* was more with PGPR addition and refrigerated storage at 90 DAS.

Results presented in Table 22 showed that the population of *K solubilisers* significantly increased with PGPR addition. The treatment L_3 registered the highest population of 12.50 with PGPR addition and refrigerated storage and it was on par with PGPR addition and open storage at 15 DAS. At 30, 45, 60 and 90 DAS also, L_3 registered the highest count with PGPR addition. Refrigerated storage was observed to be superior to open storage. In general the population of K solubilisers decreased with increase in storage period.

Part III

4.3 CROP RESPONSE STUDY – FIELD EXPERIMENT

Field experiments were conducted to assess the efficiency of the selected organic liquid manures on growth and yield of vegetables and the test crops selected were amaranthus and bhindi.

4.3.1 Amaranthus

4.3.1.1 Growth characters

4.3.1.1.1 Plant height

The data presented in Table 23 showed the effect of different treatments on plant height of amaranthus recorded prior to each harvest. The different treatments significantly influenced plant height at each harvest. T_3 recorded maximum plant height and was significantly superior to all other treatments. Treatments T_1, T_5 and T_6 were on par and followed by T_3 at first harvest. The lowest plant height was recorded by T_4 at first and second harvests

Table 22. Population of *P* and *K solubilisers* in liquid manures at different periods of storage after autoclaving ($\times 10^7$)

Treatments	Open condition				Refrigerated condition			
	Without PGPR		With PGPR		Without PGPR		With PGPR	
15 DAS	P	K	P	K	P	K	P	K
L_1	1.00	2.00	3.00	7.50	1.00	2.00	2.50	8.50
L_2	0.50	1.50	2.50	8.50	0.50	1.50	4.50	10.50
L_3	1.50	2.00	3.50	11.50	1.50	2.50	5.50	12.50
CD (0.05%)	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334
30 DAS								
L_1	1.00	0.50	2.00	2.50	1.00	0.50	2.00	3.50
L_2	0.50	0.50	1.50	3.00	0.50	0.50	3.00	4.50
L_3	1.00	1.50	2.50	3.50	1.00	1.50	3.50	5.50
CD (0.05%)	0.994	1.475	0.994	1.475	0.994	1.475	0.994	1.475
45 DAS								
L_1	0.50	0.50	1.00	2.00	1.00	0.50	2.00	3.50
L_2	0.00	0.50	1.50	2.00	0.50	0.50	2.50	3.50
L_3	1.00	1.50	1.50	2.50	0.50	1.00	3.00	4.50
CD (0.05%)	1.089	1.334	1.089	1.334	1.089	1.334	1.089	1.334
60 DAS								
L_1	0.50	0.00	0.50	1.50	1.00	0.50	1.50	3.00
L_2	0.00	0.00	1.00	1.50	0.00	0.50	1.50	2.50
L_3	1.00	1.00	1.00	2.00	0.50	1.00	2.00	3.50
CD (0.05%)	0.994	1.089	0.994	1.089	0.994	1.089	0.994	1.089
90 DAS								
L_1	0.00	0.00	0.00	1.00	0.00	0.00	1.00	2.00
L_2	0.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00
L_3	0.00	0.50	0.50	1.50	0.50	0.00	1.00	2.50
CD (0.05%)	0.629	0.770	0.629	0.770	0.629	0.770	0.629	0.770

DAS - Days after storage

P – *P solubilisers*

K – *K solubilisers*

(30.84 and 28.27 cm respectively). T_5 registered the lowest height at third and fourth harvests.

4.3.1.1.2 Number of leaves plant^{-1}

Data furnished in Table 23 indicated significant variation in leaf number plant^{-1} due to treatments. T_3 recorded maximum number of leaves prior to each harvest and it was significantly superior to all other treatments. T_6 followed T_3 prior to first and second harvests. The lowest number of leaves was recorded by T_2 at first two harvests (23.99 and 25.89 respectively), and T_5 at last two harvests (28.36 and 26.75 respectively).

4.3.1.1.3 Total drymatter production

Total drymatter production (Table 24) was significantly influenced by treatments. Maximum drymatter production was observed in T_3 (367.27 kg ha $^{-1}$) followed by T_5, T_2 and T_6 which were on par. The lowest production was noticed by T_1 (244.48 kg ha $^{-1}$) which was on par with T_4.

4.3.1.2 Quality attribute

4.3.1.2.1 Vitamin C content

The data on vitamin C content of amaranthus estimated prior to first harvest is presented in Table 24. The highest content was observed in T_3 (28.43 mg100 g^{-1} tissue) followed by T_2 and T_5 (28.21 mg 100 g^{-1} tissue) and the lowest was recorded in the treatment T_4 (23.08 mg 100 g^{-1}tissue).

4.3.1.3. Phyllosphere observation of microbes

Table 25 depicts the microbial population on the leaves estimated two days after foliar application . Maximum *Azotobacter* population was observed in T_1 (3× 10^3) followed by T_2, T_3 and T_5 (2× 10^3). The highest population of *Azospirillum* was recorded in T_2 (8× 10^3) followed by T_3. The treatments T_1 and T_3 registered the maximum population of *Pseudomonas* (12× 10^6) followed by T_2 .

Table 23. Effect of foliar nutrition on plant height (cm) and number of leaves $plant^{-1}$ prior to each harvest

Treatments	1st harvest		2nd harvest		3rd harvest		4th harvest	
	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves
T_1	42.34	24.83	31.32	28.31	38.41	33.16	35.72	32.17
T_2	31.73	23.99	29.72	25.89	36.27	31.82	34.00	30.24
T_3	55.99	34.66	36.35	36.77	43.95	42.80	41.98	40.72
T_4	30.84	25.66	28.27	27.35	32.94	30.73	29.89	29.16
T_5	40.32	28.08	30.09	29.54	29.03	28.36	28.80	26.75
T_6	42.17	29.33	31.18	32.00	32.66	32.66	31.70	29.59
SE	0.71	0.43	0.39	0.50	0.42	0.35	0.31	0.34
CD (0.05)	2.146	1.325	1.192	1.528	1.281	1.062	0.95	1.04

Table 24. Effect of foliar nutrition on total dry matter production (kg ha^{-1}) and vitamin C content (mg 100 g^{-1})

Treatments	Total dry matter production	*Vitamin C content
T_1	244.48	26.10
T_2	267.15	28.21
T_3	367.27	28.43
T_4	247.42	23.08
T_5	276.15	28.21
T_6	269.17	24.26
SE	3.700	
CD (0.05)	11.175	

* Data not statistically analysed

Population of *P solubilisers* was the highest in T_2 (3× 10^3) followed by T_1 and T_3 (2× 10^3) and *K solubilisers* were maximum in T_3 (3× 10^6). There was no microbial population in the phyllosphere T_4 and T_6.

4.3.1.4 Yield

Yield of amaranthus (Table 26) was significantly influenced by different foliar nutrient sources. The highest yield of 5.92 t ha^{-1} was obtained for T_5 at first harvest which was significantly superior to all other treatments. In subsequent harvests (second, third and fourth) T_3 registered the highest yields of 1.32, 3.08 and 3.08 t ha^{-1} respectively . The total yield was found to be the highest in T_3 (12.24 t ha^{-1}) and was significantly superior to all other treatments. This was followed by T_5, T_6 and T_2 which were on par. The total yield was the lowest in T_1(8.15 t ha^{-1}).

4.3.1.5 Soil nutrient status after the experiment

The available nitrogen content of soil after the harvest of amaranthus furnished in Table 27 revealed that the different treatments had no significant influence on the soil N content. However, the lowest N content was registered by T_4 (foliar application of urea).

The data given in Table 27 clearly depicts the significant influence of treatments on available phosphorous content in soil after the experiment. T_6 recorded the maximum P content (42.04 kg ha^{-1}) in soil and which was on par with T_5. The minimum content was registered by T_1 (36.25 kg ha^{-1}).

Various treatments significantly influenced the available potassium content of soil after harvest (Table 27). The highest available potassium content was recorded in T_2 (146.10 kg ha^{-1}) and was on par with T_3, T_4 and T_5. The lowest content was recorded by T_1 (141.75 kg ha^{-1}).

*Table 25. Effect of foliar nutrition on phyllosphere observation of microbes

Microbes	Treatments					
	T_1	T_2	T_3	T_4	T_5	T_6
Azotobacter (10^3)	3	2	2	0	2	0
Azospirillum (10^3)	3	8	4	0	2	0
Pseudomonas (10^6)	12	10	12	0	4	0
P solubilisers (10^3)	2	3	2	0	1	0
K solubilisers (10^6)	2	2	3	0	2	0

Table 26. Effect of foliar nutrition on yield of amaranthus (t ha^{-1})

	Yield at each harvest				Total yield
Treatments	1^{st} harvest	2^{nd} harvest	3^{rd} harvest	4^{th} harvest	
T_1	2.60	1.21	2.23	2.1	8.15
T_2	3.44	1.18	2.16	2.11	8.90
T_3	4.75	1.32	3.08	3.08	12.24
T_4	3.94	1.20	1.38	1.72	8.24
T_5	5.92	1.06	1.13	1.08	9.20
T_6	4.59	1.18	1.98	1.21	8.97
SE	0.046	0.007	0.085	0.006	0.123
CD (0.05)	0.140	0.023	0.257	0.020	0.372

Table 27. Effect of foliar nutrition on soil nutrient status after the experiment (kg ha^{-1})

Available nutrient status			
Treatments	N	P	K
T_1	224	36.25	141.75
T_2	210	38.21	146.10
T_3	224	37.71	144.80
T_4	196	36.82	145.55
T_5	224	39.25	144.75
T_6	210	42.04	143.45
SE	0	1.18	0.93
CD(0.05)	NS	3.568	2.814

4.3.1.6 Economic analysis of amaranthus cultivation

The results depicted in Table 28 revealed the significant influence of different sources of foliar nutrition on the economic analysis. T_3 was observed to be significantly superior to all other treatments in gross income, net income and B:C ratio. The highest net income of Rs. 69802 ha^{-1} was registered by T_3 giving a B:C ratio of 2.3. The treatments T_5 and T_2 were observed to be on par and followed by T_3 on gross income. Considering net income and B:C ratio T_3 was followed by T_5 and T_6 which were on par. In all economic aspects T_1 registered the lowest value and significantly inferior to other treatments except T_4 in net income and B:C ratio. T_1 registered the lowest B:C ratio of 1.64.

4.3.2 Bhindi

4.3.2.1 Growth characters

4.3.2.1.1 Plant height

The data on plant height of bhindi recorded at different periods is presented in Table 29. The data revealed that the treatments caused significant variation in plant height at different intervals. T_3 recorded maximum plant height at all stages. At 30 DAS, T_3 was followed by T_6, T_5 and T_4 which were on par. The lowest value was registered by T_2. At 60 DAS T_3 registered the highest plant height of 68.05 cm which was followed by T_6 and T_4 which were on par. At 90 and 120 DAS, T_3 was followed by T_6 and the lowest plant height was registered by T_1 (76.00 and 87.15 cm respectively).

4.3.2.1.2 Number of functional leaves plant^{-1}

The data summarised in the Table 29 revealed significant variation among treatments in the number of functional leaves $plant^{-1}$ recorded at different periods. At all stages, T_3 was found to be significantly superior to all other treatments. At 30 DAS, T_3 was followed by T_6, T_5 and T_1 which were on par. At 60, 90 and 120 DAS, T_3 was followed by T_6 which was significantly superior to other treatments. T_2 recorded the lowest leaf number at 30 and 60 DAS. At 90 and 120 DAS, T_4

Table 28. Effect of foliar nutrition on gross return, net return and B:C ratio

Treatments	Total cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	B:C ratio
T_1	49823	81500	31677	1.64
T_2	50323	89050	38727	1.77
T_3	52623	122425	69802	2.33
T_4	41663	82475	40812	1.98
T_5	46223	92050	45827	1.99
T_6	41973	89725	47752	2.14
SE		1235.82	1235.82	0.02
CD(0.05)		3724.39	3724.39	0.09

Market price of amaranthus - Rs. 10 kg^{-1}

Table 29. Effect of foliar nutrition on plant height (cm) and number of functional leaves $plant^{-1}$ at different intervals

Plant height and No. of functional leaves at different intervals								
Treatments	30 DAS		60 DAS		90 DAS		120 DAS	
	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves	Plant height	No. of leaves
T_1	41.21	12.02	61.94	33.77	76.00	36.77	87.15	34.87
T_2	40.01	10.85	63.67	33.44	87.59	36.10	98.55	33.81
T_3	46.34	15.19	68.05	42.20	92.03	45.70	103.63	40.87
T_4	42.02	10.48	63.95	32.38	87.59	35.20	98.54	31.86
T_5	42.27	11.74	63.39	34.29	87.52	37.09	97.50	34.88
T_6	42.72	12.36	65.30	36.00	89.44	39.33	99.89	36.77
SE	0.39	0.21	0.46	0.43	0.48	0.36	0.47	0.20
CD (0.05)	1.201	0.651	1.404	1.316	1.475	1.11	1.416	0.63

DAS - Days after sowing

was found to be significantly inferior to other treatments on number of functional leaves plant^{-1}.

4.3.2.1.3 Total dry matter production

The results presented in Table 30 indicated that the different sources of foliar nutrition had significant influence on the total dry matter production. Among the treatments T_3 registered the highest dry matter yield of 5.74 t ha^{-1} and was followed by T_5 and T_2. T_4 registered the lowest dry matter production of 5.30 t ha^{-1}

4.3.2.2 Chlorophyll content

Chlorophyll content of bhindi is given in Table 30. The highest chlorophyll content was observed in T_3 (29.90 mg g tissue^{-1}) which was significantly superior to all other treatments and was followed by T_5 (25.50 mg g tissue^{-1}) which was on par with T_6 (24.90 mg g tissue^{-1}). The content was the lowest in T_1 (17.91 mg g^{-1} tissue).

4.3.2.3 Phyllosphere observation of microbes

Data on microbial population on leaves observed two days after foliar nutrition is furnished in Table 31. The population of *Azotobacter* did not vary among the treatments T_1, T_2, T_3 and T_5 (2×10^3). Population of *Azospirillum* was the highest in T_2 (6×10^3) followed by T_3 and T_1. The treatment T_3 recorded the maximum population of *Pseudomonas* (14×10^6). Population of *P solubilisers* was the highest in T_2 (4×10^3). The count of *K solubilisers* was maximum in T_3 (4×10^6) followed by T_2. The treatments T_4 and T_6 failed to register any count of microbes.

Table 30. Effect of foliar nutrition on total drymatter production (t ha^{-1}) and chlorophyll content (mg g^{-1}tissue)

Treatments	Drymatter production	Chlorophyll content
T_1	5.31	17.91
T_2	5.34	22.05
T_3	5.74	29.90
T_4	5.30	21.44
T_5	5.40	25.50
T_6	5.35	24.90
SE	0.003	0.31
CD (0.05)	0.009	0.960

Table 31. Effect of foliar nutrition on phyllosphere observation of microbes

Microbes	Treatments					
	T_1	T_2	T_3	T_4	T_5	T_6
Azotobacter (10^3)	2	2	2	0	2	0
Azospirillum (10^3)	3	6	3	0	2	0
Pseudomonas (10^6)	8	9	14	0	3	0
P solubilissers (10^3)	2	4	2	0	1	0
K solubilisers (10^6)	2	3	4	0	2	0

4.3.2.4 Yield Attributes and Yield

4.3.2.4.1 Number of fruits plant^{-1}

Data on the effect of treatments on number of fruits plant^{-1} is presented in Table 32. The maximum fruit number was registered in T_3 (26.90) which was significantly higher than all other treatments. This was followed by T_6 (22.66) which was on par with T_5 (22.58). The lowest fruit number was recorded by T_1 (20.66) which was on par with T_2.

4.3.2.4.2 Weight of fruits plant^{-1}

Data furnished in Table 32 showed significant variation among treatments in the weight of fruits plant^{-1}. T_3 recorded the maximum weight of fruits (685.36 g plant^{-1}) which was significantly superior to other treatments. T_3 was followed by T6 (581.52 g plant^{-1}) which was on par with T_4 and T_5.

4.3.2.4.3 Yield

The data presented in Table 32 revealed that the different treatments tried had a significant effect on the yield of bhindi. At all the harvests the highest yield was obtained in T_3 (2.51, 2.38, 2.46, 2.92, 3.25, 2.27 t ha^{-1} respectively). In the first and fourth harvests T_3 was followed by T_5 and T_2 which were on par. However, in second harvest all other treatments except T_4 were on par and followed T_3. In third harvest, T_3 was followed by T_5 which was on par with T_2 and T_6. In fifth and sixth harvests T_3 was followed by T_6 and T_4 respectively. The treatments T_1 and T_5 registered the lowest yield in fifth and sixth harvests.

Total yield also showed significant variation among treatments and the highest yield was recorded in T_3 (15.80 t ha^{-1}) which was significantly superior to all other treatments. T_3 was followed by T_2 and T_5 which were on par. The other three treatments *viz;* T_1, T_4 and T_6 were observed to be on par with each other.

32. Effect of foliar nutrition on yield attributes and yield of bhindi

Treatments	No. of fruits plant^{-1}	Weight of fruits plant^{-1}	Yield at each harvest						
			1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest	6th harvest	Total yield
T_1	20.66	555.83	1.47	1.86	2.13	2.16	2.46	1.21	11.31
T_2	21.08	551.03	1.75	1.94	2.19	2.31	2.48	1.63	12.32
T_3	26.90	685.36	2.51	2.38	2.46	2.92	3.25	2.27	15.80
T_4	21.58	575.13	1.39	1.39	2.14	2.21	2.52	1.75	11.42
T_5	22.58	577.59	1.81	1.87	2.23	2.29	2.46	1.53	12.21
T_6	22.66	581.52	1.41	1.88	2.16	2.22	2.55	1.37	11.61
SE	0.29	4.06	0.027	0.024	0.027	0.015	0.006	0.031	0.045
CD(0.05)	0.877	12.248	0.082	0.073	0.084	0.035	0.020	0.093	0.135

4.3.2.5 Soil nutrient status after the experiment

The data on available nitrogen content of soil after the harvest of bhindi (Table 33) revealed no significant variation due to treatments.

The data presented in Table 33 clearly depicts the significant influence of treatments on available phosphorous content in soil. T_2 registered the maximum P content (44.20 kg ha^{-1}) in soil and which was on par with T_1 and T_4. The minimum content was recorded by T_3 (34.63 kg ha^{-1}).

Various treatments significantly influenced by available potassium content of soil (Table 33) after the harvest of crop. The highest content was recorded in T_2 and T_5 (157.52 kg ha^{-1}) which was on par with T_1, T_6. T_3 registered the lowest potassium content of 154 .46 kg ha^{-1}.

4.3.2.6 Economic analysis of bhindi cultivation

The data on economic analysis (Table 34) revealed the significant influence of different treatments. T_3 was found to be significantly superior to other treatments in gross income, net return and B:C ratio. The highest B:C ratio of 2.64 was registered by T_3 which was followed by T_6 (2.50) . The lowest net income (Rs. 56727 ha^{-1}) and B:C ratio (2.00) was registered by T_1 which was significantly inferior to other treatments.

Table 33. Effect of foliar nutrition on soil nutrient status after the experiment (kg ha^{-1})

Available nutrients			
Treatments	N	P	K
T_1	224	43.42	156.28
T_2	210	44.20	157.52
T_3	210	34.63	154.26
T_4	196	42.20	156.67
T_5	224	40.22	157.52
T_6	210	38.63	156.28
SE	0	1.08	0.93
CD	NS	3.281	2.012

Table 34. Effect of foliar nutrition on gross return, net return and B:C ratio

Treatments	Total cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	B:C
T_1	56423	113150	56727	2.00
T_2	57048	123200	66152	2.16
T_3	59923	158075	98152	2.64
T_4	46223	114200	67977	2.47
T_5	51923	122150	70227	2.35
T_6	46473	116150	69677	2.50
SE		449.52	449.82	0.009
CD(0.05)		1354.717	1355.632	0.02

Market price of bhindi - Rs. 20 kg^{-1}

Discussion

5. DISCUSSION

An experiment entitled “Development of an effective organic liquid manure for vegetable crops’’ was carried out with the objective of developing a safe organic phytotonic for vegetable crops, to assess its shelf life and to evaluate its efficacy on the productivity of vegetable crops. The results of the study are discussed below.

5.1 Relative efficiency of organic manures and bio inoculants for quality liquid manure production

The feasibility of developing an organic liquid manure was explored by analysing the nutrient content of common organic manures, liquid manures and comparing the same with commercial formulations. The result of analysis of common organic manures (Table 3) revealed that groundnut cake had the highest N content (6.18 %) followed by neem cake, vermicompost and poultry manure (Fig. 3). The P content was the highest in poultry manure followed by groundnut cake. Poultry manure registered the highest K content followed by groundnut cake and vermicompost. The suitability of groundnut cake, neem cake, vermicompost and poultry manure for preparing quality organic manure was earlier reported by Vipitha (2011). The efficiency of cow’s urine and vermiwash in enhancing productivity through foliar nutrition was reported earlier (Bertram, 1999). However, in the present study the nutrient content of these liquid manures was observed to be lesser than the two commercial formulations available in market (*Nutrich Z* and *Biosix*). Among the liquid manures analysed, the commercial formulation *Nutrich Z* registered the highest N, P and K content. The presence of seaweed extract, humic acid, fulvic acid and amino acid might have improved the nutrient content of this formulation.

With the aim of developing an organic liquid manure of high N content, the liquid extracts of organic manures having high N content namely, groundnut cake, neem cake and poultry manure along with vermicompost and cowdung were collected after 15 and 30 DAS and analysed for major nutrients. Though the total N content of groundnut cake was 6.18 %, the N content in the extract at 15 and 30

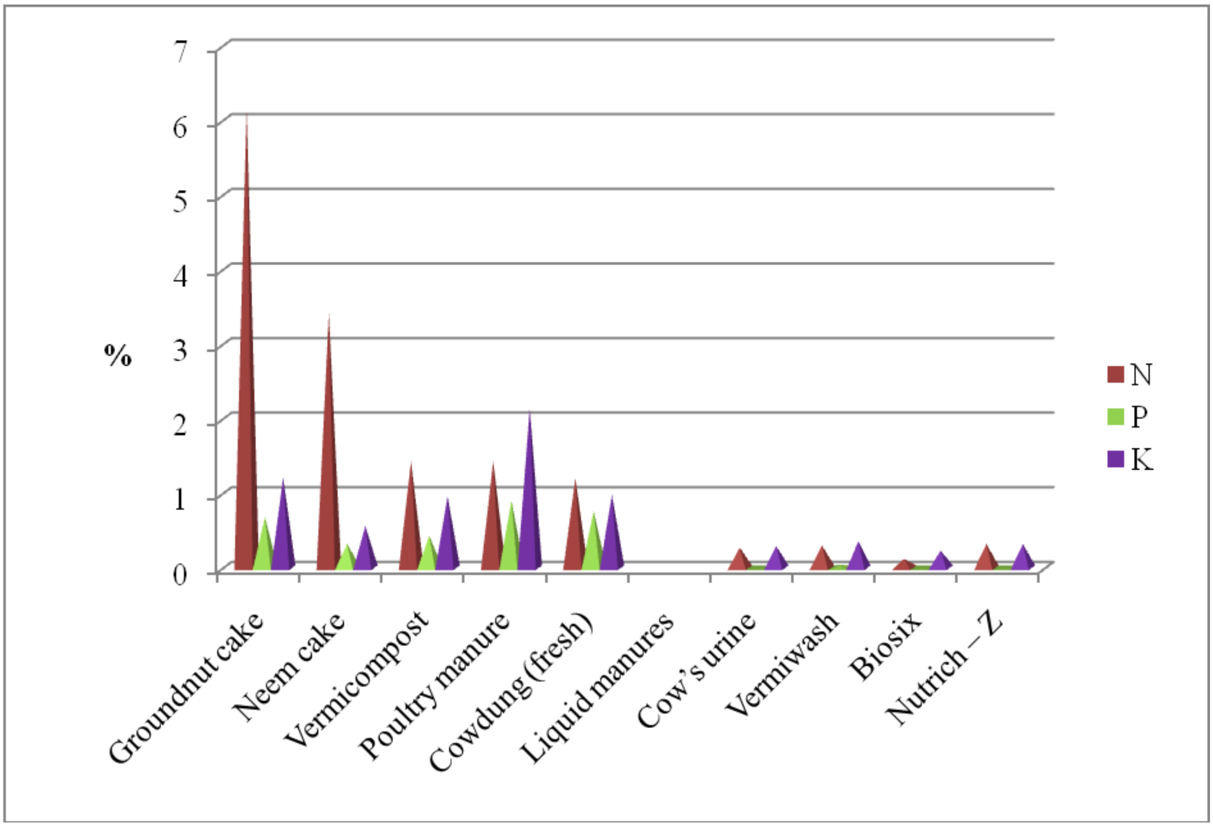


Fig.3. N, P, K content of organic manures and liquid manures

DAS were only 0.22 and 0.33 % respectively (Table 3). This revealed that only 3.5 to 5.3 % of the total N in groundnut cake was water soluble and available in the extracts. Although increasing the soaking time improved the nutrient content, it could not be recommended for practical use as the foul smell during soaking increased with increase in soaking period and the handling becomes very difficult. Since the N content of the extracts of selected manure were low, vermiwash collected from portable vermicompost units using kitchen waste and organic manure in different proportions were also analysed. Here also, the content was observed to be low ranging from, 0.20 to 0.40 % N, 0.02 to 0.07 % P and 0.10 to 0.16 % K (Table 4). This is in contrast to the reports made by Jasmine (1999) who observed comparatively a high N, P and K content of vermiwash prepared from farm waste (0.5, 0.39 and 0.46 % N, P, and K respectively). The reduction in nutrient content of vermiwash could be attributed to the variation in the quality of the substrate used for composting (Jasmine, 1999).

As the nutrient content of liquid manures from manure extracts and vermiwash collected from kitchen waste do not meet the required standard, composite organic manures were prepared with groundnut cake as the base manure and the extract collected after 7 DAS were analysed. From the result it was inferred that though the extracts of individual organic manures registered lower N content, the combinations were found to be effective in enhancing the nutrient content of the extracts. It is evident from the results presented in Tables 3 and 4. The extract of groundnut cake registered a N content of 0.22 % at 15 DAS. But the same manure in combination with vermicompost and poultry manure increased the N content of the extract and the content ranged from 0.26 to 0.62%. Among the composite manures tried, three combinations *viz;* groundnut cake and poultry manure (1:1 ratio), groundnut cake, vermicompost and poultry manure (1:0.5:0.5 ratio) and groundnut cake, neem cake and poultry manure (1:0.5:0.5 ratio) were found promising and the N content of the extracts of these combinations were 0.45, 0.50 and 0.62 % respectively. This improvement might be due to the enhanced mineralisation of N in the organic manures brought about by the microbial population in poultry manure and vermicompost. Improvement in N content of composite organic manures over individual manures was also observed from the study on quality manure production by Vipitha (2011).

Though the objective is to develop a composite liquid manure of about 2 % N, the preliminary studies conducted could not develop a manure of about 2 % N. Hence, the three combinations having high N content were selected and enriched with PGPR. On PGPR addition the nutrient content of the selected manures increased from 0.45 to 0.56 %, 0.50 to 0.64 %, and 0.62 to 0.78 % respectively. The beneficial microbes in PGPR might have favoured in vitro N fixation leading to enhanced N content. Vipitha (2011) also observed similar result. The P and K content did not show any variation by PGPR addition. The selected liquid manures are observed to be acidic and this might be due to the release of organic acids by microbial action. Based on the result of preliminary study three promising organic liquid manures analysing 0.56, 0.64 and 0.78 % N (with PGPR addition) were selected for further study.

5.2 Influence of processing and storage methods on the shelf life of liquid manures

The study was conducted after pH adjustment to assess the shelf life of selected liquid manures without reduction in the nutrient content. The liquid manures kept for storage showed mould attack and the incidence was observed early in open condition (3DAS) and was delayed by 4 days under refrigerated condition. The different storage condition (open and refrigeration), variation in the containers (plastic and earthern) and addition of PGPR could not prevent the mould incidence in these liquid manures. The physical environment might have favoured the growth of undesirable microorganisms and refrigeration slightly delayed the growth leading to four days delay on mould attack. A drastic reduction was observed in the nutrient content under storage. From the initial N content of 0.56, 0.60 and 0.78 % of the liquid manures, the content declined drastically to 0.18 to 0.24 % in open and 0.19 to 0.25 % under refrigerated condition at 7 DAS. Subsequent observation at 15 and 30 DAS also revealed a reduction in the N content. With increase in storage period the population of microbes decreased, indicating that these microbes could not multiply in these liquid manures.

Since the different storage methods could not prevent mould incidence and reduction in nutrient content, the liquid manures were subjected to autoclaving after adjusting the pH to neutral values.

The results on the nutrient analysis illustrated in Table 18 revealed that N content of all liquid manures with PGPR addition increased linearly up to 60 DAS and a slight decline was observed on 90 DAS (Fig. 4). Among the three liquid manures, extract from the combination of groundnut cake, neem cake and poultry manure in 1: 0.5: 0.5 ratio registered the highest N content of 0.78 % and the same increased to 0.87, 0.90, 0.97 and 0.98 % on 15, 30, 45, and 60 DAS. At 90 DAS the N content of same manure showed a slight decline and the content was 0.96 %. The same trend was observed in the case of other two liquid manures. PGPR addition might have enhanced the activity of free living *Azotobacter* and *Azospirillum* thereby increasing the N content of liquid manures on storage. The enhanced mineralisation and in vitro N fixation by microbes also contributed to high N content. The ability of *Azospirillum* to fix N on salts of organic acids was reported by Palaniappan and Annadurai (1999). Vipitha (2011) also observed increase in N content of composite organic manures up to three months. Subsequent reduction in nutrient status might be due to reduction in microbial population.

In the case of P, addition of PGPR enhanced the P content and the content decreased with storage period. However, the reduction was slow in refrigerated storage condition. Among the liquid manures the highest P content was registered by L_2 (0.09 %) and the same was reduced to 0.07 % at 60 DAS with refrigeration. The K content of liquid manures did not show much variation with PGPR addition and in storage though an initial reduction was observed at 15 DAS the content was maintained up to two months and reduction was observed only at 90 DAS.

Among the manures, L_3 was found to be superior as far as the nutrient content is concerned. The high nutrient content of the components *viz;* groundnut cake and neem cake used for the preparation of composite manure along with the microbial load of poultry manure might have enhanced the N content in L_3. The beneficial microorganisms present in the microbial consortium also might have enhanced the mineralisation process and resulted in further improvement in

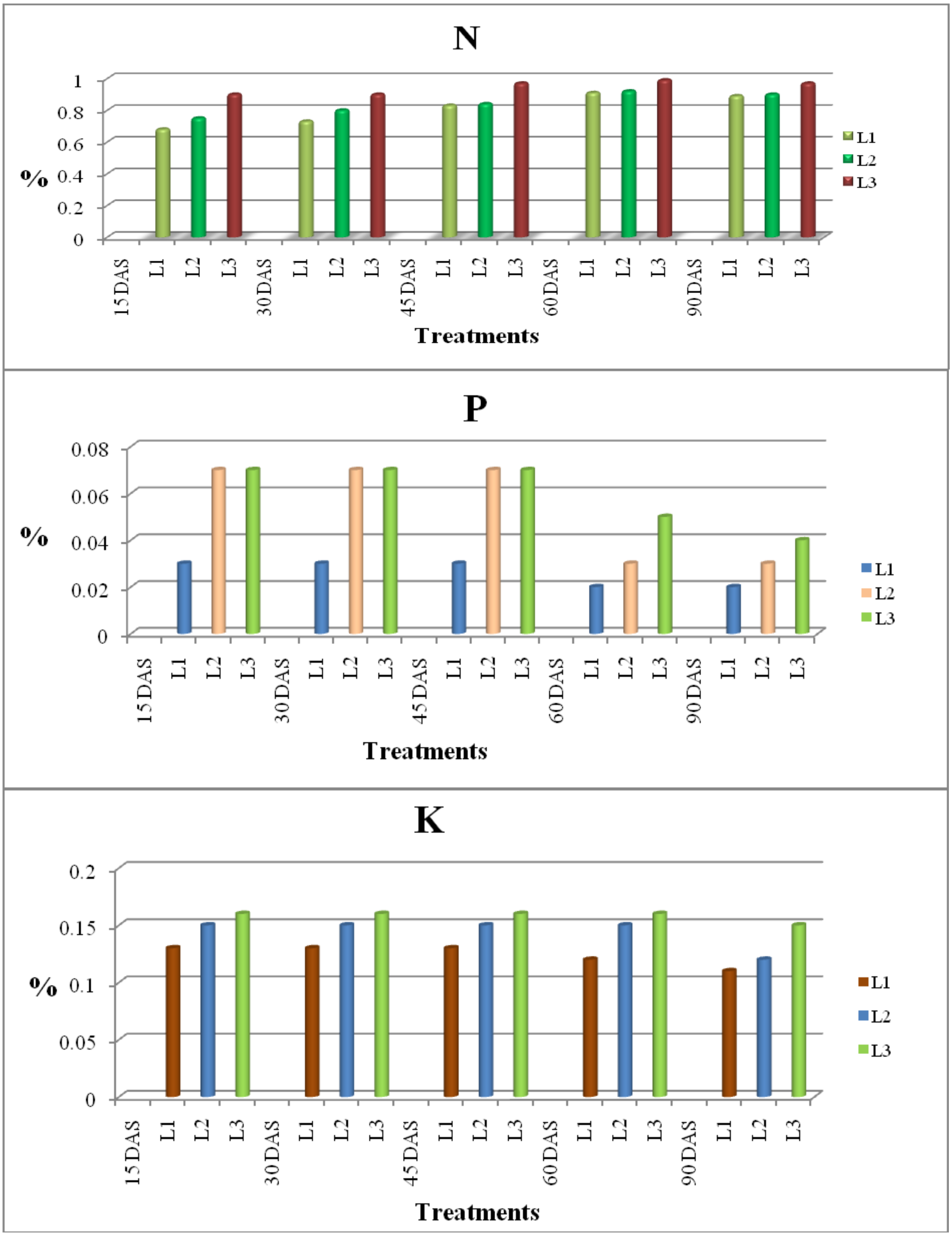


Fig.4. N,P,K content of liquid manures at different periods of storage with PGPR addition and autoclaving

nutrient content after PGPR addition.

The population of all beneficial microbes in liquid manures enhanced with PGPR addition (Table19). However, increase in storage time decreased the population (Tables 20 to 22). The refrigerated storage could maintain the population up to 15 DAS. The reduction in the population after 15 DAS could be attributed to microbial death due to absence of carbon source for further multiplication.

Autoclaving removed the foul smell and improved the shelf life. The process might have destroyed the undesirable microflora producing foul smell and prevented mould incidence on storage which in turn promoted the shelf life of these liquid manures.

From these data it could be inferred that liquid extracts of composite manures prepared from groundnut cake, neem cake and poultry manure could be stored for 60 days both under open and refrigerated condition with pH adjustment, PGPR addition and autoclaving without any nutrient reduction. The possibility of keeping vermiwash up to two months without any reduction in nutrient content was reported earlier by Murali and Neelanarayanan (2011). The microbial strains in the PGPR has the capacity for in vitro N fixation leading to enhanced N content on storage.

5.3 Response of amaranthus and bhindi to foliar nutrition with organic liquid manures

The results from the crop response study in amaranthus revealed that growth attributes like plant height and leaf number at different stages were maximum in the treatment where the topdressing of N was done by the foliar application of liquid manure prepared from the composite manure of groundnut cake, neem cake and poultry manure (1:0.5:0.5 ratio) enriched with PGPR (T_3). Beneficial microorganisms were observed on the phyllosphere of plants two days after foliar treatment with organic foliar liquid manures (Table 25). The proliferation of these micro organisms due to PGPR addition and their subsequent survival by the nutrients in liquid organic manures might have contributed to the plant growth. Analysis of the yield data revealed that though commercial formulation registered the highest yield for the first harvest, regrowth of plants after first harvest was poor. The treatment T_3 performed better in second, third and fourth harvests registering the highest total yield. Being a leafy vegetable crop, yield of amaranthus can be considered as a function of growth characters. The highest yield in T_3 is the product of increased plant height and better leaf production registered in that treatment (Fig. 5). The enhanced nutrient content in T_3 which is in a readily available form benefitted the plant growth. Improvement in yield of amaranthus with increase in plant height and leaf number was observed by Niranjana (1998). The results of the study is in confirmity with the finding where increased plant height, leaf number and yield resulted in high drymatter production in T_3 (Tables 23 to 24).

Foliar application of liquid manure (T_3) registered the highest vitamin C content (Fig. 6). The significance of organic N nutrition in enhancing the vitamin C content of amaranthus was earlier reported by Niranjana (1998) and Vipitha (2011). Though the N content of the best liquid manure T_3 is lesser than 2% foliar applied urea, the presence of invitro beneficial microorganisms might have enhanced the biological efficiency of the crop plants resulting in improved crop quality. Ryan (2007) also observed improvement in quality of vegetable crops by foliar application of compost tea.

Considering the POP recommendation, substitution of topdressed N with foliar nutrition of organic liquid manures enhanced yield to the tune of 2.5 to 27.5 %. Yield improvement in marigold by foliar nutrition of vermiwash (1:2 ratio) was reported by Shivasubramanian and Ganeshkumar (2004). Jasmine et al., (2003) also noticed yield improvement in tomato by vermiwash application at 50% concentration along with full N, P and K.

The results of crop response study on bhindi followed the same trend as amaranthus. Substitution of top dressed N with foliar application of liquid manure obtained from the composite manure of groundnut cake, neem cake and poultry manure (T_3) was superior with respect to plant height and functional leaf number at different stages. Nishana (2005) reported that the soil and foliar application of vermiwash @ 50 ml plant^{-1} resulted in enhanced growth of bhindi. This enhanced growth parameters contributed to yield by increasing yield

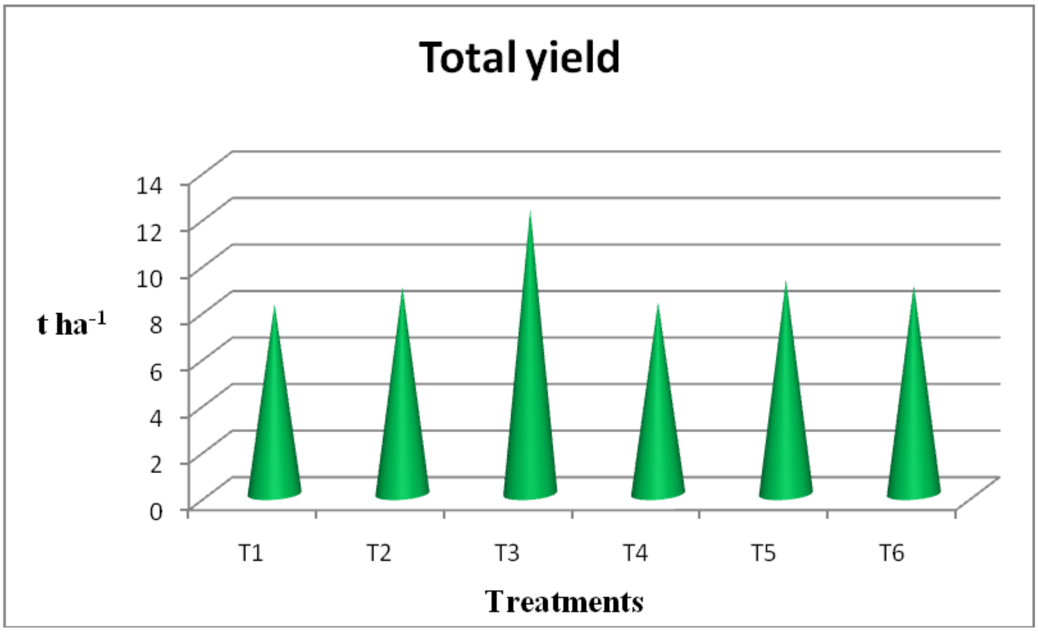


Fig. 5. Effect of foliar nutrition on total yield of amaranthus

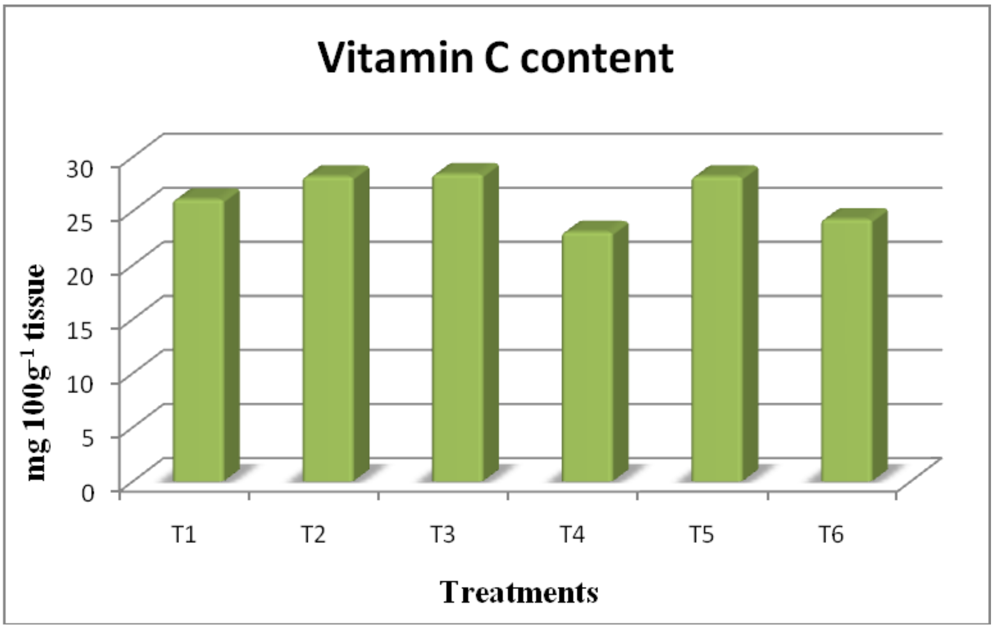


Fig. 6. Effect of foliar nutrition on Vitamin C content of amaranthus

attributes namely the fruit number plant^{-1} and fruit weight plant^{-1}. Moreover, T_3 recorded higher chlorophyll content than other treatnebts. The high N content of the liquid manure increased the chlorophyll content (Fig. 7). Whapham *et al*., (1993) also observed enhanced chlorophyll content in tomato by foliar application of sea weed extract. Increased chlorophyll content might have enhanced the photosynthetic efficiency leading to improvement in yield attributes and yield (Fig. 8). The positive influence of yield attributing characters on bhindi yield was observed earlier by Nishana (2005).

Compared to yield in POP recommendation, the bhindi yield was more in T_2, T_3 and T_5. Among the treatments T_3 was the best. The enhanced availability of nutrients and quick response of applied nutrients through foliar nutrition (T_3) might have enhanced the general growth as evident from plant height and number of functional leaves plant^{-1}. Better growth attributes along with high chlorophyll content might have increased photosynthetic rate leading to high yield in T_3. The yield improvement by foliar nutrition over soil application was to the tune of 5.76, 26.5, 4.9 % in T_2, T_3 and T_5 respectively. The beneficial effects of soil and foliar application of vermiwash on yield improvement of bhindi was earlier reported by Nishana (2005) and Gopal et al., (2010)

5.4 Soil health influenced by organic liquid manures

The N status of soil in amaranthus field analysed before and after the experiment did not show any variation. Substitution of top dressed N with organic foliar nutrition could not bring about any change in soil N status. However, the P and K status showed significant variation due to treatments. Compared to the initial values, the P and K status after the experiment was found to be increased. As P is applied as rock phosphate the slow release nature of the fertilizer might have released only a limited quantity of applied fertilizer to be utilized by the crop. Moreover, the initial P status was in the medium range, thereby enhancing the P status after the experiment. Among treatments no variation was there in P application, but the plot receiving POP registered the highest P status. K status after the experiment was more than the initial levels and among treatments T_1 registered the lowest soil K. Amaranthus being a short duration crop, the variation of treatments does not give a true picture of the

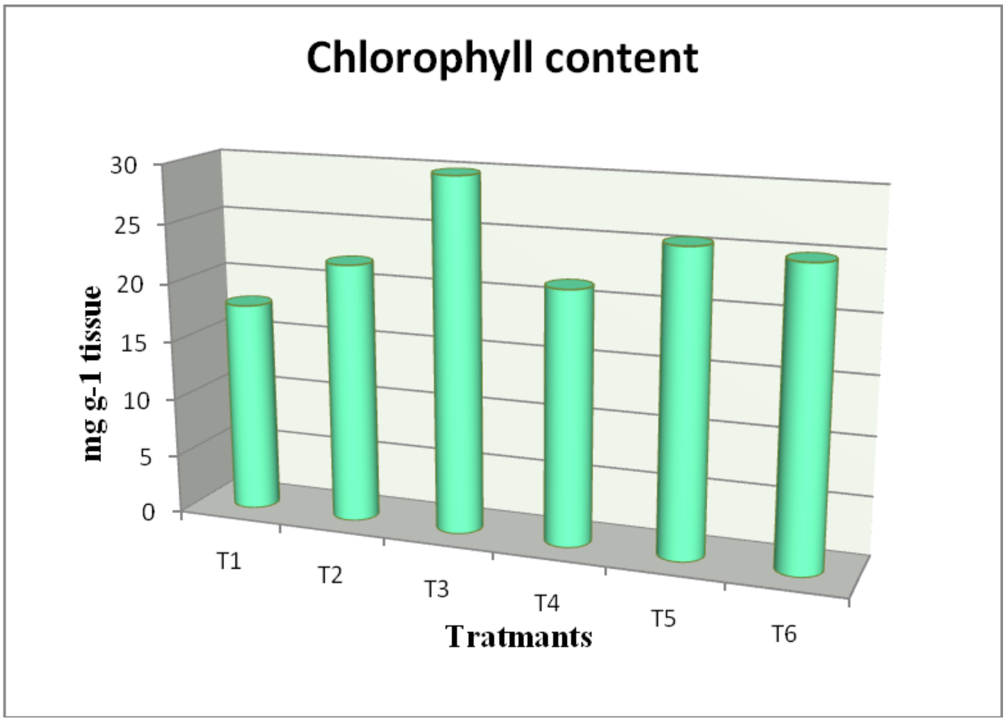


Fig. 7. Effect of foliar nutrition on chlorophyll content of bhindi

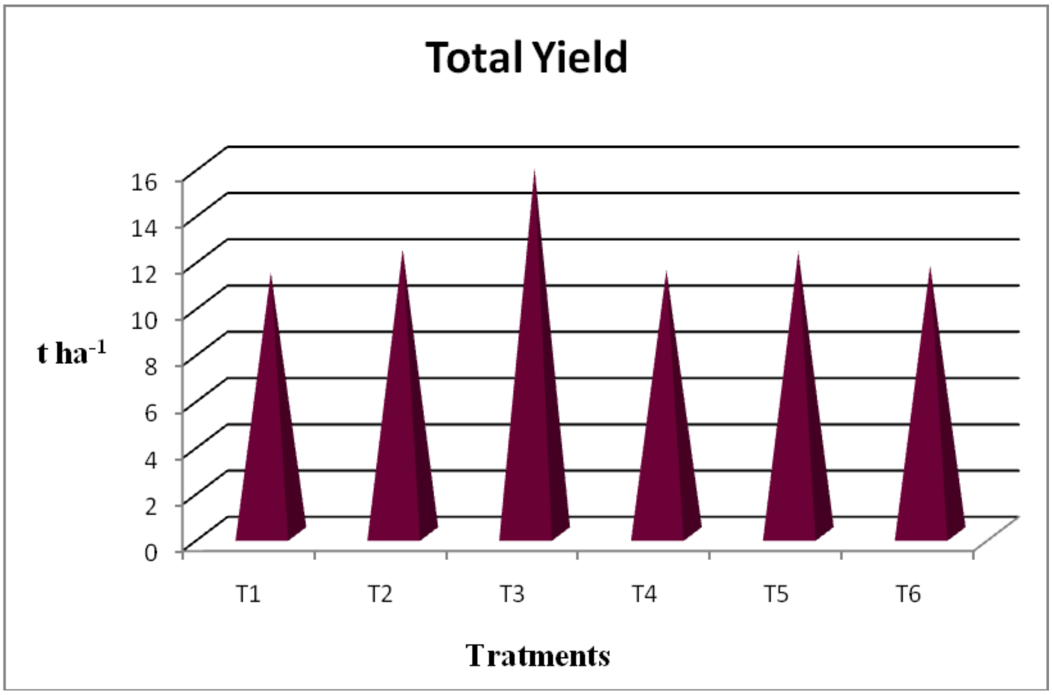


Fig. 8. Effect of foliar nutrition on total yield of bhindi

treatment influence.

The N status analysed in bhindi plot revealed no significant variation due to treatments. The treatment producing highest yield (T_3) registered the lowest P and K content. This could be attributed to enhanced nutrient absorption by plants for realising high yield. However, after the experiment the P and K status of the soil was found to be enhanced in all the treatments indicating that cultivation of vegetables with recommended nutrients and the substitution of the top dressed N with foliar fertilization did not cause any deterioration in soil fertility. Sayre (2003) reported that use of compost tea as foliar spray enhanced nutrient status of the soil. Mohan and Srinivasan (2008) also observed that organic promoters like panchagavya and EM solution improved the nutrient status of the soil. Reports on enhancement in crop production capacity of the soil by coconut leaf vermiwash application was also made by Gopal *et al*., (2010).

5.5 Economic returns influenced by organic liquid manures

The economics of using organic liquid manures for foliar nutrition as a substitute for topdressed N was compared. In amaranthus topdressing of N can be economically substituted by foliar application of the organic liquid manure prepared from groundnut cake, neem cake and poultry manure. This treatment registered maximum net returns (Rs. 69802 ha^{-1}) and B:C ratio (Fig. 9). The high yield realised from T_3 helped to enhance the returns from amaranthus. Though an increase in cost of cultivation of Rs. 10650 ha^{-1} was incurred for foliar nutrition in T_3 over POP, it was compensated by the enhanced yield (27 % more over POP) leading to higher net return (Rs. 69,802) and B:C ratio (2.33) (Fig. 10).

Compared to the POP recommendation, though the cost of cultivation was higher for foliar nutrition of bhindi, the treatments T_3 and T_5 were found to be superior to POP on net income. Among the foliar treatments, foliar application of the liquid extracts of groundnut cake, neem cake and poultry manure was found to be significantly superior in enhancing the net return and B:C ratio (Fig. 11). This treatment incurred a higher cost of cultivation (Rs. 59,923 ha^{-1}). The enhanced cost of cultivation in T_3 (Rs. 13,450 ha^{-1}) over POP was compensated by the additional income generated through enhanced yield. An additional yield of 4.19

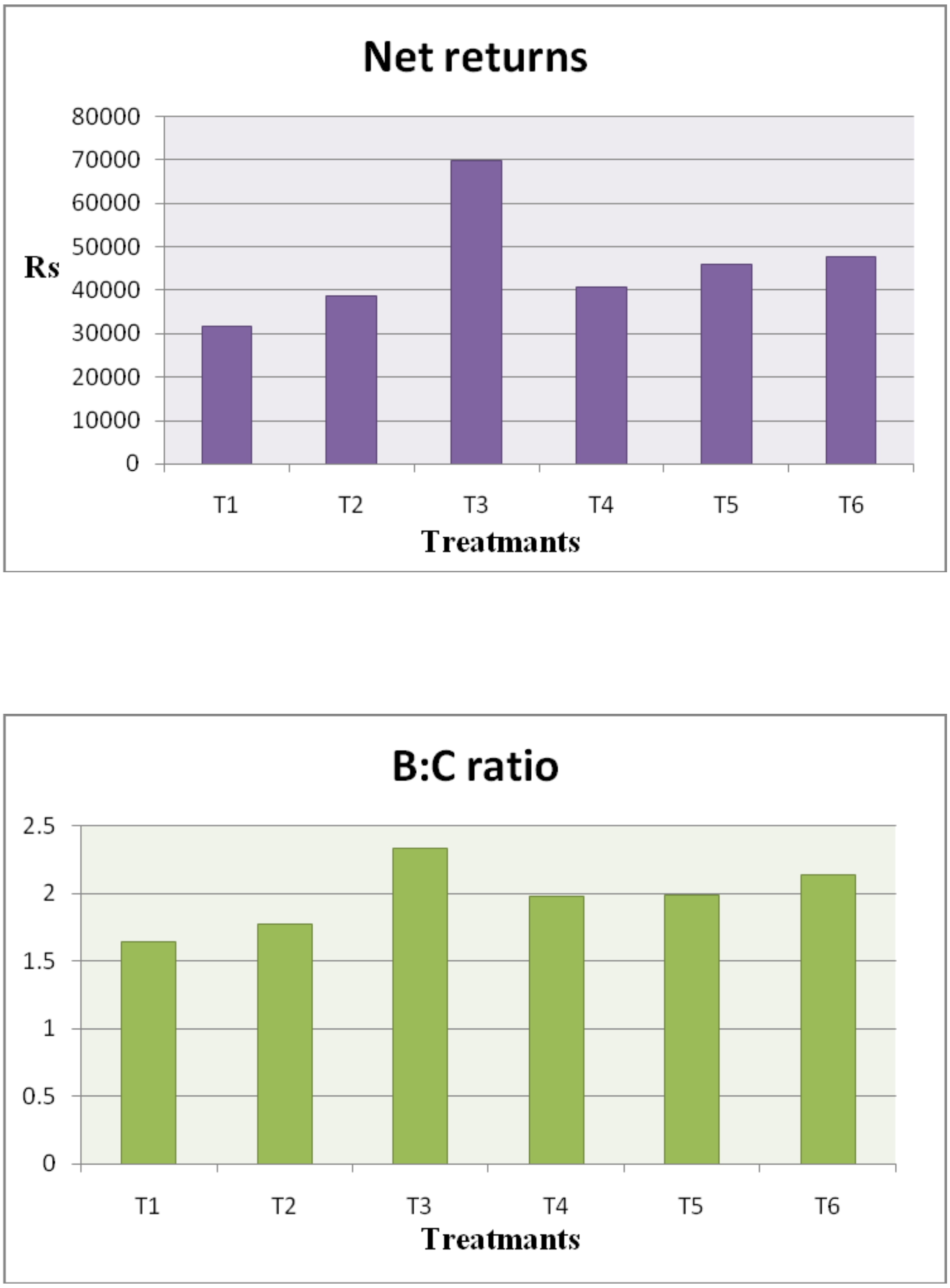
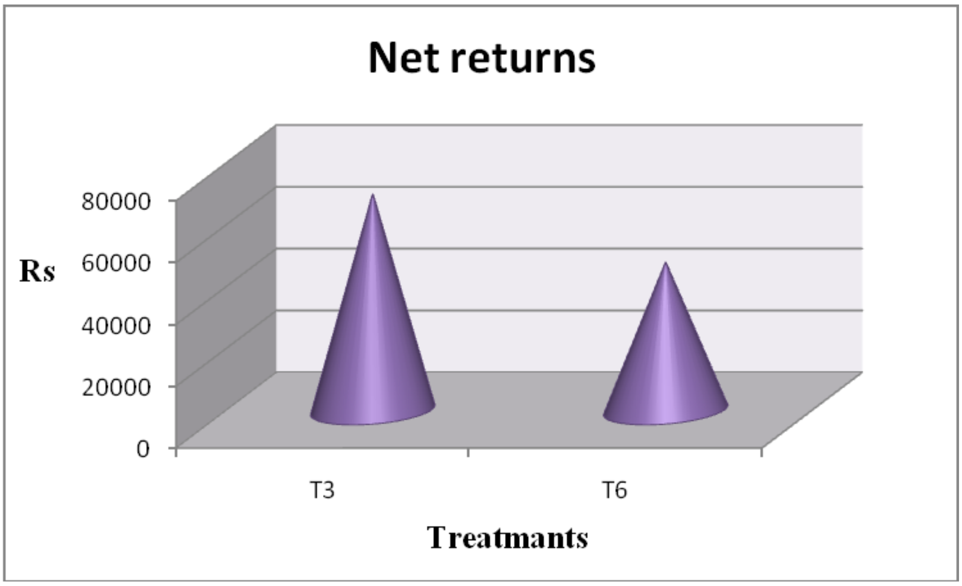


Fig. 9. Effect of foliar nutrition on net return and B:C ratio of amaranthus



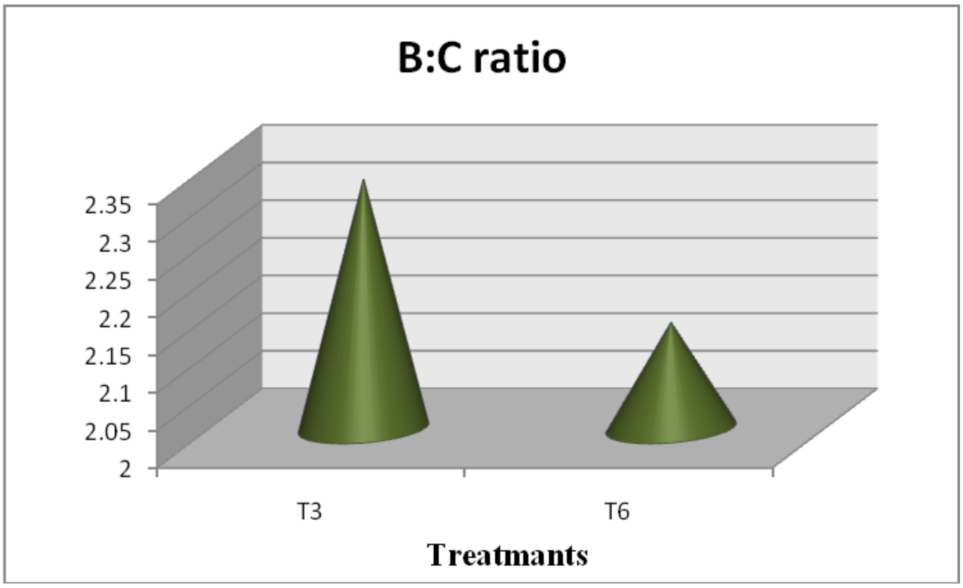


Fig. 10. Comparison of foliar nutrition with the best liquid manure (T_3) and POP (T_6) on net return and B:C ratio of amaranthus

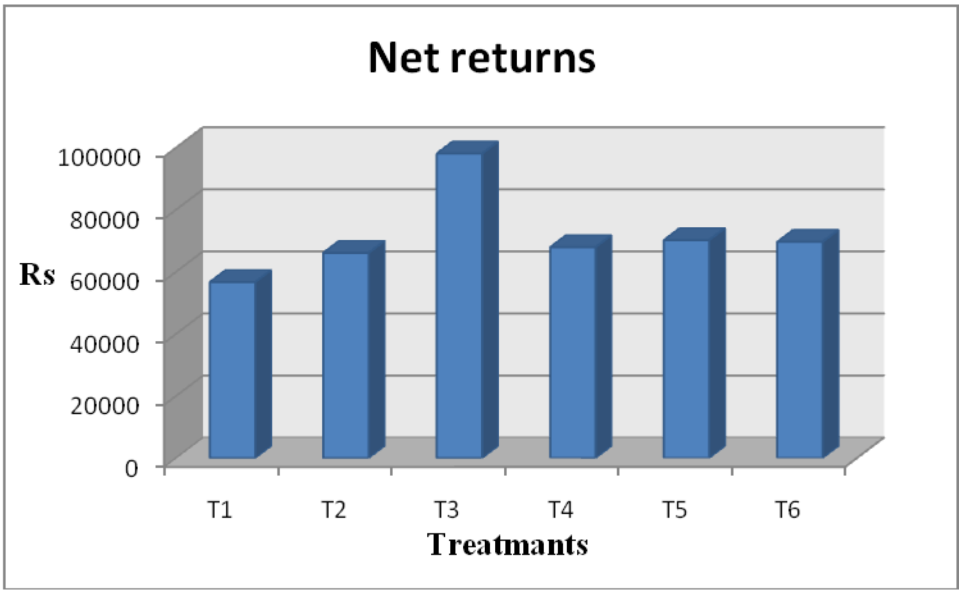
t ha_{-1} was obtained for T_3 over POP (T_6) resulting in enhanced economic returns (Fig. 12). None of the treatments resulted in a B:C ratio less than two. However, the foliar application of L_3 was superior and it was followed by the foliar application of commercial formulation *Nutrich Z* in economic aspects.

The economic feasibility of panchagavya as a foliar nutrient source over vermiwash in vegetable cowpea was reported by Deepa (2005).

To summarise, substitution of topdressing of N in amaranthus and bhindi by foliar nutrition of liquid manure from groundnut cake, neem cake and poultry manure extract is possible and the same will enhance the net return and B:C ratio.

5.6 Soil application of N for top dressing vs foliar nutrition with organic liquid manures

Analysing the yield and returns from various treatments it could be inferred that in vegetables like amaranthus and bhindi, the top dressing of N as soil application can be substituted by foliar application of organic liquid manure prepared from the composite manure of groundnut cake, neem cake and poultry manure (1:0.5:0.5 ratio). In amaranthus this substitution gave an additional yield of 3.27 t ha^{-1} over POP (27 % yield improvement) leading to additional net return of Rs. 22,050 ha^{-1}. In bhindi the yield realised from T_3 and T_5 (foliar nutrition with *Nutrich – Z*) were significantly superior to POP *ie*; 4.19 t ha^{-1} and 0.6 t ha^{-1} more than POP. To achieve this high yields, an additional expenditure of Rs.10,650 ha^{-1} has to be incurred for T_3 in amaranthus and Rs. 13,450 ha^{-1} and Rs. 5450 ha^{-1} for T_3 and T_5 in bhindi. However, the additional cost was covered by the enhanced yield in amaranthus. T_3 could realise an additional net income of Rs. 22,050 and B:C ratio of 0.14 over POP in amaranthus. In the case of bhindi also the best yielding treatments T_3 and T_5 registered an additional net income of Rs. 28,475 ha^{-1} and Rs 550 ha^{-1} over POP. All these inferences revealed that in bhindi and amaranthus substitution of topdressing of N by foliar application of organic liquid manure prepared form groundnut cake, neem cake and poultry manure was more economic. Hence this organic liquid manure can be popularised in vegetable cultivation.



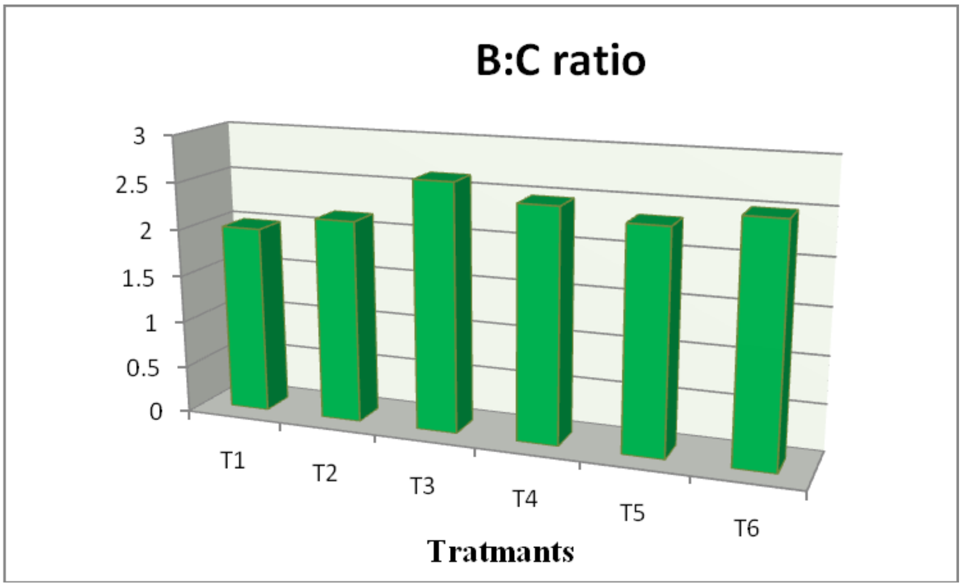


Fig. 11. Effect of foliar nutrition on net return and B:C ratio of bhindi

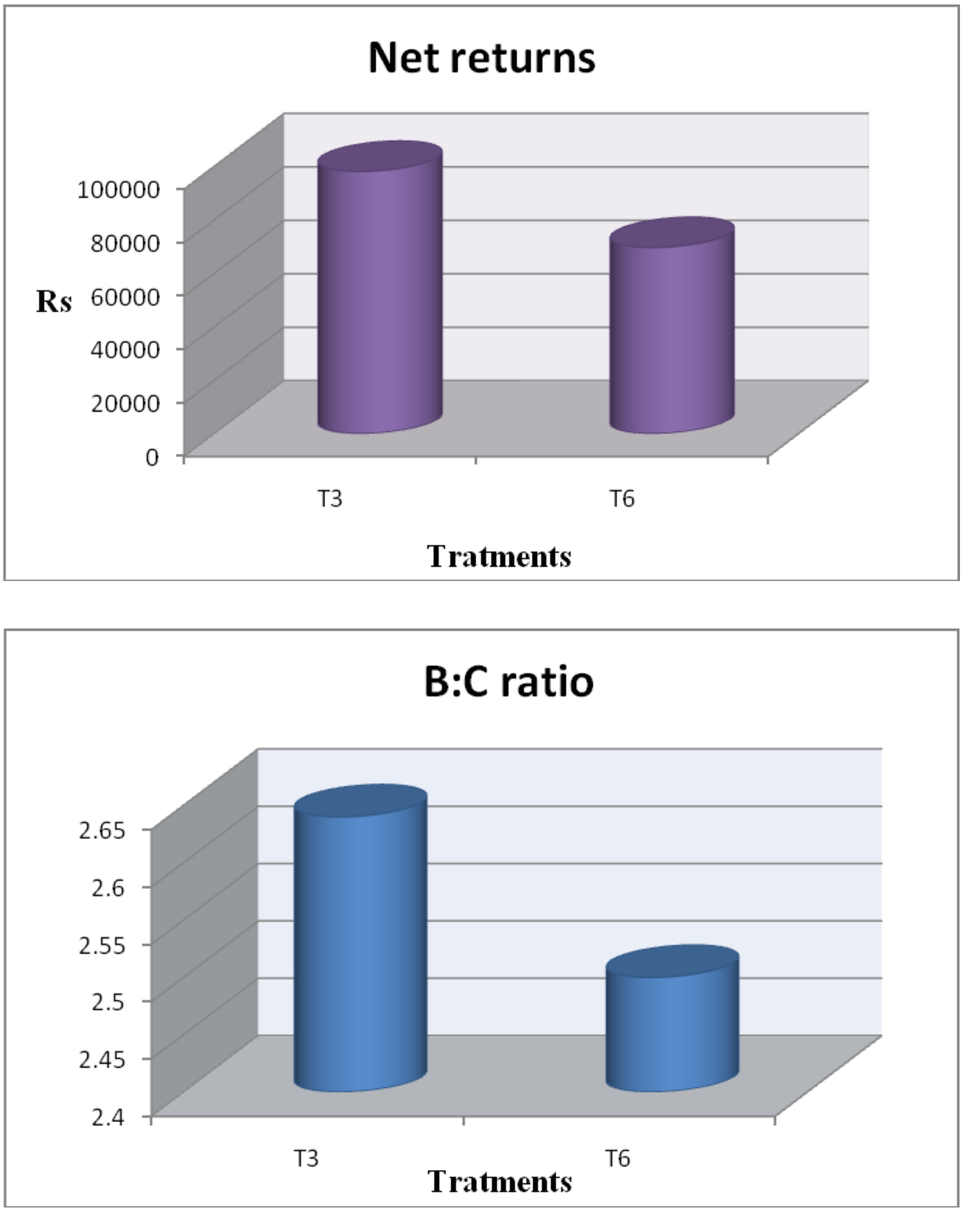


Fig. 12. Comparison of foliar nutrition with the best liquid manure (T_3) and POP (T_6) on net return and B:C ratio of bhindi

5. 7 Cost involved in developing a promising organic liquid manure

Considering the present market price for groundnut cake (Rs. 40 kg^{-1}), neem cake (Rs. 30 kg $^{-1}$) and poultry manure (Rs. 2 kg^{-1}), the cost involved in the preparation of one litre of organic liquid manure can be rounded to Rs. 10 $litre^{-1}$. The market price of the commercial formulation used in the trial, *Nutrich Z* is Rs. 800 litre.$^{-1}$ On per hactare basis 500 litres of organic liquid manure costing Rs. 5000 is required, as the organic liquid manure was applied as such without any dilution. But for commercial formulation the application rate is 3 ml $litre^{-1}$ costing Rs. 1200 ha^{-1}. Though the cost of the organic liquid manure developed is higher than the commercial formulation, high nutrient content of this formulation along with population of beneficial microbes enhanced the benefits in terms of yield and economic returns. The physical properties and shelf life of this can be improved by autoclaving. Unpleasant foul smell of liquid manure collected after seven days of soaking of composite manure can be completely removed by autoclaving. Moreover, storage of the liquid manure can be done even in open condition up to two months with increase in N content. Liquid manures can be prepared according to the farm requirement, enriched with PGPR and can be directly applied to the foliage.

Summary

6. SUMMARY

The present investigation entitled "Development of an effective organic liquid manure for vegetable crops" was carried out at College of Agriculture, Vellayani during 2010–2012. The main objective of the study was to develop a safe organic phytotonic and to evaluate its influence on growth and yield of vegetables and to assess the economics of using liquid manures. The investigation comprises three phases, *viz;* preparation of composite liquid manures, shelf life study and crop response study. The study was conducted under laboratory conditions during January 2011 to November 2011

1. PREPARATION OF COMPOSITE LIQUID MANURES

Characterisation of selected organic manures like groundnut cake, vermicompost, neem cake, poultry manure, and cowdung were done to develop a quality liquid manure. The results revealed that groundnut cake registered the highest N content of 6.18 % followed by neem cake (3.42 %). Poultry manure had the highest P content (0.90 %) followed by cowdung (0.76 %) and groundnut cake (0.68 %). The K content was maximum in poultry manure (2.14 %) followed by groundnut cake (1.21 %).

The nutrient content of organic liquid manures and extracts of organic manures *viz*; groundnut cake , neem cake, poultry manure, compost, cowdung (fresh) and vermicompost were analysed at 15 and 30 DAS. The nutrient content ranged from 0.01 to 0.32 % N, 0.003 to 0. 016 % P and 0.02 to 0.36 % K. As the nutrient content was low, the vermiwash collected from combinations of kitchen waste and organic manures were analysed. The results revealed that maximum N content (0.4 %) was observed in T_9 (kitchen waste + poultry manure+ groundnut cake) and T_1 (kitchen waste + cowdung). Highest P content was registered in T_7 (kitchen waste + cowdung + groundnut cake) and maximum K content was recorded in T_2, T_3, T_5 and T_7 (0.16 %).

As the nutrient content of the liquid manures from organic manures and vermiwash could not meet the required content of 2 % N, composite organic manures were prepared by mixing different proportions of organic manures, and the liquid extract collected after 7 days of soaking were analysed. The results revealed that maximum N content of 0.62 % was obtained in T_6 (groundnut cake + neem cake + poultry manure in 1: 0.5:0.5 ratio) followed by T_5 (groundnut cake + vermi compost + poultry manure in 1: 0.5: 0.5 ratio) and T_4 (ground nut cake and poultry manure in 1: 1 ratio). P content was the highest in T_5 and T_3 (0.08 % each) and maximum K content was registered by T_5 and T_6 (0.17 % each). Nutrient content of these composite liquid manures increased after the addition of PGPR. Maximum N content was obtained in T_6 (0.78 %) followed by T_5 and T_4. The highest P content was recorded in T_5 (0.09 %) and K content was maximum in T_6 (0.17 %).

The physical and chemical characters of organic liquid manures were analysed *viz*; odour, colour, pH and EC, nitrogen, phosphorous and potassium. In general the liquid manures were acidic with high EC values.

2. SHELF LIFE STUDY

Storage life of selected liquid manures was assessed in open and refrigerated condition, earthern and plastic containers and with and without PGPR addition after adjusting the pH. Experiment was laid out in CRD with two replications. Mould incidence was observed in different storage conditions. Though an increase in N content was observed with PGPR addition, the nutrient content and microbial population decreased with increase in storage time.

Another study was conducted after autoclaving the liquid manures to enhance the shelf life. The study was conducted under laboratory conditions with twelve treatment combinations and three replications. Autoclaving helped to remove the foul smell and increased the shelf life of liquid manures. The nutrient content of liquid manures were analysed after autoclaving with and without PGPR addition both under open and refrigerated condition. The results revealed that PGPR addition and method of storage significantly enhanced N content of all liquid manures. The N content of the three liquid manures increased on storage up to two months, and thereafter a slight decline in nutrient content was observed. The liquid manures kept both under open and refrigerated condition without PGPR addition showed a significant decline in N content on storage. The P content decreased with increase in storage period. However, L_2 and L_3 maintained higher P content with PGPR addition and refrigerated storage up to 45

DAS. The treatment L_3 registered the highest K content with PGPR addition and refrigerated storage at 15, 30 and 45 DAS. Though the K content showed a slight reduction from the initial value at 15 DAS, the same content was maintained up to 60 DAS and a decline was observed at 90 DAS.

The microbial population of liquid manures were also assessed after autoclaving with and without PGPR addition prior to storage. PGPR addition enhanced the population of *Azotobacter*. The treatment L_2 registered the highest population of *Azotobacter* with PGPR addition, the population declined at 30, 45, and 90 days of storage. The *Azospirillum* population in different liquid manures enhanced with PGPR addition and the population was reduced with increase in storage time. Among the liquid manures, L_2 registered the highest population of *Pseudomonas* at 15 DAS while the population was more in L_3 at 30, 45, 60 and 90 DAS. In the case of *P* and *K solubilisers* also the population was declined during storage.

3. CROP RESPONSE STUDY FOR EVALUATION OF LIQUID MANURES

Crop response study was conducted as field investigation with six treatments and four replications using amaranthus and bhindi as test crops. Design adopted was RBD.

Amaranthus

The results of field study revealed that foliar application of organic liquid manure L_3 (T_3) as a substitute to top dressed N, enhanced the growth parameters of amaranthus like plant height, number of leaves prior to harvest leading to high drymatter production.

The treatment T_3 recorded the highest vitamin C content (28.43 mg 100^{-1}g tissue) followed by T_2 and T_5 (28.21 mg 100^{-1}g tissue).

The phyllosphere observation of microbes at two days after foliar application revealed that maximum *Azotobacter* population was observed in T_1. The highest population of *Azospirillum* was recorded in T_2. The treatments T_1 and T_3 registered the maximum population of *Pseudomonas*. Population of *P solubilisers* was the highest in T_2 and *K solubilisers* was maximum in T_3. There was no microbial population in the phyllosphere of T_4 and T_6.

Amaranthus yield was maximum in T_3 (12.24 t ha^{-1}) and was significantly higher than all other treatments. The treatment T_1 recorded the lowest yield (8.15 t ha^{-1}) which was on par with T_4.

Soil nutrient status analysed after the experiment did not indicate any change in available N content due to treatments. Various treatments significantly influenced available phosphorous content in soil after the experiment. T_6 recorded the maximum P content (42.04 kg ha^{-1}) in soil and which was on par with T_5. The minimum content was registered by T_1 (36.25kg ha^{-1}). The highest available potassium content was recorded in T_2 (146.10 kg ha^{-1}) and was on par with T_3, T_4 and T_5. The lowest content was recorded by T_1 (141.75 kg ha^{-1}).

Economic analysis of different treatments indicated that T_3 was significantly superior to all other treatments in gross income, net income and B: C ratio. The highest net income of Rs. 69802 ha^{-1} was registered by T_3 giving a B: C ratio of 2.3. In all economic aspects T_1 registered the lowest value and significantly inferior to other treatments.

Bhindi

Foliar application of organic liquid manure L_3 (T_3) as a substitute for top dressed N favoured crop growth as indicated by significant improvement in plant height and number of functional leaves recorded at different intervals

Drymatter production was also maximum in T_3. The treatment T_4 registered the lowest drymatter production.

The highest chlorophyll content was observed in T_3 (29.90 mg g $tissue^{-1}$) which was significantly superior to all other treatments and the content was the lowest in T_1 (17.91 mg g^{-1} tissue).

The microbial population on leaves observed two days after foliar nutrition indicated that population of *Azotobacter* did not vary among the treatments T_1, T_2, T_3 and T_5 (2×10^3). Population of *Azospirillum* was the highest in T_2. The treatment T_3 recorded the maximum population of *Pseudomonas.* Population of *P solubilisers* was the highest in T_2 and the count of *K solubilisers* was maximum in T_3. The treatments T_4 and T_6 failed to register any count of microbes.

Yield attributes like number of fruits $plant^{-1}$, weight of fruits $plant^{-1}$ and total yield were also significantly influenced by treatments. The highest number of fruits plant^{-1} was recorded in T_3 (26.99) which was significantly higher than all other treatments. The lowest number of fruits was recorded by T_1 (20.66).

T_3 recorded the maximum weight of fruits (685.36g plant^{-1}) which showed significant difference from other treatments. The lowest weight of fruits was recorded by T_2 (551.03g plant^{-1}) which was on par with T_1.

The different treatments tried had a significant effect on the yield of bhindi. At all the harvests the highest yield was obtained in T_3 (2.51, 2.38, 2.46, 2.92, 3.25, 2.27 t ha^{-1} respectively). Total yield was maximum in T_3 (15.80 t ha^{-1}) which was significantly superior to all other treatments. The lowest yield was registered in T_1 (11.31t ha^{-1}).

The data on available nitrogen content of soil after the harvest of bhindi revealed no significant variation due to treatments. The available phosphorous content varied with treatments and T_2 registered the highest P content (44.20 kg ha^{-1}). The minimum content was recorded by T_3 (34.63 kg ha $^{-1}$). The K content was the highest in T_2 and T_5 (157.52 kg ha^{-1} each) which was significantly superior to other treatments. The treatment T_3 registered the lowest potassium content of 154 .46 kg ha^{-1}.

The results of economic analysis also showed significant variation due to treatments. T_3 was found to be significantly superior to other treatments in gross income, net return and B:C ratio. The highest B:C ratio of 2.64 was registered by T_3 which was followed by T_6 (2.50) . The lowest net income (Rs. 56727 ha^{-1}) and B:C ratio (2.00) registered by T_1 which was significantly inferior to other treatments.

The following conclusions are drawn based on the results of the present study

- A promising liquid manure can be prepared from composite organic manure containing groundnut cake, neem cake and poultry manure in 1: 0.5: 0.5 ratio. Composite organic manure is mixed with water in 1:5 ratio and the extract is collected after seven days of soaking.

- PGPR addition enhanced the nutrient content of liquid manures. Autoclaving improved the physical properties and shelf life. The liquid manures after autoclaving can be stored in open/ refrigerator for two months with increase in N content.

- Substitution of top dressing of N in bhindi and amaranthus by foliar application of promising organic liquid manure increased the yield and economic return.

Future line of work

Based on the results of the study the following topics can be considered for further study

- Explore the possibility of developing liquid manures of higher N and K content

- Standardise low cost methods to improve the physical properties of organic liquid manures

- Evaluate the efficiency of organic liquid manure for soil and foliar application on container grown/ soil less culture of vegetables.

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DEVELOPMENT OF AN EFFECTIVE ORGANIC LIQUID MANURE FOR VEGETABLE CROPS

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ABSTRACT

An investigation entitled "Development of an effective organic liquid manure for vegetable crops" was carried out at College of Agriculture, Vellayani during 2010–2012. The main objective of the study was to develop a safe organic phytotonic with about 2% nitrogen and to evaluate its influence on growth and yield of vegetables and to assess the economics of using liquid manures. The investigation comprises three phases *viz*; preparation of composite liquid manures, shelf life study and crop response study.

The preliminary part of the experiment was conducted as a laboratory study. The nutrient content of organic sources along with common liquid manures like cow's urine, vermiwash and two commercial organic liquid formulations (*Nutrich–Z and Biosix*) were estimated. It was observed that the highest N content of 6.18 % was registered by groundnut cake. Poultry manure had the highest P (0.90 %) and K content (2.14 %).

The liquid extracts of common organic sources and vermiwash collected from portable vermicompost units prepared by mixing kitchen waste with different proportion of organic sources were also analysed for their nutrient content. In general, the N content of these extracts and vermiwsah ranged from 0.01 to 0.33%. To prepare a liquid manure with high N content, composite manures were prepared by mixing organic manures in definite proportions. The N content was maximum in the extract collected seven days after soaking of the composite manure groundnut cake + neem cake + poultry manure in 1:0.5:0.5 ratio.

Based on the nutrient content, three promising liquid extracts of composite manures were selected for further study and the shelf life study was conducted after pH adjustment. The study was conducted in CRD with two replications. The results of the study indicated that the different containers and storage methods could not increase the shelf life of the liquid manures due to foul smell and mould growth. To improve the shelf life, these manures were subjected to autoclaving after pH adjustment and another laboratory study was conducted in CRD with three replications. The results of the study indicated that the nutrient content of

liquid manures increased with PGPR addition. The N content of liquid manures increased up to 60 DAS and a slight decline was observed at 90 DAS. Storage in open and refrigerated condition did not cause any variation in N content. Though P content increased with PGPR addition, it declined with increase in storage period. The K content did not show any rapid decline on refrigerated storage up to three months.

The crop response study was conducted with six treatments (three liquid manures, a commercial formulation of liquid manure, urea spray and control) laid out in RBD with four replications. Amaranthus and bhindi were selected as test crops. The results revealed that the liquid manures prepared from the composite manure of ground nut cake + neem cake + poultry manure (1: 0.5: 0.5) enhanced the growth characters and yield both in amaranthus and bhindi. Moreover, vitamin C content of amaranthus and chlorophyll content of bhindi were improved by foliar nutrition with organic liquid manure.

The study on economic analysis revealed that the same liquid manure registered the highest net return (Rs. 69802 ha^{-1} for amaranthus and Rs. 98152 ha^{-1} for bhindi) and B:C ratio (2.33 and 2.64)

Appendices

APPENDIX – I

Weather parameters during the experimental period (November 2011-February 2012)

Standard weeks	Maximum temperature (^0C)	Relative Humidity (%)	Rainfall (mm)
44	29.2	88.5	48.0
45	31.0	80.2	41.5
46	31.1	81.6	0.0
47	30.1	81.4	8.2
48	29.2	88.9	111.0
49	30.7	80.6	0.5
50	31.0	82.6	17.0
51	30.5	76.4	5.0
52	29.3	82.8	36.0
1	30.8	-	79.4
2	30.3	-	83.42
3	29.5	5	76.2
4	30	-	78.6
5	31.1	-	76.2
6	30.8	-	77.4
7	30.6	-	81.5
8	31.4	-	76.4
9	31.8	-	76.5

Appendix II

Average input cost and market price of produce

Sl. No.	Items	Cost
	INPUTS	
A	**Labour**	
1.	Man labourer	Rs.350.00 day^{-1}
2.	Women labourer	Rs.175.00 day^{-1}
B	**Cost of manures and fertilizers**	
1.	FYM	Rs. 400 t^{-1}
2.	Groundnut cake	Rs. 40 kg^{-1}
3.	Neem cake	Rs. 30 kg^{-1}
4.	Vermicompost	Rs. 7.0 kg^{-1}
5.	Poultry manure	Rs. 2.0 kg^{-1}
6.	Urea	Rs. 6.0 kg^{-1}
7.	Rajphos	Rs. 4.0 kg^{-1}
8.	Muriate of potash	Rs. 5.5 kg^{-1}
	OUTPUT	
	Market price of amaranthus	Rs. 10 kg^{-1}
	Market price of bhindi	Rs. 20 kg^{-1}