CHARACTERIZATION AND EVALUATION OF ON- FARM LIQUID ORGANIC MANURES ON SOIL HEALTH AND CROP NUTRITION

by

SREYA U PARVATHI

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THESIS

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VELLAYANI, THIRUVANANTHAPURAM-695522

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DECLARATION

I, hereby declare that this thesis entitled **"CHARACTERIZATION AND EVALUATION OF ON-FARM LIQUID ORGANIC MANURES ON SOIL HEALTH AND CROP NUTRITION"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Sreya

Vellayani,

Date: 24-11-2017

Sreya U Parvathi

(2014 - 21-127)

CERTIFICATE

Certified that this thesis, entitled **"CHARACTERIZATION AND EVALUATION OF ON-FARM LIQUID ORGANIC MANURES ON SOIL HEALTH AND CROP NUTRITION"** is a record of research work done independently by Ms. Sreya U Parvathi under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani,

Date: 24-11-2017

Dr. K . Ushakumari

(Major Advisor, Advisory Committee)

Professor

Department of Soil Science and

Agricultural Chemistry

College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Sreya U Parvathi, a candidate for the degree of **Doctor of Philosophy in Agriculture** with major in **Soil Science and Agricultural Chemistry**, agree that this thesis entitled **"CHARACTERIZATION AND EVALUATION OF ON-FARM LIQUID ORGANIC MANURES ON SOIL HEALTH AND CROP NUTRITION"** may be submitted by Ms. Sreya U Parvathi in partial fulfilment of the requirement for the degree.

Dr.K.Ushakumari
(Chairperson, Advisory Committee)
Professor
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani

Dr. Sam. T .Kurumthottical
(Member, Advisory Committee)
Professor and Head
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani

24/11/17
Dr. B. Aparna
(Member, Advisory Committee)
Assistant Professor (Sr scale)
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani

Dr. K. N. Anith
(Member, Advisory Committee)
Professor
Department of Agricultural Microbiology
College of Agriculture, Vellayani

24/11/17
Dr. Vijayaraghava Kumar
(Member, Advisory Committee)
Professor (Research coordination)
Professor and Head
Department of Agricultural Statstics
College of Agriculture, Vellayani

24/11/17
EXTERNAL EXAMINER
Dr. K. BASKAR, M.Sc.,(Ag.), Ph.D.,
Professor (SS & AC)
Agricultural Research Station,
Tamil Nadu Agricultural University,
Kovilpatti - 628 501.

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LIST OF ABBREVIATIONS

@	- At the rate of
^{0} C	- Degree Celsius
AAS	- Atomic Absorption Spectrophotometre
B:C	- Benefit : Cost ratio
Ca	- Calcium
$CaCl_2$	- Calcium chloride
$CaCO_3$	- Calcium carbonate
CD	- Critical Difference
cfu	- Colony forming units
cm	- Centimeter
CRD	- Completely Randomised Design
Cu	- Copper
DAT	- Days After Transplanting
DMSO	- Diemethyl sulphoxide
dS m^{-1}	- deci Siemens per meter
DTPA	- Diethylene Triamine Penta Acetic acid
EC	- Electrical Conductivity
EM	- Effective microorganism
et al.	- And others
EVC	- Enriched vermicompost
FAA	- Fish Amino Acid
Fe	- Iron
$FeCl_3$	- Ferric chloride
Fig.	- Figure
FYM	- Farm Yard Manure
g	- gram
GA	- Gibberellic acid
h	- hour
HCl	- Hydrochloric acid
HNO_3	- Nitric acid
$HClO_4$	- Per chloric acid
IAA	- Indole Acetic Acid
i.e.,	- That is

LIST OF ABBREVIATION CONTINUED

K	–Potassium
KAU	- Kerala Agricultural University
kg ha^{-1}	- kilogram per hectare
L	- Litre
LAI	- Leaf Area Index
µg	- Micro gram
M	- Molar
Mg	- Magnesium
mg kg^{-1}	- milligram per kilogram
mL	- Milli litre
Mn	- Manganese
MSL	- Mean Sea Level
N	- Nitrogen
NaOH	- Sodium hydroxide
$NaHCO_3$	- Sodium biocarbonate
nm	- Nano meter
No.	- Number
ND	- Not detected
N.S	- Non significant
OC	- Organic carbon
P	- Phosphorous
POP	- Package of Practices
ppm	- parts per million
%	- Per cent
RDF	- Recommended Dose of Fertilizers
rpm	- rotation per minute
S	- Sulphur
SE	- Standard Error
TPF	- Triphenyl Formazan
TTC	- Triphenyl Tetrazolium Chloride
Viz.,	- Namely
UV	- Ultra violet
Zn	- Zinc

Introduction

1. INTRODUCTION

Agriculture has not been a mere profession but a way of life in India. It is also the base for all other cultural forms. Agriculture is the process of producing food, fodder, fibre and other desired products by the cultivation of plants and the raising of domesticated animals. Farming practices in India date back to more than 4000 years and organic farming is very much inborn to this country. As mentioned in Arthashastra, farmers in the Vedic period possessed a fair knowledge of soil fertility, selection of seeds, plant protection, seasons of sowing and sustainability of crops in different lands. The farmers of India followed to the natural laws while developing farming systems practices and this has helped in maintaining the soil fertility over the long period of time.

In post-independence period, the most important challenge before the country has been to produce enough food for the growing population got major financial and political support. This package of high yielding production technology has helped the country to become food surplus but it has also resulted in the problems of soil health, environmental pollution, pesticide toxicity and overall sustainability of agricultural production.

Both population and economic growth are invariably accompanied with generation of large amounts of agricultural, animal and municipal and industrial wastes that are known to adversely affect environmental quality and human health. Waste generation increasing day by day with increasing food production. Recycling of wastes in agriculture has therefore become an issue of global importance.

Agricultural soil is adversely affected by chemical fertilizers, pesticides and heavy machineries and it has been observed that most of the soil are not responding towards productivity. Organic farming is a form of agriculture, which evades the use of synthetic inputs such as synthetic fertilizers, pesticides, herbicides, plant growth regulators and livestock feed additives. The greatest challenge in the coming years is to provide safe food for the growing population in the country. In this regard, organic farming which is a complete production management system for promoting and enhancing health of agro-ecosystem, has gained wide gratitude as a valid alternative to conventional food products and ensures safe food for human consumption.

Organic farming is an age old traditional practice evolved by our fore fathers where in only organic manures or natural inputs available on the farm are used. Thus reduces the cost of production against chemical inputs. Organic farming provides balanced nutrition thereby taking care of soil health by improving physical, chemical and biological properties of the soil through nutrient cycling (Anon., 2008). It also guarantees environmental safety and food products free from toxic substances. The natural inputs used in organic farming are easily available, releases nutrients slowly, supplies macro and micro nutrients and provides favourable soil environment for microbial population (Devakumar *et al.*, 2011).

Jeevamrutha, Panchagavya, Fish amino acid, Vermiwash, Cow urine etc. are some of the liquid organic formulations used in organic farming. Liquid organic manures improve plant growth directly through nutrient mobilization, production of plant growth hormones and indirectly through suppression of plant pathogens or by inducing systemic resistance in plants. According to Mishra and Gopalakrishnan (2010), use of liquid organic manures is an integral part of organic farming. Liquid formulations add much needed organic and mineral matter to the soil and play an important role in the buildup of soil organic matter, beneficial microbes and enzymes besides improving physical and chemical properties of soil (Revusehab, 2008).

Liquid manure is a manure in liquid form. The plant can absorb nutrients about 20 times faster through the leaves than if they are applied through the soil (Agro Chadza, 2011). Therefore, liquid manures are helpful to overcome temporary nutrient shortages. The liquid manures can either be used as a foliar fertilizers or be applied to the soil. In organic farming they are mainly used to stimulate growth during the growing season.

These organic liquid manures play a key role in promoting growth, providing immunity to plant system and protect the crop from harmful soil-borne and seed borne pathogens. India has been endowed with rich biodiversity, varied types of soil, copious rainfall and abundant sunshine. India is rich in traditional farming systems which exhibits two salient features *viz.*, a high degree of biodiversity and a complex system of indigenous technical knowledge. Traditional agricultural practices based on natural and organic methods of farming offer several effective, feasible and cost effective solutions to most of the basic problems being faced in conventional farming systems.

The use of fermented liquid organic fertilizers, effective microorganisms (EM) as foliar fertilizers have been introduced to modern agriculture in recent years to produce food with good quality and safety (Galindo *et al.,* 2007). Use of fermented curd, rich in beneficial microorganisms, is also practiced elsewhere both to augment plant growth and suppress pest loads on crop plants.

Liquid manure can work as a pest control source, and also provides nutrients for the plants. They are easily preparable, biodegradable, less expensive, eco-friendly and non-hazardous for human health and environment. Though many farmers are getting better yield by using organic liquid manures, scientific validation has to be carried out.

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. At present in Kerala the liquid organic manures *viz.*, cow urine, panchagavya, fish amino acid, jeevamrutha and vermiwash are widely used for organic farming and good agricultural practices without any scientific validation. The production of these organic manures are cheap, affordable and can be prepared in farmers' farm.

A very few reports are available on characterization, nutrient release pattern methods of applications of these liquid organic manures for organic farming management. The present study is proposed against this backdrop.

Vegetables are integral part of a balanced diet and are considered as protective foods. They are rich source of vitamins, minerals and dietary fibre. The requirement of vegetables is 300 g person $^{-1}$ day^{-1} but actual consumption is very low *i.e,* 174g person^{-1}day^{-1} (Gajanan and Hedge, 2009). Since vegetables are mostly consumed fresh or only partially cooked, they should be devoid of residual effect of chemicals. Organically grown vegetables are preferred for their flavor, taste, nutritive value, extended shelf life and safety.

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 fertilizers 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. Though several liquid organic manures are available, their low nutrient content necessitates several spraying which limit their use in field conditions.

Among the wide variety of vegetables being cultivated in India, bhindi (*Abelmoschus esculentus* L. Moench.) is a popular one. It is a good source of vitamins A and B, protein and minerals. It is also an excellent source of iodine and is useful for the treatment of goiter. India is the largest producer of bhindi with a production of 4526 t ha^{-1} (NHM, 2009). This vegetable is very popular in Kerala and is also exported to foreign countries.

Considering the challenges in vegetable production, food safety, soil fertility, ecological stability, economic viability and resource conservation, it is high time that we adopt organic nutrient sources having immediate nutrient availability for sustainable vegetable production.

Hence keeping all the above aspects in view, the present investigation entitled "Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition" was undertaken with the following objectives:

i. The characterization of on-farm liquid organic manures *viz.,* cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha

ii. To monitor the nutrient release pattern of liquid organic manures under laboratory conditions

iii. To evaluate the efficacy of soil and foliar applications of these manures on soil health and crop nutrition using bhindi as test crop

Review of Literature

2. REVIEW OF LITERATURE

Organic farming is the right approach to the present day agriculture. Increase in the use of organic sources of nutrients is important in the context of organic farming and sustainable agriculture. Compost, manures and organic fertilizers are now being recommended and also utilized widely for increasing crop productivity and for improving soil and environmental quality. Liquid organic nutrition in vegetables is especially important as they provide quality food which are very important for providing health security to people. The main objective of the study was the characterization of on-farm liquid organic manures *viz.,* cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these manures on soil health and crop nutrition using bhindi as test crop.The available literature relating to the above topic is reviewed here under.

2.1 LIQUID FORMULATIONS

Liquid organic manures play an important role in enhancing soil and crop productivity. Commonly used on-farm liquid organic manures are cow urine, panchagavya, jeevamrutha, vermiwash and fish amino acid. Several studies were conducted on the nutrient content of common organic liquid manures. Liquid organic manures maintain soil health due to the build up of soil organic matter and beneficial microbes and enzymes besides improving physical and chemical properties of soil (Ravusehab, 2008). Panchagavya, a vedic liquid organic formulation, is a blend of five products from cow *viz.,* dung, urine, milk, curd and ghee. Nowadays modified panchagavya is gaining popularity among the organic farmers of Kerala and Tamil Nadu (Shilaja *et al,* 2014). Each and every ingredient used for the preparation of panchagavya is rich in beneficial microorganisms and nutrients (Babou, 2005). Cow dung will act as a medium for the growth of beneficial micro-organisms, cow urine contributes nitrogen essential for the plant growth and milk is a source of calcium, protein, carbohydrates, fat and amino acids. The nutrient content of cow urine was reported to be 0.9-1.2 per cent N, 0.2-0.5 per cent P and 0.5-1 per cent K (Bertram, 1999). Vermiwash is an aqueous extract of a column of freshly formed vermicompost and surface washing of earthworms, which contains beneficial microorganisms and water soluble fractions of substances present in both vermicompost and body surface of the earthworms (KAU, 2009). Vermiwash contains 0.05 per cent N, 0.039 per cent P and 0.046 per cent K (Jasmine, 1999).

As per the reports of Ingham (2003), the nutrient content of compost tea is 0.5-0.75 per cent N, 0.25-0.5 per cent P and 0.5-0.75 per cent K. Jeevamrutha is an enriched consortium of soil microorganisms prepared from farm wastes such as cattle dung and urine along with other ingredients like jaggery, pulse flour, fertile soil and water (Kabse *et al.*, 2009). Ravikumar *et al.* (2011) reported that the addition of jaggery and pulse flour with continuous stirring while preparing jeevamrutha will help in faster multiplication of nitrogen fixing bacteria. Amino acids are nitrogen part of the five elements of fertilizer. Fish amino acid is a liquid made from fish trash. Fish emulsions have been documented to promote seedling growth, fruiting and microbe action in the soil organisms (Sundararaman, 2009).

Varghese and Prabha (2014) study suggests that, vermiwash revealed potential application in sustainable development in agriculture biotechnology with respect to its origin, cost effectiveness, availability, reproducibility, reliability as well as biopesticide and ecofriendly soil conditioner.

2.2 EFFECT OF ORGANIC LIQUID MANURES ON SOIL PROPERTIES

According to Yawalkar *et al.* (1977) cow urine comprised of 1 per cent N and 1.35 per cent K_2O and thus can serve as valuable fertilizer material.

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.

Bertram (1999) reported the nutrient content of cow urine to be 0.9-1.2 per cent N, 0.2-0.5 per cent P and 0.5-1 per cent K.

Arancon *et al.* (2006) observed more value of nitrogen in vermiwash treated crop because it could have provide a large source of nitrogen for mineralization. The maximum nitrogen was 69 ppm in vermiwash and 55 ppm in control.

Jeevamrutha 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 jeevamrutha at very low rate act as a tonic to soil besides improving soil health.

Ansari *et al.* (2008.b) observed the initial value of samples showed the pH of soil 7.97, OC 1 per cent, available N 0.1 per cent, Mg 5 mg kg $^{-1}$, Ca 11 mg kg $^{-1}$ and Zn 10.44 mg kg $^{-1}$.The maximum increase in pH was observed 8.88 in chemical fertilizer.The maximum organic carbon increased 0.14 per cent in vermiwash. The calcium increases 5 mg kg $^{-1}$ in vermiwash and vermicompost is due to presence of Ca^{2+} ions in vemiwash and vermicompost. The magnesium increases 1mg kg^{-1} in vemiwash and vermicompost due to greater availability of Mg^{2+} ions.

Application of jeevamrutha maintains soil health and productivity by improving physic chemical and biological properties of soil (Manjunatha *et al.*, 2009).

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).

The analysis of vermiwash showed high level of macro and micronutrients like Ca, K, S, P, organic carbon, Fe, Mn, Cu and Zn. Therefore, it may be concluded that significant increase in the growth of vermiwash treated plants and their grain yield is due to high level of macro and micronutrients available in the vermiwash (Hatti *et al*., 2010).

Cattle urine is a good source of nitrogen, phosphate, potassium, calcium, magnesium, chlorite and sulphate. Application of cow urine has also been reported to correct the micronutrient deficiency, besides improving the soil texture and working as a plant hormone (Khanal *et al*.,2010).

Analysis of nutrient composition of jeevamrutha (Sreenivasa *et al.,* 2011) has revealed the presence of nitrogen (0.077 -0.1 per cent), phosphorous (0.016 - 0.017 per cent), potassium (0.012- 0.019 per cent), iron (29.7- 128.2 mg kg $^{-1}$), zinc (1.27-4.29 mg kg $^{-1}$), copper (0.38 - 1.58 mg kg $^{-1}$) and manganese (1.8 -10.7 mg kg $^{-1}$).

Manyuchi *et. al.* (2013) observed that the vermiwash quantities applied over time increases the organic matter of soil. In addition, increased iron content of soil has tendencies to lower the manganese content.

The field experiments were conducted to study the available N,P,K and S in soil with the effect of panchagavya made from cow (PG-C) and buffalo (PG-B) products sprayed to plants and applied to soil with different concentrations (3 and 5 per cent to plant and 9 and 15 per cent to soil) at different intervals (3 sprays - 30, 60 and 90 DAS; 4 sprays - 20, 40, 60 and 80 DAS) during Rabi 2007-08 and Kharif 2008. The available nutrients *viz.,* N, P, K and S was highest with PG-C @ 15 per cent to soil

(T_{10}) but it was at par with soil application of PG-B @ 15 per cent to soil and PG-C @ 5 per cent - 4 sprays (Vajantha *et al.*, 2013).

According to Jain *et al.* (2014), soil applied with panchagavya @ 4 per cent recorded higher content of macro and micronutrients and microbial activity when compared to vermicompost and farm yard manure applied soils.

Ramalingam *et al.* (2014) studied the potential use of trash fish manures in agricultural fields. Nutrient and minerals were analysed in trash fish samples. High amount of nitrogen (6%), phosphorous (5%) and potassium (4%) were present in trash fish and used for plant growth study.

Organic farming mainly relies on locally available materials and on-farm resources as the nutrient source. The liquid organic formulations *viz,.* panchagavya and jeevamrutha are meant to improve the soil properties without damaging the environment by utilizing the waste materials (Amareswar and Sujathamma, 2015).

Higher total nitrogen, available phosphorus, Ca, Mg, organic carbon, pH, exchangeable K and Na were obtained under human and cattle urine treatments as compared to control (Nwite *et al.*, 2015).

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.

2.3 EFFECT OF ORGANIC LIQUID MANURES ON THE PRODUCTION OF GROWTH PROMOTING HORMONE AND ENZYMES

Vermiwash contains several enzymes, plant growth hormones, vitamins along with micro and macro nutrients which influence growth (Shield and Earl, 1982).

The study of microbial biomass, dehydrogenase and alkaline phosphatase activity to obtain a more complete and precise definition of soil fertility was suggested by Beyer *et al.* (1992).

According to Tomati and Galli (1995), growth of ornamental plant after adding vermiwash showed similar growth pattern as with addition of auxins, gibberellins and cytokinins through the soil.

According to Cooper and Warman (1997) application of compost showed significant increase in dehydrogenase activity in silty clay soil than the application of manures and fertilizers.

Monreal *et al.* (1998) reported that elevated enzyme activities appear to be associated with conditions promoting microbial synthesis of enzyme and such sensitivity would make soil enzyme activities as effective indicators of changes in soil quality.

Tateno (1998) observed an increase in the activity of dehydrogenase due to poultry manure application in a clay loam soil.

Reddy (2004) reported that promoting use of panchagavya as a nutrient and a hormone can help to get better yield at very cheap cost.

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).

Panchagavya contains growth regulators such as IAA, GA and cytokinin, essential plant nutrients, naturally occurring beneficial micro-organisms and plant protection agents such as *Pseudomonas* and saprophytic yeasts. Total productivity in terms of total dry matter production, NPK uptake and crude protein yield were higher for green gram plants treated with panchagavya (Somasundaram and Sankaran, 2004).

Venkateswara *et al.* (2005) and Vijayananthan and Kumar (2006) have reported that vermiwash contains IAA, IBA ,GA etc. and they opined that vermiwash increases growth and yield in many flower, vegetable and fruit crops.

Manjunatha (2006) observed a marked increase in dehydrogenase activity in the soils of organic farms than conventional farms in the selected major cropping systems *viz.*, cotton, sugarcane, jowar and vine yard.

Panchagavya has been used in many applications as growth promoter, bio-enhancer and immune stimulant in plants and animals. It was found that panchagavya at 30 days of age recorded better proposition of chemical and microbial composition favourable for utilization as a growth promoter and it did not have direct antibacterial activity (Mathivanan *et al.*, 2006).

Panchagavya contains major and micro nutrients necessary for the plants, vitamins, essential amino acids, growth promoting factors like IAA, GA and beneficial microorganism like azotobacter, phosphobacteria and *pseudomonas* in abundant numbers it also contains some useful fungi and actinomycetes (Selvaraj *et al.*,2007).

According to Mohan and Srinivasan (2008), organic promoters like panchagavya and EM solution enhanced the yield of brinjal.

Shwetha (2008) reported that the combined application of fermented organics *viz.,* beejamrutha, jeevamrutha, panchagavya along with organics such as compost, vermicompost, green leaf manure recorded the highest soil biological activity.

Similarly, dehydrogenase activity was higher with combined application of organics and fermented organics than their individual applications and RDF + FYM.

The microorganisms in the soil is an important source and drain of nutrients in the soil, promoting mineralization of organic matter making available inorganic nutrients NO_3, H_2PO_4, $SO_4{}^{2-}$ and CO_2 . The dehydrogenase activity can be used as an indicator of microbial activity. Dehydrogenase enzyme was reported to be higher by over 730 per cent in MSW treatment and by over 993 per cent I treatment with cow manure as compared with amended control soil (Bundela *et al.*, 2010).

Vermiwash was identified as a bio-liquid rich in nutrients and plant growth hormones (Gopal *et al.*, 2010).

Kumar and Singaram (2011) reported increase in dehydrogenase, urease and catalase activity in soil by the application of panchagavya @ 3 per cent as foliar spray.

According to Ravikumar *et al.* (2011), the foliar spray of panchagavya facilitated easy transfer of plant nutrients due to the stimuli caused by the presence of growth regulators such as IAA and GA, which in turn increased the crop production.

Fathima and Sekar (2014) observed that by the application of 10 per cent vermiwash the germination percentage and seedling growth was maximum treatment in both the experimental plants but response to gibberellic acid and 20 per cent vermiwash slightly varied between the two plants.

A trial was conducted at Cashew Research Station, Madakkathara, Thrissur during 2008 - 2011 to enhance flower production in bush jasmine, using bioregulators and cow urine. One year old plants grown in pots were sprayed with paclobutrazol, cycocel, GA_3 and cow urine at various concentrations at monthly intervals during February - May and observations on vegetative and floral characters were recorded.

The study revealed that vegetative and floral characters were significantly improved by the application of GA_3 cow urine and cycocel. Maximum flower yield was noticed in GA_3 20 mg kg^{-1} followed by cycocel 1000 mg kg^{-1}. Lowest yield recorded was in paclobutrazol treated plants. Monthly flower yield was also improved by the application of cow urine and bio regulators (Sobhana, 2014).

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

2.4 EFFECT OF ORGANIC LIQUID MANURES ON MICROBIAL PROPERTIES

Debosz *et al.* (1999) reported that incorporation of organic manure into the soil increases soil biological activity.

Bhatcharyya *et al.* (2001) reported that application of municipal solid waste compost variably increased the microbial biomass.

Lalitha *et al.* (2000) recorded that the significance increase in the nitrogen content of the soil, nitrogen of the soil increases due to the nitrogen fixing bacteria by using vermiwash.

According to Palekar (2006) the enormous amount of microbes present in jeevamrutha enhanced microbial activity in soil.

The useful microorganisms from panchagavya and their establishment in the soil improved the sustainability of agriculture (Swaminathan *et al.*, 2007).

Devakumar *et al.* (2008) reported that liquid manures like beejamrutha, jeevamrutha and panchagavya very higher microbial population of bacteria, fungi, actinomycets, N-fixers and P-solubilizers. Further, they have reported that application of these formulations have increased yield in paddy, field bean, maize and soyabean.

Beneficial microbes in panchagavya improved seed germination, length of seedlings and seedling vigour in wheat indicating as an efficient plant growth stimulant (Naik and Sreenivasa, 2009).

According to Gopal *et al.* (2010) application of coconut leaf vermiwash increased the population of soil microorganisms, mostly plant valuable ones and their activities permitted increased uptake of the nutrients.

In an experiment to find out the anti fungal efficiency of panchagavya, Baby and Sankarganesh (2011) observed that in certain culture plates, even though the medium has the lower pH value it does not support the growth of fungal organisms at higher concentration but allowed bacterial colonies. This may be due to the antifungal and nutrient compositions present on the sample solution. The presence of various microbial growths in all the plates indicates ensured the availability of the nutrient sources.

According to Gore and Sreenivasa (2011), jeevamrutha will promote biological activity in soil and as a result the nutrient availability to the crop will be improved. They have also enumerated microbes present in jeevamrutha namely fungi (13.40×10^3 cfu ml^{-1}), bacteria (19.70 x 105cfu ml^{-1}), actinomycetes (3.50×10^3 cfu ml^{-1}), nitrogen fixers (4.60×10^2 cfu ml^{-1}) and P solubilisers (4.20×10^2cfuml^{-1}).

According to Ravikumar *et al.* (2011) application of jeevamrutha along with bio digester improved the yield in groundnut and it could be due to the addition of calcium and presence of nitrogen fixing bacteria.

Due to the production of certain anti-microbiological substances by earthworms vermiwash were found to have potent antimicrobial activity (Govindarajan and Prabhakaran, 2012).

The biological properties of soil after the harvest of green gram was improved with the soil application of panchagavya at 15 and 30 DAS along with the recommended dose of organic manures (Chaudhari *et al.*, 2013).

Devakumar *et al.* (2014) noticed higher colony forming units of bacteria, N-fixers, fungi and actinomycetes in jeevamrutha which, revealed that the formulation is a rich consortia of naturally occurring soil microbes. They also observed that jeevamrutha would give better result if it is used within 9-12 days after preparation.

2.5 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 secretary products of earthworms, along with major and micronutrients enhanced the growth of plants.

Jasmine (1999) noticed that soil application of vermiwash @12.5 per cent 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.

According to Lalitha *et al.* (2000) soil application of organic inputs like vermicompost in grouping with vermiwash resulted in healthier 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.

Cynthia (2003) observed that in *Withania somnifera*, the plant height, plant spread, number of laterals, number of leaf plant^{-1}, fresh and dry weight of shoot, number of tubers plant^{-1}, fresh and dry weight of tubers, harvest index, leaf area, leaf area index, relative water content, total chlorophyll content, highest dry matter production and total alkaloid content were increased due to spraying 4.0 per cent panchagavya.

Field trial conducted by Kanimozhi (2003) revealed that the foliar spray of panchagavya @ 4 per cent in Coleus forskohlii improved the number of roots (14.99), root length (13.73 cm), root diameter (2.49 cm), root weight (459.35 g plant^{-1}) and root yield (12.40 kg plot^{-1}) as compared to control (5.23 kg plot^{-1}).

According to Thangavel *et al.* (2003) vermiwash will be beneficial for crop production. It will provide macro and micronutrients and growth promoting substances which stimulate plant growth. Increases in organic matter content, uptake of N, P, K growth and yield also were noticed.

Studies conducted by Shivasubramanian and Ganeshkumar (2004) revealed that the enzymes present in vermiwash and secretions of earthworms stimulated the yield of crops. They also noticed enhanced productivity of marigold by the application of vermiwash. Vermiwash spray enhanced the growth parameters *viz.*, plant height, number of laterals, number of leaves and leaf area as well as yield parameters *viz.*, number of days to flowering and number of flowers per plant in marigold.

Panchagavya and jeevamrutha are effective in promotion of plant growth and fruiting (Yadav and Mowde, 2004).

Field experiments conducted at Kerala Agricultural University revealed that soil and foliar application of vermiwash @ 50 ml $plant^{-1}$ provided extreme growth in bhindi (Nishana, 2005). It was also observed that soil application of neem cake (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.

In an experiment it was reported that foliar application of 3 per cent panchagavya increased plant height, LAI and dry matter production which was close to 0.05 per cent humic acid application in increasing the plant height, LAI, dry matter production, maximum weight of mother rhizomes and highest yield (Satish *et al.*, 2006).

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).

According to Chandrakala (2008) the combined application of liquid manures, beejamrutha + jeevamrutha + panchagavya recorded significantly higher fruit length, number of fruits per plant and chilli yield over control.

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.

According to Mohan and Srinivasan (2008), organic promoters like panchagavya and EM solution boosted the yield of brinjal. Combined application of liquid manures like beejamrutha, jeevamrutha and panchagavya recorded knowingly higher growth in chilli (Chandrakala, 2008).

Shwetha (2008) conducted an experiment to know the effect of nutrient management through organics in soybean-wheat cropping system at Main Agricultural Research Station, Dharwad on a medium deep black clay loam soil reported that significantly higher leaf area index, plant height, number of branches, dry matter accumulation, seed yield and yield parameters like number of pods per plant with the application of organic manures in combination with fermented organics *viz.*, beejamrutha, jeevamrutha, panchagavya over organics alone application.

An experiment conducted to study the effect of panchagavya on the germination of okra seeds revealed that panchagavya @ 3-5 per cent can impart better germination (Balasubramanian *et al.*, 2009).

Kondapa *et al.* (2009) studied the effect of organic and inorganic sources of nutrients on the performance of chilli (*Capsicum annuum* cv. Byadgi Dabi) and observed highest number of branches per plant (33.98) for 50 per cent of the recommended fertilizer rates (RFR) + 50 per cent N through FYM + BF + panchagavya, 50 per cent RFR + 50 per cent N through VC + BF + panchagavya (32.89), 50 per cent RFR + 50 per cent N through FYM + BF (30.82) and 100 per cent RFR + panchagavya (30.38). The highest number of fruits per plant was obtained with 50 per cent RFR + 50 per cent N through FYM + BF + panchagavya (49.86), 50 per cent RFR + 50 per cent N through VC + BF + panchagavya (45.64), 50 per cent RFR + 50 per cent N through FYM + BF (45.12) and 50 per cent RFR + 50 per cent N through VC + BF (43.30). The highest dry weight of 100 fruits was registered for 50 per cent RFR + 50 per cent N through FYM + BF + panchagavya (139.50 g), 50 per cent RFR + 50 per cent N through VC + BF + panchagavya (133.67 g), 50 per cent RFR + 50 per cent N through VC + BF (131.50 g) and

50 per cent RFR + 50 per cent N through FYM + BF (130.33 g).

Nekar *et al.* (2009) recorded that the impact of foliar application of liquid organic manures on productivity and growth of groundnut. Application of panchagavya and cow urine recorded significantly superior dry matter production, plant height, pod yield, test weight and net returns compared to control.

Jeevamrutha has to be applied once in 15 days @ 50-200 litres acre^{-1} during vegetative stage, flowering stage and grain filling stage and can also be applied alone or along with irrigation water (Ramprasad *et al.*, 2009).

The cattle urine application increased the weight of the fruit and maximum fruit weight (255.16g) was obtained at 55 per cent cow urine with (6sprays), which was significantly superior over rest of treatments followed by 35 per cent cow urine with 6 sprays (245.0g) (Damodhar and Shinde, 2010).

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

Ramaswamy *et al.* (2010) conducted a field al to compare the effects of farm yard manure, vermicompost, seaweed (*Hypnea muciformis* Lamour) extract and liquid organic manures in combination and individually in okra. Increased LAI and fruit weight were observed in vermicompost and liquid organic manures treated plants.

Spraying panchagavya 3.0 per cent solution and tying at tip after male bud removal resulted in uniform and big finger size. Also size of top and bottom hands were uniform and earlier harvest was achieved (Gurudayalsahu, 2012).

Kumar *et al.*(2012) reported the application of vermiwash increases growth, flowering and corm yield characters of gladiolus when they are applied along with recommended fertilizers doses.

Patil *et al.*, 2012 observed that application of cow urine on chickpea at the rate of 10 per cent at flowering initiation and 15 days after flowering recorded higher plant height (35.78cm) at harvesting, number of branches at harvesting (4.82), leaf area index at 90 DAS (1.30), number of pod per plant (60.86) and grain yield (2114 kg ha^{-1}) as compare to control.

Rajan and Murugesan (2012) reported that in pot culture studies which were carried out to find out the effects of vermiwash spray on the growth of cow pea (*Vigna ungiculata)*, excellent growth in the shoot length of plants were recorded which received 75 and 100 per cent concentration of vermiwash.

Hemant *et.al.* (2013) reported that vermiwash sprayed on the tomato plants, nit showed a significant growth of plants such as, shoot length, number of leaves.

The physical parameters such as the number of leaves and buds were observed after 10, 20, 30 days treatment with vermiwash in mulberry (Karthikairaj and Isaiarasu, 2013). The number of leaves and buds differed between leaf and root application. The growth of mulberry plants was significantly higher in plots treated with vermiwash. Foliar application resulted in rapid leaf growth and increased number of leaves.

The biochemical contents (carbohydrates, protein, and amino acids) in *Abelmoschus esculentus* (L.) Moench and *Vigna mungo* increased with 3 per cent concentration of panchagavya spray (Rajesh and Jayakumar, 2013). It is evident from the results that the chlorophyll content of methi and bhindi plants increased with increase in concentration of cow urine.

Shashikumar *et al.* (2013) found that the application of 3 per cent panchagavya along with RDF could improve the height of plants, number of branches, dry matter production and yield in black gram compared to the RDF alone.

Pradeep and Sharanappa (2014) noted that the effect of different sources of organic manures on growth, yield, quality, economics and soil quality of chilli (*Capsicum annuum* L.). 3 sprays of 3 per cent panchagavya and vermiwash. The 3 sprays of panchagavya (3%) + enriched biodigested liquid manure (EBDLM) at 125 kg N equivalent (eq.ha^{-1})noted more plant height (87.00 cm), leaf-area index (2.00), leaf area duration (51.90 days), branches per plant (32.90), dry fruit yield (0.90 t ha^{-1}), total dry matter production per plant (105.70 g), fruits per plant (39.00), fruit length (14.40 cm).

Effect of vermiwash on growth and yield parameters of brinjal was observed in experimental and control plot. Significant plant height was observed in experiment plot II on 90 days and followed by plot I, when compared with control on 90 days (Sundararasu and Jeyasankar, 2014).

Increase in cow urine concentrations increased the performance of all phenotypic characters of methi and bhindi such as plant height, shoot and root length, number of leaf, leaf length and breadth were increased with increased concentration of urine as compared to control (Jandaik *et al.*, 2015).

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

2.6 ORGANIC LIQUID MANURES ON YIELD OF CROPS

Panchagavya when sprayed on foliage facilitates instant uptake of nutrients (Sharma, 1970) which leads to the effective conversion of vegetative phase to flowering phase. Further, the enhanced vegetative growth coupled with adequate reserved food materials promotes easy differentiation of vegetative buds into flower buds leading to earliness in flowering and increase in the number of flowering shoots.

Buckerfield *et al.* (1999) reported that daily applications of vermiwash increased radish yield by 7.3 per cent.

Jasmin (1999) reported that application of vermiwash along with inorganic fertilizers produced marked increase in fruit yield in tomato. At higher concentrations (25 and 50%) of vermiwash, inorganic fertilizer could be reduced to half of the recommended dose without any yield reduction.

Presence of naturally occurring, beneficially effective microorganisms (EM) predominately lactic acid bacteria (*Lactobacillus*), yeast (*Saccharomyces*), actinomycetes (*Streptomyces*), photosynthetic bacteria and certain fungi besides biofertilizers such as azotobacter, azospirillum and phosphobacterium were detected in panchagavya which improved soil quality, growth and yield of crops especially in corn (Xu and Xu, 2000).

Balasubramanian *et al.* (2001) reported that dipping of rice seedlings in panchagavya before transplanting enhanced the growth and yield.

Field trial conducted by Muthuvel (2002) to study the effect of liquid organic formulations on growth and yield of okra revealed that application of four sprays of panchagavya @ 3 per cent and moringa leaf extract @ 25 ml plant^{-1} given at fortnightly intervals recorded higher plant height and number of branches whereas panchagavya treated plants registered highest number of fruits plant^{-1} and fruit yield ha^{-1}.

Jasmine *et al.* (2003) opined that the yield of tomato was significantly increased by the application of vermiwash. Vermiwash at 50 per cent concentration 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.

Application of vermicompost at 5 t ha^{-1} and groundnut cake at 250 kg ha^{-1} along with foliar spray of panchakavya 3 per cent for 4 times recorded the maximum yield of hot pepper which was comparable with the inorganic fertilizers (Maheswari *et al.*, 2003).

Panchagavya and vermicompost combination has given the highest pod yield of french bean variety Ooty 2, which was 36 per cent higher than the conventional method (Selvaraj, 2003).

In a study conducted by Somasundaram *et al.* (2003) it was found that increase or decrease the levels of PG from 3 per cent level decreased the yield. At higher concentration, scorching was observed resulting in reduced photosynthetic activity and yield. They also observed increased number of seeds pod^{-1}, higher grain weight and grain yield by the application of panchagavya in green gram. Additional revenue and higher B:C was also reported.

Sreedhar (2003) carried out an experiment to study the effect of bio regulators on black nightshade and reported that panchagavya at 4.0 per cent recorded highest plant growth, number of leaves, leaf area, leaf and stem dry weight, dry matter production, leaf fresh and dry weight, fruit fresh and dry weight, single plant yield, yield hectare^{-1}, ascorbic acid and TSS content.

According to Thangavel *et al.*, (2003) the yield of paddy was improved by foliar application of vermiwash.

Field application of cattle urine along with irrigation water produced comparable maize fodder yield (Gangaiah, 2004).

Manjunatha *et al.* (2004) evaluated panchagavya as foliar spray and as soil drenching, found that soil drenching or foliar spray of 3 yield panchagavya improved growth and yield.

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.

Application of panchagavya as 3 per cent spray 4 times for bhindi augmented the yield level in poultry manure (10.27 t ha^{-1}) treated plot which was comparable to inorganic supplementation (10.39 t ha^{-1}) with pesticide spray (Louduraj *et al.*, 2005).

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).

According to Prabhu (2006) spraying panchagavya increased yield, fruit size, colour, taste and shelf life of mango.

Panchagavya applied @ 3 percent spray along with different organic manures at 0, 30, 50 days after sowing in rice recorded significantly higher grain yield (5.43t ha^{-1}) over no panchagavya spray (4.99 t ha^{-1}) (Ramanathan, 2006).

Shivamurthy and Patel (2006) observed that the effectiveness of cow urine for seed treatment in improving the chlorophyll a and chlorophyll b content thereby contributing to yield improvement in wheat.

Somasundaram and Singaram (2006) reported that panchagavya spray was found effective on many crops than the foliar spray of recommended nutrients and growth regulators. The superiority of the panchagavya in different crops was noticed with respect to the improvement in growth, yield components and yield of crops over no panchagavya spray from their studies conducted at Coimbatore.

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.

Study conducted by Somasundaram *et al.* (2007) to investigate the response of green gram to varied concentrations of foliar applications of panchagavya showed that increasing or decreasing the levels of panchagavya from 3 per cent level decreased the yield parameters and yield. At higher concentration scorching was observed resulting in reduced photosynthetic activity and yield. They also observed increased number of seeds per pod, higher grain weight and grain yield by the application of panchagavya. Additional revenue and higher B: C was also reported.

In an experiment to find out the effect of vermicompost and vermiwash on the productivity of spinach, onion and potato it was found that yield of spinach was significantly higher in plots treated with 5 per cent vermiwash spray whereas yield of onion was higher when treated with 10 per cent vermiwash spray (Ansari, 2008b).

Chandrakala (2008) reported that the combined application of beejamrutha, jeevamrutha and panchagavya increased yield and dry matter production in chilli. The yield of brinjal could be increased by 33 per cent by the application of organic promoters like panchagavya and EM solution (Mohan and Srinivasan, 2008).

Myint *et al.*(2009)concluded with their experiment the foliar application of fish waste extract @ 40cc per 20 litre of water on soybean crop showed the higher plant height (74.83cm), leaf length (11.87 cm), dry weight (4740.83 kg ha^{-1}) and seed yield (3850.83 kg ha^{-1}) as compare to control.

Patil *et al.* (2008) reported that foliar spray of cow urine and water on green gram. In case of foliar spray of cow urine results the higher growth and yield contributing characters significantly.

In an experiment it was found that 1:20 ratio vermiwash application influenced the growth of plants. Application of vermiwash along with enriched vermicompost increased the yield and quality of crops (Masils *et al.*, 2009).

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

Mohanalakshmi and Vadivel (2008) found that application of poultry manure (5 t ha^{-1}) with panchagavya (3%) in aswagandha exhibited significantly superior performance by registering the highest root yield of 1354.50 kg ha^{-1}.

Abhilash (2011) reported 20 per cent more yield in red amaranthus and confirm boost in growth and colour when fish amino acid was given as foliar spray.

Lekshmi (2011) to evaluate the effect of two enriched compost *viz.*, BM compost and EM compost at different rates alone as well as in combination with two growth promoters *viz.*, panchagavya and vermiwash on physico chemical and biological properties of soil and also their impact on crop performance using chilli variety Vellayani Athulya as test crop. From the result it was concluded that that 75 per cent N as BM compost and panchagavya or 75 per cent N as EM compost and panchagavya was superior to all other organic sources in promoting soil health and yield and quality of chilli.

Harshavardhan (2012) has reported that spraying jeevamrutha, an organic preparation of organic substances increased yield and quality of carnations.

Patil *et al.* (2012) observed that the panchagavya @ 3 per cent by foliar application on 15, 25, 40 and 50 DAS with no inorganic. This was the low cost effective technology for production and grain yield in chick pea.

Ravi *et al.* (2012) conducted an experiment to evaluate the effect of integrated nutrient management on growth, yield and protein quality in maize. The 75 per cent RDF along with insitu green manuring of sunhemp, application of biofertilizers like azospirillum and phosphorus solubilizing bacteria, and liquid organic formulations such as panchagavya @ 3 per cent foliar spray and soil application of jeevamrutha @ 500 L ha^{-1} could save the remaining 25 per cent of fertilizer dose by improving the yield.

Sanjay *et. al.* (2012) observed that the vermiwash application gave 65, 10, 26 and 70 per cent higher yield in knoll-khol (153.23q ha^{-1}), onion (184.1q ha^{-1}), french bean (14.5 q ha^{-1} seed yield) respectively over control.

Effect of panchagavya application on growth, yield and yield attributing characters of cowpea crop, result revealed that to achieve quantative, qualitative and sustainable production of cowpea foliar spray of panchagavya @ 3 per cent is required (Patel *et al.*, 2013).

Amareswari and Sujathamma (2014b) revealed that rice production (Variety Hamsa) using jeevamrutha is commercially viable since it gave better grain yield, net returns and benefit-cost ratio as compared to chemical farming.

Fermented fish waste is found to enrich the soil nutrients required for plant growth and favourably influence the conducting functions of xylem and phloem vessels. Thus fish waste could also be used as a valuable organic liquid fertilizer for better yield from crops at lesser cost and also without the harmful effects of chemical fertilizers (Balraj *et al.*,2014).

Panchagavya 3.0 per cent spray can be done in mangoes at the crown and base for enhancing the blooming process. Spraying must be repeated at 15-20 days interval till the flowers turn into small fruits. Then the spraying must be repeated at monthly interval. This treatment is highly effective for improving the size, number and color of fruits. The taste and shelf life could also be improved (Biswas and Pait, 2014).

Businity (2014) reported that, in addition to adding with irrigation water and spraying, a 100ml of the 3.0 per cent panchagavya solution was tied up at the navel end of the bunch after the male bud is removed. The bunch size becomes uniform and the fruits split faster due to faster growth of pulp. Harvest can be done one month earlier. The size of the top and the bottom hands was uniformly big. It also prevents wilt disease. It also improved the taste, flavour and aroma of fruits.

Application of panchagavya in banana recorded bunches with regular size and the harvest was also reduced by a month in advance (Garg, 2014).

The application of nitrogen at different levels with cow urine in paddy crop significantly affected the yield and available nitrogen status of soil. Application of nitrogen @ 90 kg ha^{-1} with 60 kg ha^{-1} potassium and phosphorus + cow urine was found to be the best treatment regarding growth, yield and nitrogen content of rice (Singh *et al.*, 2014).

Effect of different treatments on yield of the chilli variety kuchinda local. Result of revealed that application of panchagavya @ 3 per cent in 10 DAS intervals showed significantly higher yield per ha as compare to control (Swain *et al.*, 2014).

Uppar and Rayar (2014) reported that foliar sprays of liquid organic formulations like vermiwash @ 5 per cent and biodigester on mulberry plants significantly improved the leaf yield and plant growth which in turn enhanced the rearing of silk worms and cocoon production.

A field trial conducted by Vemaraju (2014) in College of Horticulture, Vellanikkara revealed that the treatment receiving jeevamrutha was found to be superior in terms of number of fruits plant^{-1}, weight of fruits plant^{-1}, yield ha^{-1} and dry matter production in organic oriental pickling melon. An experiment conducted by Soil application of jeevamrutha @ 1000 L ha^{-1}contributed significant higher yield in french bean (Basavaraj *et al.*, 2015). Murali *et al.* (2015) studied the effect of different concentrations of jeevamrutha (0, 500, 1000 and 1500 L ha^{-1}) and FYM (100, 150 and 200 per cent N) on growth and yield of organic field bean (*Dolichos lablab* L.). Higher dose of jeevamrutha and FYM significantly increased the seed yield while the lowest yield was recorded without jeevamrutha application.

2.7 ORGANIC LIQUID MANURES ON QUALITY OF CROPS

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.

Studies by Lozek and Gracova (1999) revealed that application of vermiwash resulted in decrease in fruit nitrate content in chilli by 15 per cent.

Jasmin (1999) found that soil application of vermiwash produced fruits with more shelf life and produced positive influence on the lycopene content of tomato but no influence on the ascorbic acid and crude fibre content.

Beaulah *et al.* (2002) reported that the organic manure applied with panchagavya as spray the quality parameters *viz.*, crude protein, crude fibre, ascorbic acid and carotene content in annual moringa were also higher.

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

Tejada and Gonzalez (2003) observed increased amount of chlorophyll content in panchagavya treated plant. Since chlorophyll synthesis in the plants is directly related to the availability of the physiologically active Fe, N, P and S micronutrients in plants available form. The chlorophyll formation in the leaves by presence of these nutrients to plants. The increased in carotenoids and chlorophyll 'a', 'b' content in green leaves in rice due to foliar application of organic solution.

Edwards *et al.* (2004) have been suggested that vermiwash influence the fruit quality.

Hannah *et al.* (2005) observed that the panchagavya spray produced with tastier banana fruits and sprayed to banana crop @ 3 per cent resulted in improvement in quality of fruits *viz.*, total soluble sugars, total sugars and reduced the negative quality character like acidity.

According to Chandrakala (2008) the combined application of beejamrutha + jeevamrutha + panchagavya and panchagavya alone increased ascorbic acid, oleoresin and colour value by 8.02 and 6.74, 7.89 and 7.00 and 8.25 and 7.17 per cent, respectively over control.

Kumar *et al.* (2008) reported that the effects of the foliar spraying of panchagavya and moringa (Moringa sp.) leaf extract at 2.0 or 4.0 per cent each, humic acid at 0.1 and 0.2 per cent, cytozyme at 1.0 per cent and Atonik at 1.0 per cent applied on the 25^{th}, 45^{th} and 65^{th} days of paprika (*C. annuum* var. longum cv. Kt Pi-19) growth. Application of biostimulants significantly enhanced the yield and physiological and biochemical characters of paprika. Panchagavya at 4.0 per cent significantly increased dry matter production per plant and concentrations of ascorbic acid, total soluble solids, oleoresin, capsaicin and capsanthian in paprika.

Vennila and Jayanthi (2008) reported that water regulation in developing fruits of okra can be controlled by the auxin present in panchagavya and it resulted in increased ascorbic acid and crude protein content.

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

Cattle urine increased the soil pH which may leads to higher P availability increased in yield of bitter gourd by the application of cattle urine was also reported by (SSM-P, 2009).

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

According to Abhilash (2011) 20 per cent increase in growth and yield and enhanced the colour of red amaranthus with foliar spray of fish amino acid.

Singh (2011) observed that the organic manures could sustain the soil fertility and sustain crop productivity in okra. The growth, yield and quality of produce was significantly influenced with organic treatments such as poultry manure, panchagavya, fish amino acid, fermented leaf extract and fermented oil cakes compared with inorganic fertilizer (POP).

Liquid organic manures significantly increased growth and yield in okra and amaranthus (Pillai, 2012) and also increased the shelf life and quality of these vegetables.

Krishnan (2014) revealed the probability of producing salad cucumber under organic management in a profitable manner. Application of FYM, vermicompost and cow dung slurry has contributed higher yield and foliar spraying of panchagavya and FAA contributed better appearance and keeping quality for the produce.

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

2.8 EFFECT OF LIQUID FORMULATIONS ON CROP NUTRITION

Hangarge *et al.* (2004) reported that the application of liquid organic slurry @ 2 L m^{-2} along with vermicompost @ 5 t ha^{-1} in chilli resulted in higher available N (353 kg ha^{-1}), P_2O_5 (21 kg ha^{-1}) and K_2O (284 kg ha^{-1}) content in the soil.

Boomathi *et al.* (2005) reported that the increase in uptake of nutrients and fruit yield with foliar spray of panchagavya was ascribed to increased biological efficiency of crop plants and creating greater source and sink in the plant system.

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

Kondapa *et al.* (2009) recorded the highest N and P uptake (78.46 and 16.69 kg ha^{-1}) in the treatment that received 50 per cent RDN + 50 per cent N through FYM + BF panchagavya. The highest K uptake (75.20 kg ha^{-1}) was recorded in the treatment that received 50 per cent RDN + 50 per cent N through VC + BF + panchagavya.

Gopal *et al.* (2010) inferred that the nutrient content of plant was increased by the application of coconut leaf vermiwash.

The soil application of jeevamrutha significantly increased the availability of phosphorus in soil as compared to the RDF revealing its effect in solubilizing the phosphorus in soil pool (Ninan *et al.*, 2013). This could be due to the increased activity of PSB present in Jeevamrutha which is capable of releasing phosphate ions.

Foliar spray of panchagavya along with leaf extract of neem at branching and flowering stages improved the nutrient uptake of nitrogen and phosphorus in ground nut (Choudhary *et al.*, 2014).

2.9 ORGANIC LIQUID MANURES ON PEST AND DISEASE RESISTANCE

Fish amino acid and Panchagavya are also found to be efficient in the management of pests affecting the crop (Higa and Wididana, 1991).

Rodriguez *et. al.* (2000) also found that the vermiwash inactivate the soil-borne pathogens and pests. They found that only half of the plants of tomatoes sprayed with vermiwash were infected with phytopthora infestans (that cause 'late-blight' disease) as those of control ones (Zaller, 2006).

Jayasankar *et al.* (2002) inferred that 0.9 per cent of cow urine as foliar spray by low volume hand sprayer effectively controlled the cercospora leaf spot in field beans.

Mishra (2002) reported that soil drenching with panchagavya @ 10 per cent had successfully controlled the bacterial wilt of tomato. Selvaraj (2003) also observed that foliar spray of panchagavya in potato reduced the population of cut worms, which in turn resulted in higher yield.

Solaiappan (2002) noticed that the bacteria present in panchagavya proceeded as a biocontrol agent. Natarajan (2003) observed that 5 per cent spray of panchagavya could control bacterial blight of paddy.

Giradi and Smitha, (2003) observed that a significant decrease 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.

Sundararaman (2004) observed that natural preparations like panchagavya will be of much help in the conversion from chemical farming to organic farming. Panchagavya acts 75 per cent as manure and 25 per cent as pest controller. It stimulates plant growth, rectifies micro nutrient deficiencies and helps plants to develop resistance against diseases.

Louduraj *et al.* (2005) reported that application of panchagavya @ 3 per cent spray 4 times for bhindi augmented the yield level in poultry manure (10.27 t ha^{-1}) treated plot which was comparable to inorganic supplementation (10.39 t ha^{-1}) with pesticide spray.

Palanikumar (2005) stated that cow urine contains sulphur and has similar activity as endosulfan, the modern pesticide. It was also reported to have nitrogen, phosphorus, potash, iron, calcium, sodium etc. helping the plants to keep good health.

Application of vermiwash increased the resistance power of crops against various diseases and enhanced the growth and productivity of crops (Suthar *et al.*, 2005 and Yadav *et al.*, 2005).

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* diseases.

Cow urine for the control of pests and as a growth promoter for the growing crops (Sairam, 2008).

Suhane *et al.* (2008) reported that the controlled all incidences of pests and diseases by vermiwash was significantly reduced the use of chemical insecticides and pesticides on vegetable crops and the products. These were significantly different from others with high market value.

Machenahalli *et al.* (2013) reported the disease suppressing activity of panchagavya @ 5-10 per cent against pseudoperonospora cubensis, the causal agent of downy mildew of *Cucumis sativus*. Panchagavya was investigated invitro for the suppression of *Curvularia lunata* causing grain discoloration in rice and it revealed that the seed treatment with panchagavya inhibited mycelia and spore germination of the pathogen and the treatment further improved the seed germination and vigour index (Sumangala and Patil, 2009).

Upperi *et al.* (2009) reported that the incidence of rust and defoliation in plants given cow urine pray ranged from 3-4 per cent when compared to control (6 to 8.5 %). The cow urine sprayed plot had least mean incidence (4.0%) and defoliation (2.5 %) and high yield (6.5 t ha^{-1}) compared to control (8.5 %), (14.8 %) and (3.5 t ha^{-1}) respectively. This is due to the nutrient composition of cow urine which has toxic inhibitory action against fungal growth and multiplication and at the same time it has supplied the required nutrients during different stages of crop growth.

Raj (2010) observed that application of organic growth promoters such as panchagavya, dashagavya and EM solution reduced foliar blight of amaranthus caused by rhizoctonia solani when compared to inoculated control, Panchagavya application caused suppression of disease by 47.29.

Panchagavya is an efficient plant growth stimulant that enhances the biological efficiency of crops. It is used to activate biological reactions in the soil and to protect the plants from disease incidence (Nileema and Sreenivasa, 2011).

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

Vallimayil and Sekar (2012) investigated the antiviral activity of panchagavya in sunhemp as systemic host and cluster bean as assay host at different time intervals. Panchagavya @ 3 per cent as seed treatment and foliar spray showed higher yield and lesser SSMV (Southern Sunhemp Mosaic Virus) activity over control treatment in sunhemp. Higher viral inhibition rate was also registered in the panchagavya sprayed plants of cluster bean.

In addition to nutrients, fermented liquid organic formulations contain plant growth hormones and microbial load which helps to boost the plant growth, improve metabolic activities and impart resistance to pest and diseases (Geetha and Devaraj, 2013).

Mallinath and Biradar (2015) reported improved population of natural enemies such as spiders and coccinellid beetles by the application of panchagavya @ 2 per cent which in turn controlled the thrips population in onion.

Adhao (2013) observed that panchagavya suppressed the growth of *Fusarium oxysporum*. Superior antifungal activity of panchagavya was recorded in the plate receiving 4 percentage w/v panchagavya treatment as compared to control.

The spraying of fish amino acid at weekly intervals could reduce leaf spot diseases and leaf feeder attack in amaranthus in farmer's field (KAU,2014).

The highest fruit yield coupled with reduction in aphid population and reduction in the damage shoot and fruit borer which are major menses in commercial mango cultivation . The significant superior results are obtained with cow urine @ 50 per cent on par with the vermiwash @ 50 per cent (Karkar *et al.*, 2014).

Mishra *et al.*(2014) concluded that the vermiwash with bio-pesticide is the better option for the growth, productivity as well as management of *Lucinodes orbanalis* infestation on brinjal crop.

Radha and Rao (2014) identified bacterial isolates from panchagavya like *Bacillus safensis* and *Bacillus cereus* which were antagonistic to plant pathogen *Rhizoctonia bataticola.*

According to Sarkar *et al.* (2014), application of Panchagavya @ 3 per cent as foliar spray in tomato, chilli and cowpea induced the production of polyphenol oxidase, a defense related enzyme which could have triggered the immune system of plant to acquire resistance against diseases.

Chauhan and Singh (2015) reported that effect of vermiwash with neem plant parts on the germination, growth, productivity of okra and its pest infestation.

Esakkiammal *et al.* (2015) reported that vermiwash acts as pesticide, disease curative and crop tonic and increase the yield of crops in multiples.

Effects of panchagavya on growth and biocontrol of tomato plant (*Lycopersicon esculentum* L. inn). In this study we can show that morphological features were noted after 10, 20 and 30 days PG was sprayed on the leaf at 12 days intervals. After 15 days of spraying PG the brown spots are begin to disappear and on the 16 day the plant was free of brown spot diseases. PG proved to be enhancement of plant growth as well as biocontrol of tomato leaf spot diseases (Serfoji, 2015).

Sujatha *et al.* (20I5) reported that the application of compost prepared using weeds and jeevamrutha improved the resistance against fungal and bacterial pathogens fit field.

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.

2.10 EFFECT OF ENRICHED VERMICOMPOST ON SOIL HEALTH

Lee (1985) observed that the application of vermicompost has increased the pH of the soil. Worm casts have a pH near to neutral range than the surrounding soil and the possible factors that act on soil pH may be excretion of NH_4^+ ions from calciferous glands of the earthworms.

Studies on the effect of compost addition by Martin and Marinissen (1993) revealed that the activity of dehydrogenase increased to the range of 210 μg TPF hydrolysed 24 $h^{-1}$with the application of vermicompost.

Vijayalekshmi (1993) reported that soil properties such as porosity, soil aggregation, soil water transmission and conductivity of soil were improved for soil treated with worm cast when compared with no worm cast amended soil.

Soils could be sustained through the use of organic amendments like vermicompost and inoculation of earthworms which facilitates humus formation and reduces leaching of nutrients from the soil by their slow release (Thampan, 1995).

Organic C content and pH has increased significantly by vermicompost application (Pushpa, 1996).

Compost and compost extracts applied to soil improve its quality by altering the chemical and physical properties, increase organic matter content, water holding capacity and provide macro and micro nutrients essential for plant growth. (Weltzien, 1991; Scheuerell and Mahaffe, 2004; Heather *et al.*, 2006).

Incorporation of organic waste significantly increased the soil pH and nutrient status of an acid soil (Lal *et al.*, 2000).

Pizzeghello *et al.* (2002) reported that rice straw compost extract improved soil fertility, modified soil physical and chemical conditions directly due to higher nutrient content and humic acid percentage.

According to Senthilkumar and Surendran (2002), vermicompost application has influenced the physical, chemical and biological properties of soil. They also opined that vermicompost had improved the water holding capacity of soil and acted as a mine for various plant essential nutrients such as N, P, K, S and trace elements

Bonde and Rao (2004) observed that the application of organic residues significantly lowered the bulk density over control. Among different residues, FYM resulted in greater availability of nitrogen, phosphorus and potassium in soil compared to other treatments (wheat straw and press mud compost) including control in cotton-soybean cropping system.

Addition of azolla increased pH from 7.1 to 7.8 but decreased the total solids of slurry from 5.40 per cent in cow dung alone to 2.68 per cent in the ratio of 1:1. Azolla meal contained (% DM) 21.4 crude protein, 12.7 crude fibre, 2.7 ether extract, 16.2 ash and 47 carbohydrate and a gross energy value of 2039 kcal kg^{-1} was also obtained.The concentrations of calcium, phosphorus, potassium and magnesium were 1.16, 1.29, 1.25 and 0.25 per cent respectively, while those of sodium, manganese, iron, copper and zinc were 23.79, 174.42, 755.73, 16.74 and 87.59 mg kg^{-1}, respectively. The chemical score index showed the potential azolla meal as a good source of protein. Leucine, lysine, arginine and valine were the predominant essential amino acids while, tryptophan and the sulphur- containing amino acids were deficient (Alaladi and Lyayi, 2006).

Application of azolla has been found to improves the physical and chemical properties of the soil. These improvements were significant for nitrogen, organic matter and other cations (Mg, Ca and Na) released unto the soil. Careful management of soils in the tropics with azolla results in better production of crops since its production is cheap, affordable and can be done in farmers farm (Awodun, 2008).

According to Singh and Rao (2009) organic manures are nature's best mulches and soil amendments which improve soil structure, aeration and also increase the soil's water holding capacity.

Azolla absorbs all its nutrients from water and phosphorus is the most common limiting element for its growth (Giridhar *et al.*, 2012). Both dung slurry and vermicompost are rich in nutrients including phosphorus thus their addition resulted in rapid azolla multiplication and significantly better yield.

Azolla besides containing around 25 per cent crude protein is also found to contain essential minerals like iron, calcium, magnesium etc and appreciable quantities of Vitamin A and Vitamin B_{12} (Mathur *et al.*, 2013).

2.11 EFFECT OF ENRICHED VERMICOMPOST ON CROP GROWTH, YIELD AND QUALITY

Kale *et al.* (1992) reported a significant increase in P uptake in rice plants treated with vermicompost.

Application of vermicompost had significantly increased the P uptake in green gram when compared to FYM (Reddy and Mahesh, 1995).

According to Vasanthi and Kumaraswamy (1996) vermicompost + NPK treated plants had given higher P content.

According to Meera (1998) use of vermicompost coated seeds had produced the maximum uptake of all nutrients. Soil analysis of available nutrients revealed that the treatments receiving vermicompost had significant influence on the Ca, Mg, Zn, Cu and Mn content in soil compared to inorganic fertilizers.

Vermicompost and phosphobacteria in combination with two inorganic P sources namely superphosphate and Tumis rock phosphate were verified in a calcareous black soil for their effect on yield parameter of black gram (CO5) and cotton (LRA 5155). The application of TRP (100 %) along with vermicompost and phosphobacteria in black gram recorded the highest grain and haulm yield. In cotton, effect of SSP and TRP on kapas yield and stover yield were on par (Thiyageswari and Perumal, 1998).

According to Sailajakumari (1999), application of enriched vermicompost with rock phosphate had increased the plant height, number of branches, nodules number and yield in cowpea and also increased the available N, P_2O_5, and K_2O status of the soil.

Arunkumar (2000) reported that vermicompost when applied to amaranthus had recorded highest ascorbic acid content and lowest fibre content.

Sailajakumari and Ushakumari (2001) reported highest protein content in plants treated with vermicompost than with FYM.

Deepa (2005) observed that enriched vermicompost application has increased number of flowers, number of pods and length of pod in cowpea.

Devi Krishna (2005) reported that plants which received vermicompost with PSM had found highest pod yield as well as highest nutrient uptake of bhusa and pod of cowpea.

According to Thimma (2006), oleoresin percent in chilli was increased by 13.89, 6.60, 3.70 and 2.30 per cent when treated with poultry manure @ 7.50 t ha^{-1}, vermicompost @ 10 t ha^{-1}, FYM (50 %) + vermicompost (50 %), FYM (50 %) + neem cake (50 %) respectively over RDF.

Singh *et al.* (2009) reported that application of P and S enriched vermicompost increased oleoresin and essential oil content in coriander.

By using *Azolla pinnata* as a substrate for vermicomposting by *Eisenia foetida* , the conversion rate was 17.91± 0.30 per cent, 43.46± 0.67 per cent, 83.15± 0.53 per cent and 100 per cent for first, second, third and fourth fortnight respectively. The worm cast showed increased level of organic nitrogen, total phosphorus, calcium, magnesium, sodium and potassium (Ishtiyaq and Khan, 2010).

Rock dust, which was used as a nutrient source for enrichment consisted of 57.26 per cent Si, 5.07 per cent Fe_2O_3, 0.85 per cent P_2O_5, 3.27 percent K_2O, 6.42 per cent CaO, 8.23 per cent MgO etc. Five types of composts enriched with different additives *viz.,* mineral enriched compost (Rock dust 25%), bio enriched compost (composting inoculum 5 g kg^{-1}),bio mineral enriched compost (rock dust 25%+ composting inoculum 5 g kg^{-1}), mineral enriched vermicompost (rock dust 25%) and ordinary compost were prepared and used for investigation. Among the various enriched composts prepared, mineral enriched vermicompost recorded high nutrient content. The C:N of rock dust enriched composts were found to be narrow compared to bio enriched and ordinary compost, which indicated that composting period was reduced by the addition of rock dust (Sreeja ,2014).

Buffalo dung with vermicompost in azolla production, improves azolla's palatability among Buffaloes without any untoward impact on its yield. Poor palatability was considered one of the major impediments in wider adoption of azolla production among dairy farmers in the region, so it is believed that by following this refinement, azolla production can be taken up for feeding of the animals during scarcity period (Thakur *et al.*, 2015).

2.12 EFFECT OF ORGANIC MANURES ON NUTRIENT RELEASE PATTERN IN SOIL

The nutrient release pattern of different organic manures was studied by various workers. Allison and Klein (1945) have reported that immobilization of nitrogen proceed very rapidly during the first seven days, then at a constantly decreasing rate. The average nutrient release percentage of wood ash: phosphorus, (5.7%) potassium (40%) magnesium (48%) calcium (74%) sodium (16%) (Ohno and Erich, 1990).

Eghball *et al.* (2002) observed that mineralization of organic N is expected to be low for composted manure (18%) and high for swine or poultry (hens) manure (55%). In an incubation study conducted with FYM, poultry manure and vermicompost, Nair (2003) reported that there was a progressive increase in the availability of N and P_2O_5 till the 90^{th} day for all the three manures and in the case of available K_2O there was a progressive increase up to the 60^{th} day and there after decreased. Among the three organic manures, poultry manure showed higher availability of the three nutrients.

Sheeba (2004) inferred from an incubation experiment that available N, P_2O_5 and K_2O content of the soil increased up to 45 days of incubation, then the availability slowly declined. Asha (2006) reported that poultry manure mineralized rapidly releasing almost all its nutrients within a period of 30-60 days. Application of rock dust at a higher rate (12 t ha^{-1}) along with an equal quantity of FYM resulted in the maximum release of almost all nutrients *viz* N, P, K ,Fe ,Mn and Zn throughout the incubation period (Divya, 2008).

Amending soils with biochar or compost effectively fixed Al and Fe instead of P, thus making P available by keeping the inorganic P in a bioavailable labile P pool for a comparatively higher amount of time as against addition of triple super phosphate alone devoid of organic amendments (Ching *et al.*,2014). Ogbonna *et al.*, 2012 observed that farm waste compost on application to soil grown with maize increased the soil pH organic matter content, total N, available P, exchangeable cations, CEC and increased Fe and Zn contents but Mn content was reduced.

Fortified cow dung increased soil NPK contents by 25 and 62 per cent respectively and soil Ca and Mg contents by 2 and 8 per cent respectively (Ayoola and Makinde, 2014).

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.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled" Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition" was carried out at College of Agriculture, Vellayani during 2014-2017. The main objective of the study was the characterization of on-farm liquid organic manures *viz.,* Cow urine, Panchagavya, Fish Amino Acid, Vermiwash and Jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these liquid organic manures on soil health and crop nutrition using bhindi as test crop. The investigation was carried out in three phases.

1) Preparation and characterization of on –farm liquid organic manures *viz.,* Cow urine, Panchagavya, Fish Amino Acid, Vermiwash and Jeevamrutha,
2) Laboratory incubation study to monitor nutrient release pattern from the liquid organic manures
3) Evaluation of efficacy of soil and foliar applications of above on-farm liquid organic manures on soil health and crop nutrition using bhindi as test crop.

Materials and methods used for study are described in this chapter.

PART I

3.1 PREPARATION AND CHARACTERIZATION OF ON-FARM LIQUID ORGANIC MANURES

3.1.1 Preparation of on-farm liquid organic manures

3.1.1.2 Cow urine

Fresh cow urine was collected from the Department of Animal Husbandry, College of Agriculture, Vellayani was used for the study (Plate.1).

3.1.1.3 Preparation of Panchagavya

Panchagavya was prepared in a plastic drum of capacity 100 L. Cow dung (7 kg) and cow ghee (1kg) were mixed in a clean plastic drum thoroughly both in morning and evening hours and kept aside for 3 days. After 3 days Cow urine (10 L) and water (10 L) were added.The mixture was kept for 15 days with regular mixing both in morning and evening hours.After 15 days, added cow milk (3 L),cow curd (2 L), tender coconut water (3 L), jaggery (3 kg) and well ripened poovan banana 12 Nos. The contents were stirred twice a day both in morning and evening. Panchagvya (Plate.1) was ready for use after 30th day (KAU, 2009).

3.1.1.4 Preparation of Jeevamrutha

Jeevamrutha (Plate.1) was prepared in a large plastic drum. Cow dung (10 kg) and cow urine (10 L) were added to 200 L of water. Then added jaggery (2 kg), flour (2 kg) and hand full of good soil. Stirred the contents clockwise for couple of minutes and this should be done 3 times a day. The solution was kept for fermentation for 72 hours (Palekar, 2006).

3.1.1.5 Preparations of Vermiwash

For the collection of vermiwash, a cement tank with side tap was constructed and a layer (5 cm thickness) of small brick pieces or gravel was placed at the bottom of the tank. Above it, a layer of coconut fibre of 3-4 cm thickness was placed. A definite quantity of bio waste (4 kg) was added to the system along with 2 kg of earthworms. After two weeks, the entire mass of bio wastes were converted to brownish black compost. Then sprinkle two litres of water to the tank containing earthworms and freshly formed vermicompost. Vermiwash (Plates.1) was collected through the side tap after 24 hours. Again bio waste was added to the system and the process was repeated to collect the required quantity for study (KAU, 2009).

3.1.1.6 Preparations of Fish Amino Acid

Fish was cut into small pieces and the fish pieces were added to sliced jaggery in the ratio 1:1 in a plastic bucket layer by layer and stored in a cool place under anaerobic condition. Kept it away from direct sunlight for 30 days. The end product (Plate.1) was filtered and diluted for application (Sundararaman, 2009).

3.1.2 Characterization of on –farm liquid organic manures

Liquid organic manures *viz.,* cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha were characterized for physical, chemical, biological and biolchemical properties as per standard procedures outlined in Table.1

3.1.2.1 Physical and Chemical characterization

Physical properties *viz.,* colour and odour, chemical properties like pH, EC , organic carbon, labile carbon, primary, secondary and micronutrient contents were estimated as per standard procedures (Table.1)

Cow urine

Panchagavya

Jeevamrutha

Vermiwash

Fish Amino Acid

Plate.1 Different types of on-farm liquid organic manures used for the study

Table1. Analytical procedures followed in the analysis of on-farm liquid organic manures

SI. No	Parameters	Methods	Reference
1	Colour	Visual evaluation	
2	Odour	Sensory evaluation	
3	pH	pH meter method	Jackson (1973)
4	EC	Conductivity meter method	Jackson (1973)
5	Organic carbon	Walkley and Black rapid titration method	Walkley and Black (1934)
6	Total Nitrogen	Microkjedahl digestion and distillation	Jackson(1973)
7	Total Phosphorus	Diacid(HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer	Jackson(1973)
8	Total Potassium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	Jackson (1973)
9	Total Calcium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)
10	Total Magnesium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)
11	Total Sulphur	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and turbidimetry	Massoumi and Cornfield(1963)
12	Total Micronutrients Fe, Mn, Zn ,Cu	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)

3.1.2.2 Biochemical activity

Important biochemical activities *viz.,* urease activity, acid and alkaline phosphatase activity, dehydrogenase activity, IAA, GA, cytokinin and ascorbic acid content of various liquid organic manures were determined as per standard procedures and are presented in Plate 2 to 3.

3.1.2.2.1 Urease Enzyme Activity (ppm of urea g^{-1} soil h^{-1})

Broadbent *et al.* (1964) described the method of estimation of urease enzyme activity in the soil samples.1 g soil was taken in a 50 ml conical flask and 20 ml of 500 ppm urea solution was added. Then kept for incubation at 37 ^{0} C for 4 hours. After that, the flasks were taken out and added 100 mg $CaSO_4$ to stop the urease activity in the sample. To the filtrate 10 ml of colouring agent, p – dimethyl amino benzaldehyde was added and the volume was made upto 50 ml. Colour developed after 5 minutes and the resulted greenish yellow solution was read by spectrophotometer at 420 nm. Urea standards of known concentration were also prepared.

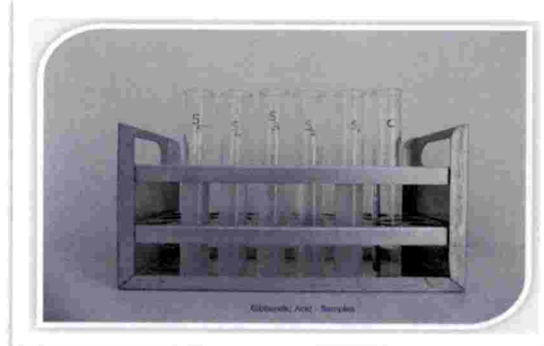
3.1.2.2.2 Acid Phosphatase Activity (μg of p-nitrophenol g^{-1} of soil h^{-1})

The acid phosphatase activity of soils was determined using the procedure outlined by Tabatabai and Bremner (1969). The enzyme activity was expressed in μg of p-nitrophenol released g^{-1} soil h^{-1}on dry weight basis at 37 ^{0} C at pH 6.5. In a 100 ml volumetric flask, 1gm soil was weighed. Toluene (0.2 ml) and modified universal buffer having pH 6.5 (4 ml) were added to the flask, followed by 1 ml of 0 .05 M p-nitrophenyl phosphate and kept in the incubator after swirling the flask for one hour at 37 ^{0} C. After incubation period, 1 ml $CaCl_2$ (0.5 M) and 4 ml NaOH (0.5 M) were added. The filtrate with yellowish colour was collected and read in spectrophotometer at 420 nm. The concentration of p-nitrophenol in the filtrate was determined by plotting standard curve.

Acid phosphataseAlkaline phosphatase

DehydrogenaseUrease

Plate.2 Different enzyme assay of on-farm liquid organic manures



Indole Acetic acidGibberellin

Cytokinin

Plate. 3Estimation of hormone contents of on-farm liquid organic manures

3.1.2.2.3 Alkaline Phosphatase Activity (µg of p-nitrophenol g^{-1} soil h^{-1})

The procedure for alkaline phosphatase assay was outlined by Tabatabai and Bremner (1969).The enzyme activity was expressed in µg of p-nitrophenol released g^{-1} of soil h^{-1} at 37 ^{0} C at pH 11. The procedure followed was same as acid phosphatase assay except for the use of modified universal buffer at pH 11.

3.1.2.2.4 Dehydrogenase Activity (µg of TPF g^{-1} soil 24 h^{-1})

The dehydrogenase activity was measured by the procedure described by Casida *et al.,* 1964. One gram of air dried sample blended with 0.2 g $CaCO_3$ and added 1 ml of 3 per cent 2, 3, 5 - triphenyl tetrazolium chloride (TTC) and distilled water (2.5 ml), mixed well and kept for incubation (24 hours) at room temperature. After 24 hours, added methanol (10 ml) and was shaken for one minute. The sample was then filtered using a glass funnel plugged with absorbent cotton and the whole amount of soil in the tube should be transferred into the funnel by washing with methanol. The tube was washed and the soil was transferred into the funnel. The reddish colour in the absorbent cotton was vanished while washing with methanol. Filtrate, which was red in colour, was made up to 100 ml with methanol and the colour intensity was measured using spectrophotometer at 485 nm. The concentration of dehydrogenase in the sample was obtained by plotting standard graph drawn by using tri phenyl formazon (TPF) as standard.

3.1.2.2.5 Indole Acetic Acid (IAA) Estimation

IAA estimation was performed by slight modification of Ahmad *et al* 2005. 1 mg of sample was collected and dissolved in 1N NaOH solution then centrifuged at 6000 rpm for 30 minutes. Supernatant was mixed with 1 drop of orthophosphoric acid and 2 ml of Salkowski's reagent (50 ml, 35% perchloric acid and 1 ml, 0.5 M $FeCl_3$). Development of a pink color indicated IAA production and the amount of IAA was measured by spectrophotometric method at 530 nm. Values were plotted against standard IAA values.

3.1.2.2.6 Gibberellic acid (GA) extraction and determination

10 ml of samples were filtered, and then samples were acidified to pH 2.5 with HCl and extracted using liquid-liquid (ethylacetate/$NaHCO_3$) extraction (1). Gibberellic acid in the ethyl acetate phase was measured by UV spectrophotometer (Elico- UV/VIS) at 254 nm (2). The amount of gibberellic acid was calculated from the standard curve (Cho *et al.,* 1979).

3.1.2.2.7 Bioassay for cytokinins estimation

Cytokinins reduce the growth of cucumber cotyledon which is primarily due to cell expansion rather than cell divison (Letham, 1971). This test is sensitive to kinetin (10µg to 25 mg/L) and is insensitive to IAA. Although GA shows weak activity in this test, it does not interfere with the response to cytokinin.

Select uniform sized cotyledon. Float the preweighed cotyledon in group of 5 in 7 ml of either water or test solution in 10 cm petri dishes or place them on filter paper moistened with test solution. Incubate leaves under fluorescent light for 3 days. After incubation, remove the leaves, blot them dry and determine their fresh weight or measure the leaf area. Correspondingly, run a standard with known concentration of kinetin and draw a dosage response curve. Calculate the concentration of cytokinins present in the extract from a standard curve.

3.1.2.2.8 Ascorbic acid

Ascorbic acid content of various liquid organic manures were estimated as per the standard procedure expressed in mg 100 g^{-1} (Sadasivam and Manickam, 1996).

3.1.3.3 Biological activity

Biological properties like total bacteria, fungi and actinomyctes count, N fixer, P solubilizer, K solubilizer, *E coli.* and *pseudomonas sp.* Microbial counts (Plate.4) and Table.2 in the soil samples were enumerated by serial dilution technique given by Timonin (1940) Appendix I.

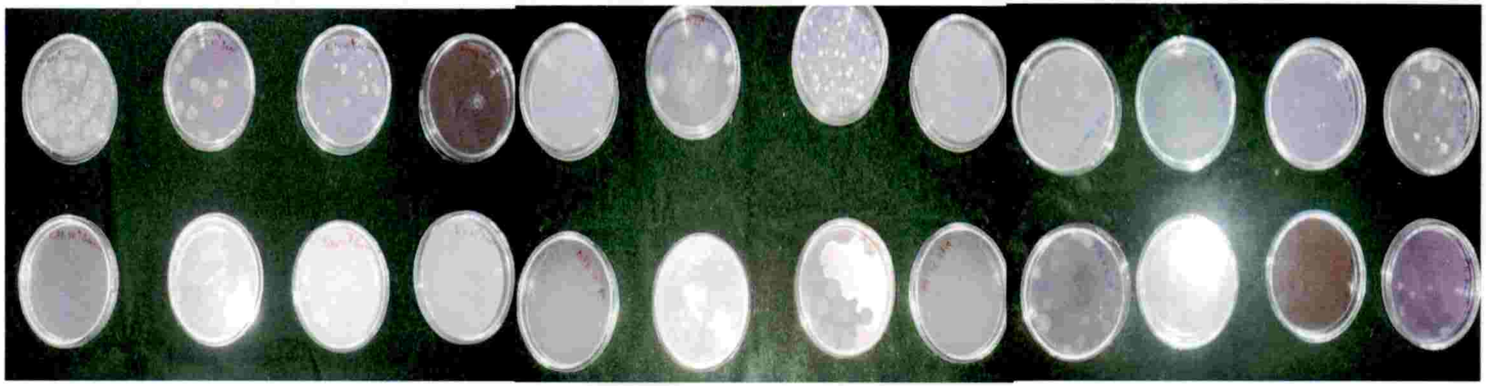
Table 2. Media used for estimation of microbial population

Sl. No.	Microflora	Media used	Reference
1	Bacteria	Nutrient Agar medium	Atlas and Parks (1993)
2	Fungi	Martin's Rose Bengal Agar	Martin (1950)
3	Actinomycetes	Ken knight's agar medium	Coppuccino and Sheman (1996)
4	*E.coli*	Eosin methylene blue	Levine (1918)
5	Azospirillum	Nitrogen free bromothymol blue medium	Dobereiner *et al.* (1976)
6	Azotobacter	Jensen's medium	Jensen (1942)
7	P solubilizers	Pikovskaya's media	Rao and Sinha (1963)
8	K solubilizers	Aleksandrov agar medium	Sugumara and Janartham (2007)
9	Pseudomonas *sp.*	King's B agar medium	King *et al.*(1954)

PART II

3.3. LABORATORY INCUBATION STUDY

The incubation study was conducted under laboratory condition for a period of two months from 3-1-2016 to 4-3-2016 (Plate.5). The main objective of the study was to assess the nutrient release pattern from different liquid manures like cow



Jeevamrutha Fish Amino AcidPanchagavya

Vermiwash Cow urine

Plate.4 Microbial enumeration of on-farm liquid organic manures

Plate.5 General view of laboratory incubation study

urine, panchagavya, fish amino acid jeevamrutha and vermiwash at periodic intervals *viz.*, 0^{th}, 7^{th}, 15^{th}, 45^{th} and 60^{th} day of incubation.

3.3.1 Collection and preparation of soil sample for incubation study

The soil for the incubation study was collected from model organic farm under the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. Soil samples collected were thoroughly mixed, air dried under shade and sieved through 2 mm sieve. Five kilogram of soil was filled in plastic buckets and on-farm liquid organic manures were added separately as per treatments. Sixty percent moisture was maintained throughout the study period by replenishing the moisture lost by evaporation which was found by calculating the weight difference. The details of experiment are presented below.

3.3.2 Design and Layout of the Experiment

Design : CRD

Treatments : 6

Replications : 4

3.3.3 Treatments details

T_1 : Soil alone 5 kg

T_2 : Soil 5 kg + Panchagavya 10 %

T_3 : Soil 5 kg + Fish amino acid 10 %

T_4 : Soil 5 kg + Cow urine 10 %

T_5 : Soil 5 kg + Jeevamrutha 10 %

T_6 : Soil 5 kg + Vermiwash10 %

The layout of the laboratory incubation study was presented in Fig.1

R1	R2	R3	R4
T_1	T_2	T_6	T_5
T_4	T_6	T_5	T_2
T_6	T_4	T_1	T_3
T_2	T_5	T_3	T_6
T_5	T_3	T_4	T_1
T_3	T_1	T_2	T_4

Fig.1 Layout of incubation study

3.3.4 Soil sampling

Samples were drawn at 0th, 7th, 15th, 30th,45th and 60th day of incubation and analysis was done for the following parameters.

3.3.5 Analysis of soil sample

Parameters *viz.,* pH, EC, available N, P, K, Ca, Mg, Fe, Mn, Zn and Cu were determined to study the changes during different intervals of incubation.

PART III

3.4 POT CULTURE EXPERIMENT

Pot culture experiment was conducted during April 2016 to April 2017 to the study of efficacy of soil and foliar applications of various liquid organic manures *viz.*, Cow urine, Panchagavya, Fish Amino Acid, Vermiwash and Jeevamrutha, on soil health and crop nutrition. In pot culture study, 75 per cent of the N requirement of crop was met through the application of enriched vermicompost (enriched with azolla 10%) (Plate.6).

3.4.1 Preparation of Enriched Vermicompost with azolla

The biowaste consisted of banana leaves and pseudostem was filled into tank of size 2.5 x 1 x 0.5m and well mixed with cow dung in the ratio of 10:1 on volume basis. Two weeks after filing the tank, 1 kg of earthworm (*Eudrillus euginae*) was introduced into the biowaste- cow dung mixture. Azolla at the rate of 10 per cent was added to the biowaste as additive for enriching the vermicompost. The moisture level was maintained at 60 per cent by adding water as and when required. Frequent raking was done for aeration. Final compost was ready by 75 days (Plate.7).

The prepared enriched vermicompost were analyzed and analytical methods are given in Table.3

Plate.6 General view of the pot culture experiment

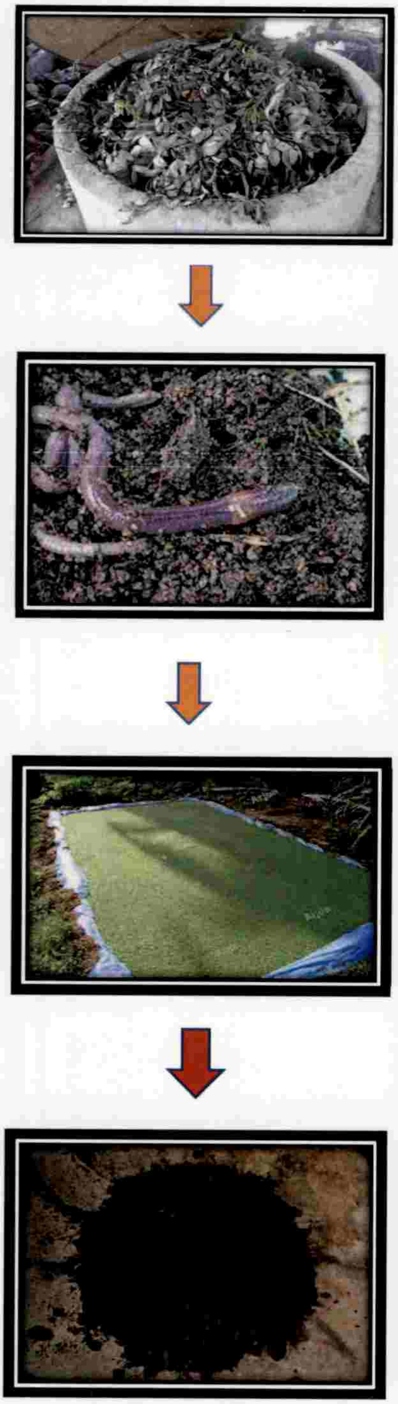


Plate.7 Production of enriched vermicompost with azolla

Table 3. Analytical methods followed in the analysis of vermicompost enriched with azolla

Sl.No.	Properties	Methods	Reference
1	pH	1:2.5 soil: water	Jackson (1973)
2	EC	Conductivity meter	Jackson (1973)
3	Nitrogen	Microkjedahl digestion and distillation	Jackson (1973)
4	Phosphorus	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer	Jackson (1973)
5	Potassium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	Jackson(1973)
6	Calcium and Magnesium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)
7	Micronutrients : Fe, Mn, Zn and Cu	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)
8	Microbial count (log cfu g^{-1})	Serial dilution plate technique	Timonin (1940)

3.5.1 Experimental site

The pot culture experiment was conducted at Model organic farm under the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. Geographically the area is situated at $8^0 50'$ North latitude and $76^0 90'$ East longitude and at an altitude of 29 m above MSL.

3.5.2 Season

The period of crop growth was from April 2016 to April 2017. Average rainfall, temperature, evaporation and relative humidity at monthly intervals were collected from meteorological observatory attached to the College of Agriculture, Vellayani during the cropping period and are given in Appendix II and graphically presented in Fig.2.

3.5.3 Soil

The soil used for the pot culture experimental was sandy clay loam belonging to the taxonomic class Loamy Kaolinitic Isohyperthermic Typic Kandiustult.

3.5.4 Crop and Variety

The bhindi variety Anjitha was used as test crop for pot culture experiment. Anjitha variety was released in the 23^{rd} Kerala State Seed Sub Committee meeting. The seed material was obtained from the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani Variety details are given in Appendix III.

3.6 METHODS

The different methods used for the analysis of soil and plant samples and details of pot culture experiment are presented below (Fig.3).

3.6.1 Details of experiment

Design	: CRD
Crop	: Bhindi
Variety	: Anjitha
Replication	: 3
Treatments	: 13

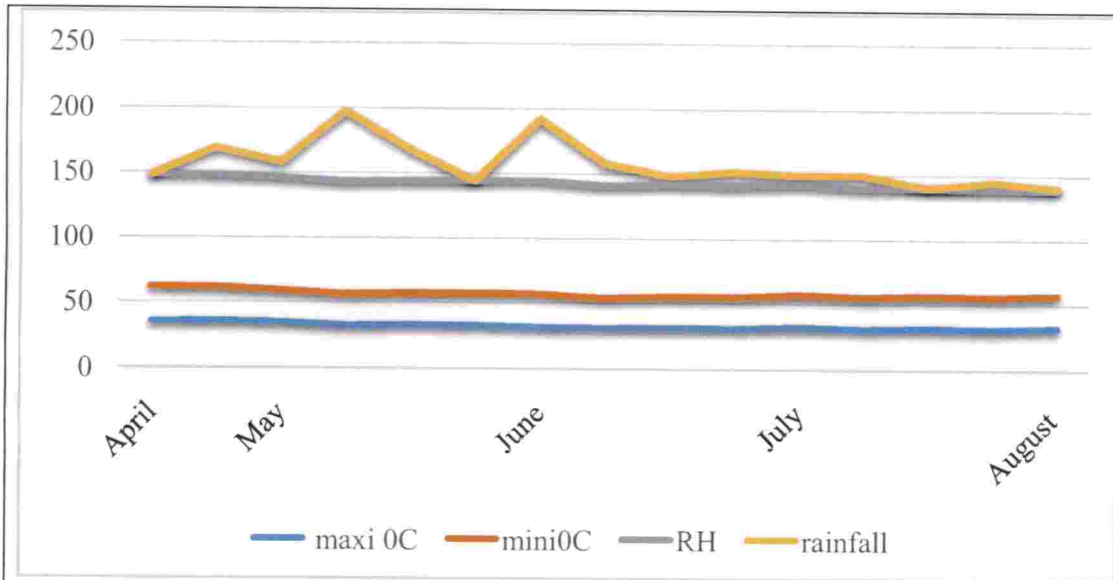


Fig .2 Weather data during the growth period of bhindi crop

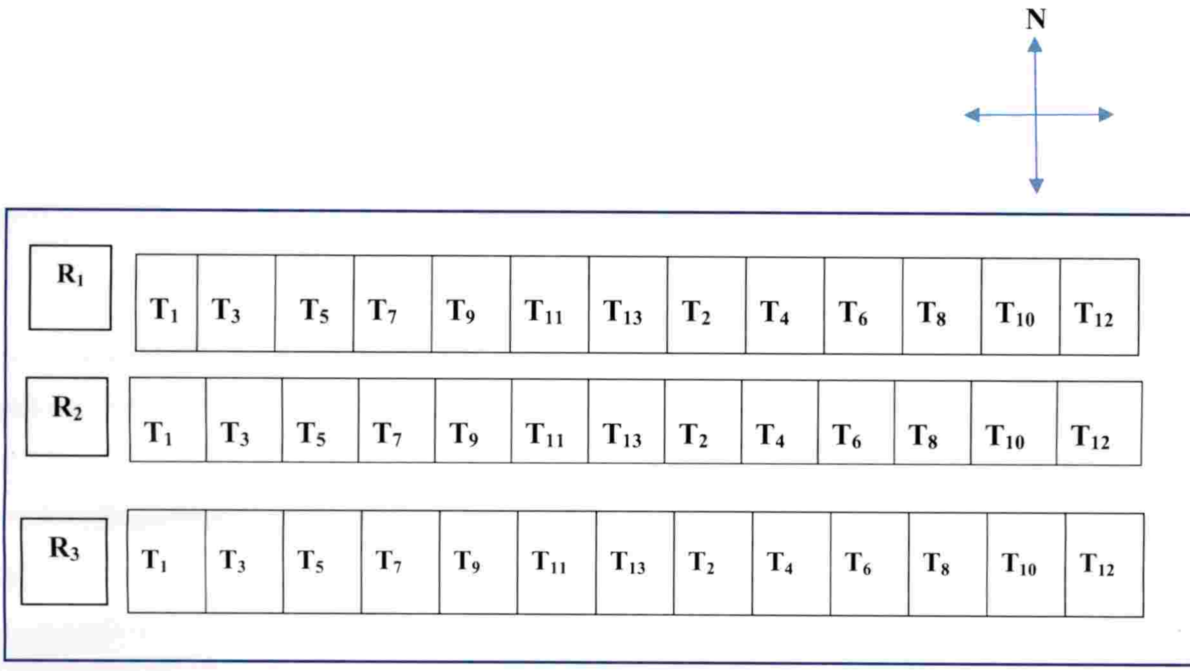


Fig. 3 Lay out of pot culture experiment

The experiment was conducted by adopting the following treatments.

T_1 : KAU PoP (FYM 12 t/ha NPK 110: 35: 70 kg/ha)

T_2 : Organic Adhoc PoP

T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)

T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)

T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)

T_6 : 75 % N as EVC + Panchagavya 3% (soil application)

T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)

T_8 : 75 % N as EVC + Cow urine 10 % (soil application)

T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)

T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)

T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)

T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)

T_{13} : Absolute control

Note: EVC- Enriched vermicompost (enriched with azolla10 %)

3.6.2 Manures and Fertilizers

Grow bags were filled with soil collected from Model organic farm and arranged at a spacing of 60 x 30 cm, with basal dose of FYM @ 12 t ha^{-1} was applied uniformly in all treatments except absolute control. The recommendation of chemical fertilizers (KAU PoP) for bhindi is 110:35:70 kg NPK ha^{-1} and was applied for T_1 treatments. Vermicompost enriched with azolla was used as N source for supplying 75 per cent N requirement of crop for the treatments T_3 to T_{12}. Diluted liquid organic manures were applied periodically at ten days intervals as per treatments

3.6.3 After cultivation

Plant population was maintained uniformly by gap filling and thinning wherever necessary. Irrigation and weeding were done as and when required.

3.7 BIOMETRIC OBSERVATIONS

3.7.1 Growth Characters

3.7.1.1 Plant height

Height of plants was measured from base of the plant to the terminal leaf bud at first and final harvest and the expressed in centimeters (cm).

3.7.1.2 Inter nodal length at first harvest

Inter nodal length was recorded at first harvest. The inter nodal length was measured as vertical distance between two adjacent leaf axils and expressed in centimeters (cm).

3.7.1.3 Number of branches per plant

Number of branches per plant was recorded at first harvest.

3.7.1.4 Leaf area index (LAI)

LAI was computed using the formula suggested by Watson (1952) at first harvest.

LAI= Leaf area /Land area

3.7.1.5 Dry matter production

Dry matter production was recorded by recording fresh weight and oven dry weight of plant. The fresh samples were first shade dried and then oven dried at 70^0C to a constant weight and dry matter production was expressed in g plant $^{-1}$.

3.8 PHYSIOLOGICAL CHARACTERS

3.8.1 Estimation of chlorophyll content

0.1g of weighed fresh sample was take and cut into small bits and kept over night in 10 ml of acetone (80%) :DMSO mixture(1:1 v/v) and the coloured solution was used for reading in spectrophotometer. Absorbance was read at 663 nm and 645 nm.The chlorophyll content was calculated as mg g^{-1} by using the formula given below (Hiscox and Israelstam, 1979).

Chlorophyll a = $(12.7x\ A_{663}\ -2.69\ x\ A_{645})\ x\ V/1000\ x\ 1\ /\text{fresh weight}$

Chlorophyll b = $(22.9\ x\ A_{645}\ -\ 4.68\ x\ A_{663})\ x\ V/1000\ x\ 1\ /\text{fresh weight}$

Total chlorophyll content = $(8.02\ x\ A_{663} + 20.2\ x\ A_{645})V/1000\ x\ 1\ /\text{fresh weight}$.

3.9 YIELD AND YIELD ATTRIBUTES

3.9.1 Days to first flowering

Number of days to reach first flowering was counted from the date of sowing to the date at which first flowering in a plot was observed.

3.9.2 Number of flowers formed

Total number of flowers from the observational plants were recorded and the average was worked out.

3.9.3 Number of fruits per plant

Number of fruits harvested from observational plants were counted and the average was worked out.

3.9.4 Length of fruit

Length of the fruits harvested from observational plants were measured and the mean length was worked out and expressed in centimeter.

3.9.5 Girth of fruit

The fruits used for measuring the length were used for recording the girth. Girth was measured by winding a thread around the individual fruits at the centre and expressed in centimeter.

3.9.6 Average fruit weight

Weight of fruits from the observational plants was recorded and the mean was worked out and expressed in grams.

3.9.7 Total fruit yield

Fruit yield per plant was computed by adding the weights of fruits of each harvest of the observational plants and the mean values were worked out and expressed as g $plant^{-1}$.

3.10 QUALITY PARAMETERS OF FRUITS

3.10.1 Crude protein content

The nitrogen content of fruits were determined and the values were multiplied by the factor 6.25 to obtain the crude protein content of fruits and the values were expressed in per cent (Simpson *et al.*,1965).

3.10.2 Crude fiber content

The crude fiber content was determined by AOAC method (AOAC, 1984).

3.10.3 Ascorbic acid content

The ascorbic acid content of fruit was estimated by titrimetric method (Sadasivam and Manickam, 1996) and expressed in mg 100 g^{-1}.

3.11 INCIDENCE OF PEST AND DISEASES

Incidence of semi loopers and fruit and shoot borers were seen initially. Nimbicidine 5 per cent was applied at fortnightly intervals for controlling these pests.

3.12 SOIL ANALYSIS

Soil samples were analyzed before and after the pot culture experiment. The air dried samples passed through 2 mm sieve were used for the analysis of chemical properties and fresh soil samples were collected for biochemical and biological analysis using standard procedures as given in Table 4.

3.13 PLANT ANALYSIS

One plant out of the observational plants was uprooted after harvest and the root was removed. The plant was chopped, air dried and then dried at 70^0 C in a hot air oven. The dried samples were powdered and used for analysis. The standard procedures adopted are given in Table 5.

Table 4. Analytical procedures followed in soil analysis

SI. No.	Properties	Methods	Reference
1	Texture	International pipette method	Piper(1966)
2	pH	pH meter	Jackson (1958)
3	EC	Conductivity meter	Jackson(1958)
4	Organic carbon	Walkley and Black rapid titration method	Walkley and Black(1934)
5	Labile carbon	Potassium permanganate method	Blair *et al.*(1995)
6	Available N	Alkaline potassium permanganate method	Subbiah and Asija (1956)
7	Available P	Bray No.1 extraction and estimation using spectrophotometer.	Bray and Kurtz (1945)
8	Available K	Neutral normal ammonium acetate extraction and estimation using flame photometry	Jackson (1973)
9	Exchangeable Ca	Neutral normal ammonium acetate extraction and estimation using AAS	Jackson (1973)
10	Exchangeable Mg	Neutral normal ammonium acetate extraction and estimation using AAS	Jackson (1973)
11	Available S	$CaCl_2$ extraction and estimation using spectrophotometer.	Massoumi and Cornfield (1963)
12	Micronutrients Fe, Mn, Zn and Cu	0.5 N HCl extraction and estimation using AAS	Sims and Jhonson (1991)
13	Dehydrogenase	Spectrophotometric method	Casida*et al.* (1964)
14	Urease	Spectrophotometric method	Broadbent *et al.*(1964)
15	Alkaline phosphatase	Spectrophotometric method	Tabatabai and Bremner (1969)
16	Acid phosphatase	Spectrophotometric method	Tabatabai and Bremner (1969)
17	Bacteria	Nutrient Agar medium	Atlas and Parks (1993)
18	Fungi	Martin's Rose Bengal Agar	Martin (1950)
19	Actinomycetes	Ken knight's agar medium	Coppuccino and Sheman (1996)
20	*E.coli*	Eosin methylene blue	Levine (1918)
21	Azospirillum	Nitrogen free bromothymol blue medium	Dobereiner *et al.* (1976)
22	Azotobacter	Jensen's medium	Jensen (1942)
23	P solubilizers	Pikovskaya's media	Rao and Sinha (1963)
24	K solubilizers	Aleksandrov agar medium	Sugumara and Janartham (2007)
25	Pseudomonas *sp.*	King's B agar medium	King *et al.*(1954)

Table 5. Analytical methods followed in plant analysis

Sl. No.	Properties	Methods	Reference
1	Nitrogen	Microkjedahl digestion and distillation	Jackson (1973)
2	Phosphorus	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer	Jackson (1973)
3	Potassium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	Jackson(1973)
4	Calcium and Magnesium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)
5	Sulphur	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and turbidimetry	Massoumi and Cornfield(1963)
6	Micronutrients : Fe, Mn, Zn and Cu	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)

3.13.1 Uptake of plants

Plant parts were analyzed for N ,P, K ,Ca, Mg, S ,Fe ,Mn ,Zn and Cu content using standard procedures and total uptake was calculated based on their contents in the plant and their corresponding dry matter weight. The uptake values were expressed in g per plant.

3.14 ECONOMICS OF CULTIVATION

Economics of cultivation was worked out for the pot culture experiment after taking into account the cost of cultivation and prevailing market price of bhindi. The B:C ratio was calculated as follows.

Benefit : Cost ratio = Gross income /Total expenditure

3.15 STATISTICAL ANALYSIS

The data generated from the above mentioned experiments were subjected to analysis of variance as per the design, CRD and their significance was tested using F test (Snedecor and Cochran, 1975) and where the effects were found to be significant, CD was calculated using standard technique.

Results

4 RESULT

The present investigation entitled "Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition" was carried out in the College of Agriculture Vellayani during the period August 2015 to March 2017. Characterization of on-farm liquid organic manures *viz.*, cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these liquid manures on soil health and crop nutrition using bhindi as test crop envisaged in the study were the main objectives.

The investigation comprised of three parts. The first part of the experiment was the preparation and characterization of different on-farm liquid organic manures. Laboratory incubation study was carried out as second part of the experiment by utilizing the above mentioned on- farm liquid organic manures to monitor nutrient release pattern. The third part of the experiment was pot culture experiment to evaluate the efficacy of soil and foliar applications of these liquid manures on soil health and crop nutrition using bhindi as test crop.

The data generated from the various experiments conducted to realize the objectives of the study were statistically analysed and are presented in this chapter.

PART I

4.1 CHARACTERIZATION OF ON-FARM LIQUID ORGANIC MANURES

4.1.1 Physical and physico-chemical characters of on-farm liquid organic manures

Data presented in Table.6 shows the physical and physico-chemical characters of on-farm liquid organic manures *viz.*, cow urine, panchagavya, jeevamrutha, vermiwash and fish amino acid.

The colour and odour of the cow urine were pale yellow and ammonical smell respectively. Colour of jeevamrutha was moderate green with mild foul odour. Panchagavya has a light brown colour and fermented odour. FAA was dark brown in colour and odourless. The colour and odour of the vermiwash were honey brown and odourless.

Among the liquid organic manures studied, FAA and panchagavya showed acidic pH and other three liquid organic manures *viz.,* cow urine, jeevamrutha and vermiwash recorded neutral pH. The pH was the highest for cow urine (7.40) followed by vermiwash (7.30), jeevamrutha (7.00), panchagavya (5.70) and FAA (4.26). Panchagavya registered the highest electrical conductivity (10.20 dSm^{-1}) followed by vermiwash (9.65 dSm^{-1}), cow urine (7.80 dSm^{-1}), FAA (5.63 dSm^{-1}) and jeevamrutha (1.53 dSm^{-1}). The results revealed that FAA registered the highest organic carbon content of 39.96 per cent followed by panchagavya (0.84%), cow urine (0.46%), vermiwash (0.23%) and jeevamrutha (0.09%).

4.1.2 Major and Secondary nutrient contents of on-farm liquid organic manures

The on-farm liquid organic manures *viz.,* cow urine, jeevamrutha, panchagavya, vermiwash and FAA were analysed for major and secondary nutrient status and the results are presented in Table 7.

Regarding major nutrients, the maximum nitrogen content was recorded in panchagavya (0.45%) followed by FAA (0.13%), vermiwash (0.08%), cow urine (0.07%) and jeevamrutha (0.04%).The highest phosphorous content was observed in

FAA (0.41%) followed by panchagavya (0.18%)), cow urine (0.06%), jeevamrutha (0.17%) and vermiwash (0.06%). The maximum K content was recorded in cow urine (0.17%) followed by panchagavya (0.11%), vermiwash (0.07%), FAA (0.06%) and jeevamrutha (0.01%).

Considering secondary nutrient status of liquid organic manures, calcium content was found to be the highest in FAA (324.00 mg L^{-1}) followed by jeevamrutha (187.00mg L^{-1}) panchagavya (147.50 mg L^{-1}) cow urine (135.23 ml L^{-1}) and vermiwash (91.27 mg L^{-1}).The magnesium was found to be the highest in FAA (49.00 mg L^{-1}) followed by cow urine (46.62 mg L^{-1}), panchagavya (46.00 mg L^{-1}), vermiwash (24.26 mg L^{-1}) and jeevamrutha (17.17 mg L^{-1}).The highest S content was recorded in FAA (565.00 mg L^{-1}) followed by jeevamrutha (553.00 mg L^{-1}), panchagavya (465.00 mg L^{-1}) vermiwash (425.00 mg L^{-1}) and cow urine (308.00 mg L^{-1}). S content of all the liquid organic manures were higher compared to Ca and Mg content. The highest contents of Ca (324.00 mg L^{-1}), Mg (49.00 mg L^{-1}) and S (565.00 mg L^{-1}) were recorded by FAA.

Table 6. Physical and physico- chemical characters of on-farm liquid organic manures

Sl. No.	Liquid manures	Colour	Odour	pH	EC(dSm^{-1})	OC (%)
1	Cow urine	Pale yellow	Ammoniacal smell	7.40	7.80	0.46
2	Jeevamrutha	Moderate green	Mild foul smell	7.00	1.53	0.09
3	Panchagavya	Light brown	Fermented odour	5.70	10.20	0.84
4	Fish Amino Acid	Dark brown	Odourless	4.26	5.63	39.9
5	Vermiwash	Honey brown	Odourless	7.30	9.65	0.23

Table 7. Major and Secondary nutrient contents of on–farm liquid organic manures

Sl. No.	Liquid manures	N(%)	P(%)	K(%)	Ca (mg L^{-1})	Mg (mg L^{-1})	S(mg L^{-1})
1	Cow urine	0.07	0.06	0.17	135.23	46.62	308.00
2	Jeevamrutha	0.04	0.17	0.01	187.00	17.17	553.00
3	Panchagavya	0.45	0.18	0.11	147.50	46.00	465.00
4	Fish Amino Acid	0.13	0.41	0.06	324.00	49.00	565.00
5	Vermiwash	0.08	0.06	0.07	91.27	24.26	425.00

4.1.3 Micronutrient contents of on-farm liquid organic manures

Micronutrient contents of on-farm liquid organic manures used in the study are presented in Table 8. The Fe content recorded the highest value in jeevamrutha (39.92 ml L^{-1}) followed by vermiwash (10.16 mg L^{-1}), panchagavya (9.21 mg L^{-1}). cow urine (7.43 mg L^{-1}) and FAA (6.62 mg L^{-1}). The result revealed that cow urine registered the highest manganese content of 0.40 ml L^{-1} followed by jeevamrutha (0.37 mg L^{-1}), panchagavya (0.27 mg L^{-1}), vermiwash (0.16 mg L^{-1}) and FAA (0.15 mg L^{-1}). For zinc content, the highest value was recorded in FAA (2.00 mg L^{-1}) followed by jeevamrutha (1.48 mg L^{-1}), cow urine (0.88 mg L^{-1}), vermiwash (0.85 mg L^{-1}) and panchagavya (0.52 mg L^{-1}). In case of copper content cow urine recorded the highest value (21.21mg L^{-1}) followed by vermiwash (2.50 mg L^{-1}), panchagavya (2.30 mg L^{-1}), jeevamrutha (2.17mg L^{-1}) and FAA (0.54 mg L^{-1}).

Table 8. Micronutrient contents of on-farm liquid organic manures, mg L^{-1}

Sl. No.	Liquid manures	Fe	Mn	Zn	Cu
1	Cow urine	7.43	0.40	0.88	21.21
2	Jeevamrutha	39.92	0.37	1.48	2.17
3	Panchagavya	9.21	0.27	0.52	2.30
4	Fish Amino Acid	6.62	0.15	2.00	0.54
5	Vermiwash	10.16	0.16	0.85	2.50

4.1.4 Enzyme activity of on- farm liquid organic manures

Data in Table.9 shows the enzyme activity of liquid organic manures. Results indicated that the highest dehydrogenase activity (371.27 μg of TPF g^{-1} soil 24 h^{-1}) was recorded by cow urine followed by fish amino acid (336.98 μg of TPF g^{-1} soil 24 h^{-1}) panchagavya (271.46 μg of TPF g^{-1}soil 24 h^{-1}), jeevamrutha (194.49 μg of TPF g^{-1} soil 24 h^{-1}) and vermiwash (39.85 μg of TPF g^{-1} soil 24 h^{-1}). From this table it is clear that the highest acid phosphatase activity was found with FAA (181.34 μg of p- nitrophenol g^{-1}soil h^{-1}) followed by cow urine (60.40 μg of p-nitrophenol g^{-1} soil h^{-1}), jeevamrutha (36.78 μg of p- nitrophenol g^{-1}soil h^{-1}), panchagavya (29.44 μg of p- nitrophenol g^{-1}soil h^{-1}) and vermiwash (23.45 μg of p-nitrophenol g^{-1}soil h^{-1}). Alkaline phosphatase activity of liquid organic manures indicated that FAA recorded the highest value of 176.67 μg of p- nitrophenol g^{-1} soil h^{-1} followed by panchagavya (18.63 μg of p-nitrophenol g^{-1} soil h^{-1}), jeevamrutha (17.02 μg of p- nitrophenol g^{-1}soil h^{-1}), cow urine (5.75 μg of p- nitrophenol g^{-1}soil h^{-1}) and vermiwash (2.90 μg of p- nitrophenol g^{-1}soil h^{-1}). Regarding the urease activity of on- farm liquid organic manures (Table. 9), FAA registered the highest value of 273.83 ppm of urea g^{-1} soil h^{-1} followed by cow urine (188.97 ppm of urea g^{-1}soil h^{-1}), jeevamrutha (170.37 ppm of urea g^{-1}soil h^{-1}), panchagavya (132.27 ppm of urea g^{-1}soil h^{-1}) and vermiwash (77.46 ppm of urea g^{-1}soil h^{-1}).

4.1.5 Hormones and Ascorbic acid contents in on-farm liquid organic manures

The hormones and ascorbic acid contents of liquid organic manures are presented in table.10. Result indicated that FAA recorded the highest value of IAA (6 μg ml^{-1}) followed by jeevamrutha (5.90 μg ml^{-1}), panchagavya (4.00 μg ml^{-1}), cow urine (0.75 μg ml^{-1}) and vermiwash (0.50 μg ml^{-1}). Data on GA content showed that FAA recorded the highest value of 35.00 μg ml^{-1} followed by jeevamrutha (34.00 μg ml^{-1}), panchagavya (24.00 μg ml^{-1}), vermiwash (12.50 μg ml^{-1}) and cow urine (11.05 μg ml^{-1}). From the results it can be inferred that among the liquid organic manures studied panchagavya recorded the highest cytokinin content of 2.82 mg L^{-1} followed by vermiwash (2.77 mg L^{-1}), jeevamrutha (2.52 mg L^{-1}), FAA (2.27 mg L^{-1}) and cow urine (2.16 mg L^{-1}).

Regarding the ascorbic acid contents of liquid organic manures studied, vermiwash registered the highest value of 37.50 mg $100g^{-1}$ followed by jeevamrutha and panchagavya (12.50 mg $100g^{-1}$), FAA and cow urine (8.30 mg 100 g^{-1}).

Table 9. Enzyme activity of on-farm liquid organic manures

Sl .No.	Liquid manures	Dehydrogenase (µg of TPF g^{-1} soil 24 h^{-1})	Acid phosphatase (µg of p-nitrophenol g^{-1}soil h^{-1})	Alkaline phosphatase (µg of p-nitrophenol g^{-1} soil h^{-1})	Urease (ppm of urea g^{-1} soil h^{-1})
1	Cow urine	371.27	60.40	5.75	188.97
2	Jeevamrutha	194.49	36.78	17.02	170.37
3	Panchagavya	271.46	29.44	18.63	132.27
4	Fish Amino Acid	336.98	181.34	176.67	273.83
5	Vermiwash	39.85	23.45	2.90	77.46

Table 10. Hormones and Ascorbic acid contents of on-farm liquid organic manures

Sl. No.	Liquid manures	IAA (µg ml^{-1})	GA (µg ml^{-1})	Cytokinin (mg L^{-1})	Ascorbic acid (mg 100 g^{-1})
1	Cow urine	0.75	11.05	2.16	8.30
2	Jeevamrutha	5.90	34.00	2.52	12.50
3	Panchagavya	4.00	24.00	2.82	12.50
4	Fish Amino Acid	6.00	35.00	2.27	8.30
5	Vermiwash	0.50	12.50	2.77	37.50

4.1.6. Microbial population of on -farm liquid organic manures, log cfu mL^{-1}

Microbial population present in various liquid organic manures are presented in Table.11. Regarding the bacterial count, vermiwash registered the highest value of 8.36 log cfu mL^{-1} followed by jeevamrutha (8.26 log cfu mL^{-1}), panchagavya (8.17 log cfu mL^{-1}), cow urine and FAA (7.83 log cfu mL^{-1}). For fungal count, the highest value was recorded by the jeevamrutha (4.91 log cfu mL^{-1}) followed by vermiwash (4.61 log cfu mL^{-1}), FAA (4.41 log cfu mL^{-1}) and panchagavya (4.23 log cfu mL^{-1}) and no fungal count was observed in cow urine. Jeevamrutha and FAA registered the same count of actinomycetes (1.23 log cfu mL^{-1}) whereas, actinomycetes were absent in cow urine, panchagavya and vermiwash. Maximum azotobacter population of 4.65 log cfu $mL^{-1}$was recorded in FAA followed by panchagavya (1.39 log cfu mL^{-1}). The highest population of K solubilizes (4.21 log cfu mL^{-1}) was registered by vermiwash followed by cow urine (4.05 log cfu mL^{-1}), panchagavya (2.81 log cfu mL^{-1}). K solubilizers were absent in jeevamrutha and FAA. P solubilizers, *E. coli* , azospirllum and *pseudomonas sp.* were absent in on-farm liquid organic manures such as cow urine, panchagavya, jeevamrutha, vermiwash and FAA.

4.2 LABORATORY INCUBATION STUDY

The incubation experiment was conducted to study the nutrient release pattern of on-farm liquid organic manures under laboratory conditions. The various soil parameters *viz.,* pH, EC, major, secondary and micro nutrients were estimated on 0^{th},7^{th},15^{th},30^{th}, 45^{th} and 60^{th} days of incubation and presented in Table 12-22.

4.2.1 pH

pH as a key factor in deciding the availability of various nutrients, the data on changes in pH under various treatments conditions require a detailed examination. Mean values of pH of soil incubated for 60 days at various intervals are given in

Table 12. It was found that there was significant variation in pH values due to various treatments.

In general, increased pH values were observed in all the treatments received diluted liquid organic manures compared to control throughout the incubation period. Soil reaction found to be increased upto 30th day of incubation and thereafter showed declining tendency on 45th and 60th day of incubation. A maximum pH value of 5.82 was recorded by T_4 (Soil 5 kg + cow urine 10 %) on 7th day of incubation and on subsequent intervals pH values were found to be decreasing. The lowest values were recorded by T_1 (Soil alone 5 kg) throughout the incubation periods. On 0th day T_6 (soil 5 kg + vermiwash 10 %) recorded the highest value of 4.67 which was found on par with T_4, T_3 and T_5. On 7th day,the highest mean value of 5.82 was observed in T_4 (Soil 5 kg + cow urine 10 %) and was significantly superior than all other treatments.T_4 (Soil 5 kg + Cow urine10 %) also recorded the highest value (5.48) on 15th day of incubation which was found to be on par with T_3 (5.17) and T_2 (5.15). On 30th and 45th day, the highest pH values of 5.80 and 5.63 were recorded respectively by T_3 (Soil 5 kg + fish amino acid 10 %) and was significantly superior than all other treatments. The highest value (5.35) was recorded by T_3 on 60th day o incubation which was on par with T_2 (soil 5 kg + panchagavya 10 %) and T_5 (soil 5 kg + jeevamrutha 10 %).

Table 11. Microbial population of on-farm liquid organic manures, log cfu ml^{-1}

Sl. No.	Liquid manures	Bacteria	Fungi	Actinomycetes	Azotobacter	Azospirillum	*E .coli*	K solubilizer	P solubilizer	*Pseudomonas sp.*
1	Cow urine	7.83	0.00	0.00	0.00	0.00	0.00	4.05	0.00	0.00
2	Jeevamrutha	8.26	4.91	1.23	0.00	0.00	0.00	0.00	0.00	0.00
3	Panchagavya	8.17	4.23	0.00	1.39	0.00	0.00	2.81	0.00	0.00
4	Fish Amino Acid	7.83	4.41	1.23	4.65	0.00	0.00	0.00	0.00	0.00
5	Vermiwash	8.36	4.61	0.00	0.00	0.00	0.00	4.21	0.00	0.00

Table 12. **Changes in pH of soil during the incubation period**

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1 Soil alone 5kg	4.48	4.58	4.35	4.37	4.98	4.79
T_2 Soil 5kg + Panchagavya 10%	4.56	5.12	5.15	5.17	5.12	5.20
T_3Soil 5kg + Fish amino acid 10%	4.61	4.79	5.17	5.80	5.63	5.35
T_4Soil 5kg + Cow urine10%	4.64	5.82	5.48	5.41	5.20	4.97
T_5Soil 5kg + Jeevamrutha 10%	4.58	4.70	5.05	5.10	5.12	5.10
T_6 Soil 5kg + Vermiwash10%	4.67	5.27	4.50	5.15	5.02	5.00
SE±	0.03	0.13	0.12	0.09	0.07	0.12
CD(0.05)	0.093	0.395	0.321	0.280	0.215	0.313

4.2.2 EC

The significant variation in electrical conductivity due to various treatments were recorded (Table.13). In general there was increasing trend with respect to this parameter on advancement of the incubation period.

The treatment T_2 (Soil 5 kg + panchagavya 10 %) recorded the highest value (0.13 dSm^{-1}) of electrical conductivity on 0^{th} day of incubation. The treatment T_4 (Soil 5 kg + cow urine 10 %) registered the highest value of EC on 7^{th} day (0.20 dSm^{-1}), 15^{th} day (0.18dSm^{-1}), 30^{th} day (0.17dSm^{-1}), 45^{th}day (0.18 dSm^{-1}) and 60^{th} day (0.41 $dS\ m^{-1}$) of incubation. T_1 (soil alone) recorded the lowest EC throughout the incubation period. On 7^{th} day of incubation, T_3 (0.16 dSm^{-1}) was on par with T_4 (0.20 dSm^{-1}). On 15^{th} day of incubation, T_6 was on par with T_4. T_4 was found to be significantly superior than all other treatments on 30^{th} day of incubation. On 45^{th} day of incubation, T_2 and T_6 (0.13 dSm^{-1}) were on par with T_4 (0.18 dSm^{-1})

Table 13. Changes in EC (dSm^{-1}) of soil during the incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1 Soil alone 5kg	0.02	0.06	0.05	0.06	0.12	0.11
T_2 Soil 5kg + Panchagavya 10%	0.13	0.07	0.09	0.07	0.13	0.13
T_3 Soil 5kg + Fish amino acid 10%	0.02	0.16	0.11	0.08	0.12	0.32
T_4 Soil 5kg + Cow urine10%	0.02	0.20	0.18	0.17	0.18	0.41
T_5 Soil 5kg + Jeevamrutha 10%	0.02	0.09	0.10	0.07	0.12	0.22
T_6 Soil 5kg + Vermiwash10%	0.03	0.10	0.13	0.07	0.13	0.15
SE±	0.004	0.025	0.019	0.007	0.005	0.026
CD(0.05)	0.011	0.075	0.056	0.021	0.015	0.078

4.2.3 Available nitrogen

Being the most important nutrient in plant nutrition, the data on available N need a thorough study and interpretation. Mean values of available N content of incubation study are presented in Table 14. There was significant difference in available N content between treatments at all periods of incubation. In general all the treatments showed an increasing trend with respect to available N throughout the incubation period.

The highest value (167.09 kg ha^{-1}) was recorded by T_3 (Soil 5 kg + Fish amino acid 10 %) which was found to be on par with T_4 (164.22 kg ha^{-1}), T_5 (161.31 kg ha^{-1}),T_6 (152.39 kg ha^{-1}) and T_2 (150.55 kg ha^{-1}) on 0^{th} day On 7^{th} and 15^{th} day of incubation T_3 (Soil 5 kg + fish amino acid 10 %) recorded the highest mean value of 234.60 kg ha^{-1} ,377.17 kg ha^{-1} respectively and followed by T_5. The highest mean value of 282.17 kg ha^{-1} was recorded by T_5 (soil 5 kg + jeevamrutha 10 %) followed by T_3 (244.32 kg ha^{-1}) on 30^{th} day. On 45^{th} day of incubation, the highest value (281.56 kg ha^{-1}) was recorded by T_6 (soil 5 kg + vermiwash 10 %) which was found to be on par with T_3 (269.26 kg ha^{-1}). On 60^{th} day of incubation, the highest mean value (343.33 kg ha^{-1}) was recorded for T_6, which was found on par with T_5 (319.35 kg ha^{-1}). In the case of vermiwash applied treatment, release of available N was found to be increased throughout the incubation period and maximum release (343.33 kg ha^{-1}) was recorded on 60th day of incubation. T_1 (soil alone) recorded the lowest value throughout the incubation period.

Table 14. Changes in available N (kg ha^{-1}) content of soil during the incubation Period

Treatments	0th	7th	15th	30th	45th	60th
T_1 Soil alone 5kg	118.04	132.52	138.25	160.78	127.00	131.88
T_2 Soil 5kg + Panchagavya 10%	150.55	154.89	175.90	193.74	162.68	181.88
T_3 Soil 5kg + Fish amino acid 10%	167.09	234.60	377.17	244.32	269.26	238.31
T_4 Soil 5kg + Cow urine10%	164.22	173.06	210.96	215.56	210.18	209.23
T_5 Soil 5kg + Jeevamrutha 10%	161.31	198.00	251.90	282.17	209.42	319.35
T_6 Soil 5kg + Vermiwash10%	152.39	157.45	206.72	239.65	281.56	343.33
SE±	5.87	9.99	21.52	12.49	8.79	8.53
CD(0.05)	17.47	29.68	63.98	37.10	25.86	25.34

4.2.4. Available phosphorus

The quantity of available P was considered to be very important in plant growth since it directly reflect the immediate P nutrition to plants. Table 15 represents the effect of various treatments and periods of incubation on available phosphorous. In general, P content was found to be increased upto 30th day of incubation and there after showed a decreasing tendency.

The highest mean value was recorded by T_3 (soil 5 kg + fish amino acid 10 %) with 52.87 kg ha^{-1}available phosphorous content and followed byT_2 (34.75 kg ha^{-1}) on 0th day of incubation. On 7th day of incubation, T_2 (soil 5 kg + panchagavya 10 %) recorded the highest mean value of 106.48 kg ha^{-1}followed by T_5 (87.17 kg ha^{-1}). In general T_3 (soil 5kg + fish amino acid 10 %) recorded the highest mean values of available P content on 0th, 15th , 30th ,45th and 60th day of incubation. On 15th day, T_3 recorded the highest mean value of 98.22 kg ha^{-1} and was on par with T_2, T_5 and T_6. On 30th day of incubation, T_3 (soil 5 kg +fish amino acid 10 %) recorded the highest mean value of 147.85 kg ha^{-1}and followed by T_5 (90.45 kg ha^{-1}). On 45th day of incubation, the highest value was recorded by T_3 (65.57 kg ha^{-1}) and was found to be on par with T_2 (53.18kg ha^{-1}). T_3 (soil 5 kg + fish amino acid 10 %) recorded the highest value of 69.76 kg ha^{-1} which was significantly superior than all other treatments followed by T_2 (58.80 kg ha^{-1}) on 60th day. The treatment T_1 (soil alone) recorded the lowest value throughout the incubation period.

Table 15. Changes in available P (kg ha^{-1}) content of soil during the incubation Period

Treatments	0th	7th	15th	30th	45th	60th
T_1 Soil alone 5kg	13.35	64.27	23.76	59.53	22.08	13.67
T_2 Soil 5kg + Panchagavya 10%	34.75	106.48	90.50	79.60	53.18	58.80
T_3 Soil 5kg + Fish amino acid 10%	52.87	64.76	98.22	147.85	65.57	69.76
T_4 Soil 5kg + Cow urine10%	30.31	67.02	72.47	62.93	25.60	28.50
T_5Soil 5kg + Jeevamrutha 10%	23.59	87.17	86.41	90.45	44.06	44.70
T_6 Soil 5kg + Vermiwash10%	18.94	77.17	87.72	71.10	42.73	32.11
SE±	5.41	6.91	4.49	13.36	4.74	1.79
CD(0.05)	16.08	20.61	13.09	39.69	14.08	5.32

4.2.5 Available potassium

The details relating to the changes in available K due to the effect of various treatments are presented in Table16. The highest mean values were recorded by T_4 (Soil 5 kg + cow urine 10 %) at different intervals of incubation period *viz.,* 0th, 7th, 15th, 30th, 45th and 60th day of incubation as 570.74 kg ha^{-1}, 622.69 kg ha^{-1} , 704. 42 kg ha^{-1}, 571.06 kg ha^{-1} ,517.61 kg ha^{-1} and 556.92 kg ha^{-1} which were found to be significantly superior than all other treatments throughout the incubation period. The available K content registered an increasing trend of release upto 30th day of incubation thereafter showed decreasing trend. The treatment T_1 (soil alone) recorded the least value throughout the incubation period

Table 16. Changes in available K (kg ha^{-1}) content of soil during the incubation Period

Treatments	0th	7th	15th	30th	45th	60th
T_1 Soil alone 5kg	101.77	149.60	139.47	126.64	113.39	137.28
T_2 Soil 5kg + Panchagavya 10%	205.62	240.48	268.26	192.36	185.41	182.28
T_3 Soil 5kg + Fish amino acid 10%	397.10	513.71	371.28	349.16	313.69	273.00
T_4 Soil 5kg + Cow urine10%	570.74	622.69	704.42	571.06	517.61	556.92
T_5 Soil 5kg + Jeevamrutha 10%	346.83	446.29	374.30	317.15	332.66	347.30
T_6 Soil 5kg + Vermiwash10%	230.90	402.30	380.38	275.21	238.85	324.17
SE±	13.07	17.69	23.98	12.52	15.02	9.54
CD(0.05)	38.79	52.36	71.09	37.11	44.69	28.34

4.2.6 Exchangeable calcium

Calcium content of the soil during incubation study was presented in Table17. The different treatments significantly influenced the calcium content of soil. In general, Ca content of different treatments increased upto 30th day of incubation thereafter showed decreasing tendency except in the case of T_4 (soil 5 kg + cow urine 10 %) .

On 0th day, the highest mean value was recorded by T_4 (422.35mg kg^{-1}) which was found to be on par with T_2 (405.34 mg kg $^{-1}$) and T_5 (385.97 mg kg $^{-1}$). T_4 (soil 5 kg +cow urine 10 %) recorded the highest value (748.29 mg kg $^{-1}$) followed by T_3 (686.02 mg kg^{-1}) on 7th day of incubation .On 15th day, the highest mean value was recorded by T_3 (839.07 mg kg $^{-1}$) and was found to be on par with

T_5 (779.41 mg kg $^{-1}$). On 30th day of incubation, the highest mean value of 1679.00 mg kg^{-1}was registered by T_3 followed by T_6 (1370.26 mg kg $^{-1}$). T_3 (soil 5 kg +fish amino acid 10 %) again recorded the highest mean value (1304.91 mg kg^{-1}) on 45th day of incubation which was on par with T_6 (1245.29 mg kg^{-1}). On 60th day of incubation, the highest mean value of 1205.00 mg kg^{-1} recorded by T_4 (soil 5 kg + cow urine 10 %) and was found to be on par with T_3 (1056.65 mg kg^{-1}). The highest mean values of exchangeable Ca content were recorded by T_3 (soil 5 kg +fish amino acid 10 %) on 15th, 30th, 45th and 60th day of incubation. The treatment T_1 (soil without treatments) was found to be inferior throughout the incubation period.

4.2.7 Exchangeable magnesium

Available magnesium content due to various treatments application during the incubation period is presented in Table 18. There was significant variation among treatments with respect to Mg content at different intervals of incubation study. In general, Mg content was found to be enhanced in all treatments on advancing incubation period upto 30th day of incubation.

On 0th day of incubation, soil treated with vermiwash 10 per cent (T_6) recorded the highest mean value of 150.73 mg kg^{-1} and was significantly superior than all other treatments followed by T_4 (135.74 mg kg $^{-1}$). Soil treated with cow urine 10 per cent (T_4) exhibited the highest release of exchangeable Mg throughout the incubation period. On 7th day of incubation, the highest mean value was recorded by T_4 (soil 5 kg+cow urine 10 %) with 242.21 mg kg $^{-1}$followed by T_5 (201.62 mg kg ^{1}).T_4 was found to be significantly superior than all other treatments. The highest value was recorded by T_4 (226.11 mg kg $^{-1}$) followed by T_6 (209.69 mg kg $^{-1}$) on 15th day of incubation and T_4 was found to be significantly superior than all other treatments. On 30th day of incubation, the highest value was registered by T_4 (286.64

mg kg $^{-1}$) and was found to be on par with T_6 (270.89 mg kg^{-1}). T_4 again recorded the highest value of 306.86 mg kg^{-1} which was significantly superior than all other treatments followed by T_6 (259.25 mg kg $^{-1}$) on 45th day of incubation. On 60th day of incubation, soil treated with cow urine 10 per cent (T_4) recorded the highest mean value of 265.39 mg kg^{-1}, which was found to be on par with T_5, T_6 and T_3. The treatment T_1 (soil alone) recorded the lowest value throughout the incubation period.

Table 17. Changes in exchangeable Ca (mg kg $^{-1}$) content of soil during the incubation period

Treatments	0th	7th	15th	30th	45th	60th
T_1 Soil alone 5kg	264.48	265.78	384.03	331.16	323.89	306.79
T_2 Soil 5kg + Panchagavya 10%	405.34	307.39	586.94	1009.05	830.76	896.18
T_3 Soil 5kg + Fish amino acid 10%	270.01	686.02	839.07	1679.00	1304.91	1056.65
T_4 Soil 5kg + Cow urine10%	422.35	748.29	614.08	1067.25	1108.14	1205.00
T_5 Soil 5kg + Jeevamrutha 10%	385.97	599.51	779.41	1017.38	1000.72	1013.30
T_6 Soil 5kg + Vermiwash10%	298.48	467.04	646.03	1370.26	1245.29	1000.02
SE±	15.98	17.57	36.67	47.42	39.48	61.58
CD(0.05)	47.27	52.18	108.9	140.8	117.07	182.89

4.2.8 Available iron

Data on available Fe content due to treatments effects during incubation period are presented in Table 19. Available Fe content showed significant difference at different intervals *viz.,* 7th, 15th, 30th, 45th and 60th day of incubation. On 0th day of incubation there was no significant difference among treatments. On 7th day of incubation, the highest value was recorded by soil treated with FAA 10 per cent (T_3) with values of 89.08 mg kg^{-1} and was on par with

T_4 (76.10 mg kg $^{-1}$). On 15th, 30th, 45th and 60th day of incubation, the highest values were recorded by soil treated with jeevamrutha 10 per cent (T_5) with values of 151.09 mg kg $^{-1}$, 313.83 mg kg-^{1},438.60 mg kg $^{-1}$ and 248.34 mg kg $^{-1}$ respectively. The treatment T_1 (soil alone) recorded the lowest value throughout the incubation period.

Table 18.Changes in exchangeable Mg (mg kg $^{-1}$) content of soil during the incubation period

Treatments	0th	7th	15th	30th	45th	60th
T_1 Soil alone 5kg	91.02	121.99	133.30	158.56	168.06	147.76
T_2Soil 5kg + Panchagavya 10%	116.89	172.31	156.49	223.40	184.25	172.65
T_3 Soil 5kg + Fish amino acid 10%	109.68	183.72	181.35	224.62	253.26	194.54
T_4 Soil 5kg + Cow urine10%	135.74	242.21	226.11	286.64	306.86	265.39
T_5Soil 5kg + Jeevamrutha 10%	102.81	201.62	196.98	246.09	216.85	257.56
T_6 Soil 5kg + Vermiwash10%	150.73	167.18	209.69	270.89	259.25	235.76
SE±	4.78	8.94	5.07	9.47	11.28	24.36
CD(0.05)	14.17	26.55	14.88	28.16	33.46	72.35

Table 19. Changes in available Fe (mg kg^{-1}) content of soil during the incubation period

Treatments	0th	7th	15th	30th	45th	60th
T_1Soil alone 5kg	21.30	23.26	21.22	25.75	36.87	31.91
T_2Soil 5kg + Panchagavya 10%	23.48	36.40	24.56	31.69	86.58	33.50
T_3 Soil 5kg + Fish amino acid 10%	24.42	89.08	35.54	38.52	78.02	24.87
T_4 Soil 5kg + Cow urine10%	26.31	76.10	32.02	30.81	49.76	41.19
T_5Soil 5kg + Jeevamrutha 10%	34.13	54.21	151.09	313.83	438.60	248.34
T_6Soil 5kg + Vermiwash10%	32.08	67.51	37.76	34.16	43.03	36.97
SE±	47.68	4.99	3.92	5.11	3.94	4.51
CD(0.05)	N.S	14.82	11.64	15.26	11.71	13.63

4.2.9 Available manganese

Manganese content of the incubation study is presented in Table. 20 and it was clear that different treatments significantly influenced the Mn content of the soil at different intervals (7th, 15th, 30th, 45th and 60th day) of incubation except 0th day of incubation.

On 7th day of incubation T_4 (soil 5 kg+ cow urine 10 %) registered the highest mean value (3.57 mg kg^{-1}) and was significantly superior than all other treatments followed by T_5 (2.05 mg kg $^{-1}$). On 15th day of incubation T_5 (soil 5 kg + jeevamrutha 10 %) recorded the highest mean value of 2.74 mg kg^{-1} followed by T_4 (2.00mg kg^{-1}). Soil treated with cow urine 10 per cent recorded the highest value of manganese content (1.80 mg kg $^{-1}$) and was found to be significantly superior than all other treatments on 30th day of incubation. T_4 (soil 5 kg + cow urine 10 %) also recorded the highest mean values of 1.80 mg kg $^{-1}$and 1.18 mg kg^{-1} on 45th and 60th day of incubation respectively. The treatment T_1 recorded the lowest Mn value throughout incubation period

Table 20.Changes in available Mn (mg kg^{-1}) content of soil during the incubation period

Treatments	0th	7th	15th	30th	45th	60th
T_1Soil alone 5kg	0.32	0.60	0.76	0.51	0.61	0.49
T_2Soil 5kg + Panchagavya 10%	0.48	1.70	0.77	0.82	0.81	0.99
T_3 Soil 5kg + Fish amino acid 10%	0.42	1.90	0.83	0.75	1.07	0.81
T_4Soil 5kg + Cow urine10%	0.45	3.57	2.00	1.80	1.80	1.18
T_5Soil 5kg + Jeevamrutha 10%	0.63	2.05	2.74	0.81	1.03	0.68
T_6Soil 5kg + Vermiwash10%	0.45	0.48	1.66	0.73	1.25	0.89
SE±	0.06	0.14	0.26	0.24	0.10	0.09
CD(0.05)	N.S	0.427	0.769	0.723	0.307	0.173

4.2.10 Available zinc

Mean value of Zn content of soil incubated for different period is presented in the Table 21. A significant difference was found among treatments with respect to available Zn content. Initially (0^{th} day of incubation), all the treatments were recorded higher values compared to values recorded on 7^{th}, 15^{th},3 0^{th}, 45^{th} and 60^{th} days of incubation. T_5 recorded the highest mean value of 8.19 mg kg^{-1} which was significantly superior than all other treatments on 0^{th}day of incubation. On 7^{th} day of incubation, T_4 (soil 5 kg +cow urine 10 %) was recorded the highest mean value (4.14 mg kg $^{-1}$) which was significantly superior than all other treatments. On 15^{th} day of incubation, T_5 was found to be the best with mean value of 3.77 mg kg^{-1} followed by T_6 (2.89 mg kg^{-1}). On 30^{th} day of incubation, T_4 recorded the highest mean value of 2.97 mg kg^{-1} which was found to be on par with T_5 (2.82 mg kg $^{-1}$) and T_6 (2.78 mg kg $^{-1}$). On 45^{th} day of incubation, T_5 registered the highest value of 3.91mg kg^{-1}which was found to be significantly superior than all other treatments. T_5 (soil 5 kg + jeevamruth 10 %) again recorded the highest mean value of 3.76 mg kg $^{-1}$ which was on par with T_6 (3.47 mg kg $^{-1}$) on 60^{th} day of incubation. During all the periods of incubation soil without any treatment was found with the lowest mean values.

Table 21.Changes in available Zn (mg kg^{-1}) content of soil during the incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1 Soil alone 5kg	3.97	2.03	2.59	1.96	2.59	2.30
T_2 Soil 5kg + Panchagavya 10%	5.43	2.59	2.63	2.07	2.90	2.67
T_3 Soil 5kg + Fish amino acid 10%	5.47	2.63	2.74	2.49	3.00	3.51
T_4 Soil 5kg + Cow urine10%	4.94	4.14	2.85	2.97	3.02	2.74
T_5Soil 5kg + Jeevamrutha 10%	8.19	2.82	3.77	2.82	3.91	3.76
T_6 Soil 5kg + Vermiwash10%	6.79	3.33	2.89	2.78	2.75	3.47
SE±	0.35	0.11	0.17	0.12	0.11	0.17
CD(0.05)	1.05	0.59	0.52	0.37	0.45	0.46

4.2.11 Available Copper

Different treatments significantly influenced the copper content of incubated soil (Table 22). There was increasing trends in the Cu content of soil from 0th day of incubation to 60th day of incubation except in the case of T_3 (Soil 5 kg + FAA10%). On 0th day, T_4 (soil 5 kg +cow urine 10 %) recorded the highest mean value of 0.79 mg $kg^{-1}$and was found to be on par with T_3, T_6 and T_2. On 7th day of incubation there was no significant difference among the treatments with respect to copper content. T_3 (soil 5 kg + fish amino acid 10%) was found to be the best (1.45 mg kg^{-1}) and was on par with T_4 (1.26 mg kg^{-1}) on 15th day of incubation. On 30th ,45th and 60th day of incubation T_4 (soil 5 kg + cow urine 10 %) was recorded the highest mean values of 1.75 mg kg^{-1}, 1.98 mg kg^{-1} and 2.22 mg kg^{-1} respectively and was found to be superior than all other treatments. Soil without any treatment (T_1) was found to be inferior during all the incubation period.

Table 22.Changes in available Cu (mg kg^{-1}) content of soil during the incubation period

Treatments	0th	7th	15th	30th	45th	60th
T_1 Soil alone 5kg	0.53	0.69	0.95	1.09	1.31	1.49
T_2 Soil 5kg + Panchagavya 10%	0.70	0.73	0.98	1.43	1.58	1.62
T_3 Soil 5kg + Fish amino acid 10%	0.75	0.94	1.45	1.22	1.79	1.68
T_4 Soil 5kg + Cow urine10%	0.79	0.91	1.26	1.75	1.98	2.22
T_5Soil 5kg + Jeevamrutha 10%	0.54	0.83	1.05	1.37	1.65	1.68
T_6 Soil 5kg + Vermiwash10%	0.74	0.90	1.03	1.33	1.41	1.86
SE±	0.06	0.03	0.18	0.08	0.07	0.17
CD(0.05)	0.18	N.S	0.39	0.24	0.17	0.34

Part III

4.3 POT CULTURE EXPERIMENT

A pot culture experiment to evaluate the efficacy of soil and foliar applications of on-farm liquid organic manures on soil health and crop nutrition using bhindi as test crop was conducted at Instructional farm, College of Agricultural, Vellayani during the period April 2016- April2017.

4.3.1 Preparation and analysis of enriched vermicompost

Vermicompost was prepared using biowaste (banana leaves and pseudostem) and cow dung mixture in the ratio 10:1. Azolla @ 10 per cent was added to the biowaste at the time of composting as additive for enriching vermicompost. The enriched vermicompost were analysed for chemical and biological properties and data are presented in Table 23. It is clear from the table that the physico-chemical properties *viz.,* pH and EC of enriched vermicompost was 7.83 and 9.40 dSm^{-1} respectively. Chemical properties *viz.,*N, P, K, Ca ,Mg, Fe, Mn, Zn and Cu content of enriched vermicompost were noted as 2.44 per cent, 0.25 per cent, 1.85 per cent 1.13 per cent and 0.27 per cent, 0.61 per cent , 81.16 mg kg^{-1}, 49.66 mg kg^{-1} and 116.33 mg kg^{-1} respectively. In case of biological properties *viz.,* bacterial fungal, actinomycetes population were recorded as 7.73 log cfu g^{-1}, 5.29 log cfu g^{-1}, and 1.53 log cfu g^{-1} respectively.

Table 23. Properties of vermicompost enriched with azolla

SI.No.	Properties	Contents
1	pH	7.83
2	EC (dSm^{-1})	9.40
3	Nitrogen (%)	2.44
4	Phosphorus (%)	0.25
5	Potassium (%)	1.85
6	Calcium (%)	1.13
7	Magnesium (%)	0.27
	Micronutrients :	
8	Fe (%)	0.61
9	Mn ($mg\ kg^{-1}$)	81.16
10	Zn ($mg\ kg^{-1}$)	49.66
11	Cu ($mg\ kg^{-1}$)	116.33
Microbial count (log cfu g^{-1})		
12	Bacteria	7.73
13	Fungi	5.29
11	Actinomycetes	1.53

4.3.2 Analysis of soil before the pot culture experiment

The soil for the pot culture experiment was collected (0 to 15 cm depth) from the Model organic farm under the Department of Soil Science and Agricultural chemistry, College of Agriculture Vellayani. The physical, chemical, biological and biochemical properties of soil samples before the experiment are presented in Table.24.

4.3.3 Biometric observation

The data of various biometric observations were presented in the Tables 25 to 27. Various growth characters of crop *viz.*, height of plants, inter nodal length at first harvest, number of branches per plant, Leaf Area index and dry matter production were recorded and presented.

4.3.3.1 Plant height

Plant height at first and final harvest were presented in Table 25. The response to treatments varied significantly with respect to plant height as inferred from the table. The highest plant height at first (98.33 cm) and final harvest (102.60 cm) was recorded by T_5 (75 % N as EVC + panchagavya 3 % foliar spray), which was found to be on par with T_9, T_1, T_3, T_{11}, T_6, and T_{10} at first and at final harvest also T_5 was on par with T_1, T_9, T_{10}, T_6, T_{11}, T_3, T_8 and T_{12}..The lowest value for plant height was observed in T_{13} (absolute control) and was significantly inferior than all other treatments.

4.3.1.2 Inter nodal length at first harvest

Data on inter nodal length of bhindi at first harvest presented in table.26 revealed that different treatments had no significant influence on inter nodal length.

4.3.1.3 Number of branches per plant

Data presented in table.26 revealed that different treatments significantly influenced the number of branches per plant. The mean value ranged from 1.33 to 7.00. The highest mean value of 7.00 was registered by the treatment T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and was on par with T_7 (6.33), T_{11} (6.00) and T_8 (4.66), whereas, the treatment T_{13} (Absolute control) recorded the lowest value (1.33).

4.3.1.4 Leaf Area Index

The average leaf area index of the plants calculated at first harvest was presented in table. 27. Treatment applications significantly influenced the LAI. T_5 (75 % N as EVC + panchagavya 3 % foliar spray) recorded the highest LAI (1.97) and was significantly superior than all other treatments. The treatment T_2 was on par with

T_3,T_6, T_7,T_8,T_9,$T_{11}$and T_{12}.The minimum leaf area index (0.09) was noticed in T_{13} (Absolute control).

Table 24. Physical, chemical, biological and biochemical properties of soil before the experiment

Sl. No.	Parameters	Content
	A. Physical Properties	
1	Mechanical composition	
	Sand (%) Silt (%) Clay (%)	60.09 9.45 24.53
2	Texture	Sandy clay loam
	B. Chemical Properties	
3	pH (1:2.5)	5.42
4	EC (1:2.5) dSm^{-1}	0.06
5	Organic carbon (g kg^{-1})	8.40
6	Labile carbon (mg kg^{-1})	1350
7	Available N (kg ha^{-1})	213.33
8	Available P (kg ha^{-1})	44.46
9	Available K (kg ha^{-1})	78.30
10	Exchangeable Ca (mg kg^{-1})	881.37
11	Exchangeable Mg (mg kg^{-1})	150.54
12	Available S (mg kg^{-1})	12.50
13	Micronutrients (mg kg^{-1}) Fe Mn Zn Cu	 11.56 2.06 6.42 0.42
	C. Biochemical Properties	
13	Dehydrogenase (µg of TPFg^{-1}soil $24h^{-1}$)	21.02
14	Urease (ppm of urea g^{-1}soil h^{-1})	59.18
15	Acid phosphatase (µg of p-nitrophenol g^{-1}soil h^{-1})	13.05
16	Alkaline phosphatase (µg of p-nitrophenol g^{-1}soil h^{-1})	ND
	D. Biological Properties	
	Microbial count (log cfu g^{-1})	
17	Bacteria	7.16
18	Fungi	4.66
19	Actinomycetes	4.16
20	Azospirillum	0.00
21	Azotobacter	0.00
22	P Solubilizers	3.40
23	K Solubilizers	0.00
24	*Pseudomonas sp.*	0.00

Table 25.Plant height (cm) affected by different on-farm liquid organic manures on bhindi (Anjitha)

Treatments	First harvest	Final harvest
T_1	83.26	102.50
T_2	67.66	70.66
T_3	79.00	82.00
T_4	66.00	69.83
T_5	98.33	102.60
T_6	78.50	91.16
T_7	71.50	72.33
T_8	61.00	80.83
T_9	84.50	98.33
T_{10}	78.00	90.66
T_{11}	78.83	83.83
T_{12}	67.83	75.83
T_{13}	43.50	45.00
SE±	8.66	9.62
CD(0.05)	25.18	27.98

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic AdhocPoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 7 5% N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4.3.1.5 Dry matter production

Perusal of data in table.27 indicated that dry matter production was significantly influenced by different treatments. The treatment T_5 (75 % N as EVC + panchagavya 3 % foliar spray) recorded the highest mean value (36.30 g $plant^{-1}$) and was on par with T_3 (35.53 g plant $^{-1}$) and T_7 (33.42 g plant $^{-1}$). The lowest value (4.25 g $plant^{-1}$) was registered by the treatment T_{13} (Absolute control).

4.3.2 Physiological characters

The data on various physiological characters were presented in the table 28.Various physiological characters of crop *viz.*, chlorophyll a, chlorophyll b and total chlorophyll contents were recorded and presented. The data revealed that the treatments caused significant influence in chlorophyll contents of bhindi.

The highest chlorophyll a content (0.26 mg g^{-1}) was observed in T_{10} (75 % N as EVC +Jeevamrutha10 % soil application), which was on par with T_7, T_3, T_9, T_2, T_8, T_{11}, T_6 and T_{12}. The chlorophyll a content was lowest in T_{13} (0.13 mg g^{-1}). The highest chlorophyll b content was observed in T_{10} (0.43 mg g^{-1}) and was on par with T_9 (0.35 mg g^{-1}). T_{13} registered the lowest chlorophyll b (0.08mg g^{-1}). Among the treatments, T_{10} registered the highest total chlorophyll content of 0.70 mg g^{-1} and was followed by T_9 (0.60mg g^{-1}). T_{13} registered the lowest total chlorophyll content of 0.15 mg g $^{-1}$.

4.3.3 Yield and Yield attributes

4.3.3.1 Days to first flowering

Data in table 29. indicated that treatment applications not significantly influenced the days to first flowering.

Table 26. Effect of on-farm liquid organic manures on internodal length at first harvest and number of branches per plant

Treatments	Inter nodal length at first harvest (cm)	Number of branches per plant
T_1	12.33	3.33
T_2	13.60	3.00
T_3	13.50	3.66
T_4	8.93	2.33
T_5	14.90	7.00
T_6	10.63	3.66
T_7	12.83	6.33
T_8	12.66	4.66
T_9	12.53	4.00
T_{10}	11.00	4.00
T_{11}	10.16	6.00
T_{12}	9.83	4.00
T_{13}:	9.33	1.33
SE±	12.39	1.00
CD (0.05)	N.S	2.92

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

Table 27. Leaf area index and dry matter production as influenced by different liquid organic manures on bhindi (Anjitha)

Treatments	Leaf area index	Dry matter production (g plant $^{-1}$)
T_1	0.45	28.68
T_2	1.18	16.07
T_3	0.79	35.53
T_4	0.45	20.38
T_5	1.97	36.30
T_6	0.79	28.16
T_7	0.49	33.42
T_8	0.93	20.75
T_9	0.74	26.06
T_{10}	0.43	25.24
T_{11}	0.59	24.81
T_{12}	0.74	20.60
T_{13}	0.09	4.25
SE±	0.24	1.68
CD(0.05)	0.70	4.88

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

Table 28.Chlorophyll a, chlorohyll b and total chlorophyll content as effected by different on-farm liquid organic manures on bhindi (Anjitha)

Treatments	Chlorophyll a ($mg\ g^{-1}$)	Chlorophyll b ($mg\ g^{-1}$)	Total chlorophyll content ($mg\ g^{-1}$)
T_1	0.18	0.17	0.35
T_2	0.24	0.21	0.48
T_3	0.25	0.23	0.48
T_4	0.16	0.08	0.25
T_5	0.25	0.20	0.46
T_6	0.21	0.12	0.28
T_7	0.25	0.17	0.44
T_8	0.22	0.19	0.41
T_9	0.25	0.35	0.60
T_{10}	0.26	0.43	0.70
T_{11}	0.22	0.16	0.38
T_{12}	0.19	0.19	0.33
T_{13}	0.13	0.08	0.15
SE±	0.03	0.06	0.07
CD(0.05)	0.074	0.132	0.211

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

Table 29. Effect of on-farm liquid organic manures on fruit characters of bhindi (Anjitha)

Treatments	Days to first flowering	Length of fruit (cm)	Girth of fruit (cm)
T_1	36.00	15.65	7.58
T_2	38.67	13.91	7.53
T_3	44.67	14.83	6.96
T_4	41.00	12.52	6.60
T_5	42.67	16.65	8.16
T_6	34.00	15.56	6.90
T_7	37.00	15.19	7.70
T_8	36.33	14.43	6.91
T_9	35.33	15.24	7.16
T_{10}	43.00	13.53	7.11
T_{11}	44.33	14.33	6.75
T_{12}	40.67	13.87	6.66
T_{13}	52.00	10.20	5.00
SE±	74.41	7.34	2.10
CD(0.05)	N.S	N.S	N.S

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4.3.3.2 Length of fruit, cm

Table.29 revealed that the length of fruit was not significantly influenced by different treatments.

4.3.3.3 Girth of fruit, cm

Girth of fruit was not significantly influenced by different treatments (Table29).

4.3.3.4 Number of flowers formed

Results of the analysis of data on number of flowers formed revealed that treatment effects were significantly different (Table 30). Mean values ranged from 9.00 to 26.33. The highest value (26.33) was recorded by T_5 (75 % N as EVC + panchagavya 10 % foliar spray) followed by T_7 (20.33) and T_{11} (18.66) which was on par with each other. The lowest value was registered by T_{13} (9.00) which was the absolute control.

4.3.3.5 Number of fruits per plant

The number of fruits per plant recorded is shown in table.30.Different treatments had significant influence on number of fruits per plant. T_5 (75 % N as EVC + panchagavya 10 % foliar spray) recorded the highest number of fruits per plant (15.33), which was on par with T_6 (13.00) and T_7 (12.00). The minimum number of fruits per plant was recorded by T_{13} (3.00).

4.3.3.6 Average fruit weight

Perusal of the data (Table 30.) on average fruit weight revealed that the effect of treatments was significantly different. The mean values ranged between 9.16 to 23.74 g.Treatment T_1 registered the highest fruit weight (23.74 g) and was on par with T_5 (18.72 g) and T_7 (18.68). The lowest value was registered by T_{13} (9.16 g) which was significantly inferior to all other treatments.

Table 30. Effect of on-farm liquid organic manures on yield and yield attributes of the bhindi (Anjitha)

Treatments	Number of flowers formed	Number of fruits per plant	Average fruit weight (g)	Total fruit yield (g plant $^{-1}$)
T_1	12.33	8.00	23.74	188.49
T_2	10.00	8.66	13.57	109.09
T_3	12.00	10.33	17.61	146.88
T_4	10.00	8.00	14.39	135.48
T_5	26.33	15.33	18.72	278.65
T_6	15.00	13.00	11.90	153.33
T_7	20.33	12.00	18.68	214.28
T_8	17.00	7.00	17.48	119.23
T_9	17.00	10.00	17.11	155.61
T_{10}	16.00	9.66	14.65	131.41
T_{11}	18.66	9.00	16.83	151.53
T_{12}	15.66	8.66	14.41	126.06
T_{13}	9.00	3.00	9.16	27.50
SE±	3.09	1.54	2.10	14.11
CD(0.05)	8.76	4.49	6.11	41.22

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4.3.3.7 Total fruit yield

Imposition of treatments had significant influence in the total fruit yield (Table 30).The mean values of total fruit yield ranged from 27.50 to 278.65 g plant^{-1}. The highest value (278.65 g plant $^{-1}$) of total fruit yield was recorded by T_5 and was on par with T_7 (214.28 g plant^{-1}) and T_1 (188.49 g plant^{-1}). The lowest total fruit yield value of 27.50 g plant^{-1} was shown by T_{13} (Absolute control).

4.3.4 Quality parameters of fruits

The data on quality parameters *viz.*, crude protein, crude fibre and ascorbic acid content of fruits are presented in table 31.

4.3.4.1 Crude protein content

Crude protein content of different treatments are given in table 31.Crude protein content was significantly influenced by various treatments. T_4 (75 % N as EVC+ fish amino acid 5 % soil application) registered the highest value of 2.47 per cent and was on par with T_7 (75 % N as EVC+ cow urine 10 % foliar spray) with 2.46 per cent. The lowest value was recorded by T_{13} (1.19 %).

4.3.4.2 Crude fibre content

Crude fibre content of fruits are presented in table 31. The lowest value was noticed in T_7 (75 % N as EVC + cow urine 10 % foliar spray) with13.93 per cent. The highest value was found in T_{13} (Absolute control) with 25.97 per cent.

4.3.4.3 Ascorbic acid

Table.31 presents the data regarding the influence of different treatments on the ascorbic acid content of fruit. T_9 (75 % N as EVC + jeevamrutha 10 % foliar spray) registered the highest mean value (12.53 mg 100 g^{-1}) and was found to be on par with T_{10} (12.33 mg 100 g^{-1}). The lowest mean value (3.56 mg 100 g^{-1}) was recorded by the treatment T_{13} (Absolute control).

4.3.5 Incidence of pest and diseases

Incidence of pest and diseases was monitored throughout the cropping period. When yellowing of leaves was observed in one or two plants it was confirmed as symptom of yellow vein mosaic viruses. Incidence of semi loopers and fruit and shoot borers were seen initially and 5 per cent nimbicidine was sprayed at fortnightly intervals.

Table 31.Quality parameters of fruits as effected by different on -farm liquid organic manures on bhindi (Anjitha)

Treatments	Crude protein (%)	Crude fibre (%)	Ascorbic acid (mg 100g^{-1})
T_1	1.37	24.08	9.40
T_2	1.83	21.79	7.92
T_3	2.16	17.65	5.50
T_4	2.47	15.99	4.95
T_5	2.19	20.54	4.40
T_6	1.58	21.55	4.10
T_7	2.46	13.93	7.90
T_8	1.93	21.50	7.83
T_9	2.02	16.03	12.53
T_{10}	1.97	20.32	12.33
T_{11}	1.91	19.64	7.03
T_{12}	2.09	19.81	6.96
T_{13}	1.19	25.97	3.56
SE±	0.06	2.11	0.46
CD(0.05)	0.186	6.130	1.342

4.3.6 Post harvest analysis of soil

The data (Table. 32-37) on soil chemical, biològical and biochemical parameters *viz.*, pH, EC, organic carbon, labile carbon, available N, P, K, Ca, Mg , S, Fe, Cu, Zn, Mn ,dehydrogenase, acid and alkaline phosphatase, urease activity, bacteria, fungi, actinomycetes, azotobacter, azospirillum, P solubilizers, K solubilizers and *pseudomonas sp*. status are presented below.

4.3.6.1 pH

Perusal of the data revealed that the application of the treatments had a significant effect on the pH of the soil (Table. 32.). The mean values ranged from 5.08 to 6.44. Treatment T_2 (Organic Adhoc PoP) registered the highest mean value of 6.44. The lowest mean value was registered by the treatment T_{13} (Absolute control). pH values ranged from very strongly acidic to slightly acidic.

4.3.6.2 Electrical conductivity

Critical appraisal of the data (Table 32.) revealed that the treatment had influenced the electrical conductivity of the soil at final harvest stage. The mean values ranged from 0.03 to 0.30 dSm^{-1}. Treatment T_4 (75 % N as EVC+ fish amino acid 5 % soil application) registered the highest mean value of 0.30 dSm^{-1} and followed by T8 (0.21 dSm^{-1}). The lowest mean value was registered by the treatment T_{13} (0.03 dSm^{-1}). Even the highest value recorded (0.30 dSm^{-1}) was classified as normal for all crops.

4. 3. 6.3 Organic carbon

The results revealed that the applied treatments had significant effect on the organic carbon content of the soil (Table.32). The mean values ranged from 3.50 to 15.60 g kg^{-1}. The highest value was recorded by T_4 (75 % N as EVC + fish amino acid 5 % soil application) with 15.60 g kg^{-1} and was on par with T_3 (14.96 g kg^{-1}). The lowest value was recorded by T_{13} (3.50 g kg^{-1}).

4.3.6.4 Labile carbon

Table 32. show that the labile carbon content of soil after the harvest of crop. The result indicated that the treatment T_8 (75 % N as EVC + cow urine 10 % soil application) recorded the highest mean value of 1809.61 mg kg $^{-1}$ and which was on par with T_2 (1757.82 mg kg $^{-1}$), T_1 (1733.77 mg kg $^{-1}$), T_6 (1711.05 mg kg $^{-1}$), T_4 (1699.27 mg kg^{-1}), T_{10} (1694.55 mg kg^{-1}), T_9 (1675.01 mg kg $^{-1}$), T_{12} (1668.91 mg kg $^{-1}$) and T_5 (1666.40 mg kg $^{-1}$). The lowest value of 1373.54 mg kg^{-1} was recorded by the treatment T_{13} (Absolute control).

4. 3. 6.5 Available Nitrogen

Various treatments significantly influenced the available N content in the soil as observed from the table 33. The mean values ranged from 59.73 to 128.80 mg kg^{-1}. T_6 (75 % N as EVC + panchagavya 3 % soil application) registered the highest mean value of 128.80 mg kg^{-1} which was on par T_5 (125.06 mg kg^{-1}), T_4 (123.20 mg kg $^{-1}$), T_3 (115.73 mg kg $^{-1}$), T_{12} (115.73 mg kg $^{-1}$) and T_8 (98.93 mg kg $^{-1}$) with treatment T_{13} registered the lowest mean value (59.73 mg kg^{-1}) and was significantly inferior to all other treatments.

Table. 32 Effect of on-farm liquid organic manures on physico-chemical properties of soil (post harvest analysis)

Treatments	pH	EC (dSm^{-1})	Organic carbon ($g\ kg^{-1}$)	Labile carbon ($mg\ kg^{-1}$)
T_1	5.68	0.08	6.67	1733.77
T_2	6.44	0.15	8.40	1757.82
T_3	5.96	0.09	14.96	1638.80
T_4	5.17	0.30	15.60	1699.27
T_5	5.70	0.07	8.40	1666.40
T_6	5.66	0.10	8.80	1711.05
T_7	5.81	0.10	6.70	1600.42
T_8	5.38	0.21	14.10	1809.61
T_9	5.85	0.09	5.30	1675.01
T_{10}	5.36	0.16	13.20	1694.55
T_{11}	5.68	0.11	14.06	1605.51
T_{12}	5.72	0.11	15.23	1668.91
T_{13}	5.08	0.03	3.50	1373.54
SE±	0.04	0.07	0.03	50.69
CD(0.05)	0.129	0.047	0.911	147.205

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4. 3. 6.6 Available Phosphorus

It is inferred from the table that the mean values of available P ranged from 38.58 to 69.68mg kg^{-1} (Table. 33). Treatment T_4 (75 % N as EVC+ fish amino acid 5 % soil application) recorded the highest mean value (69.68mg kg^{-1}) of available P and was followed by T_6 (65.52mg kg^{-1}). The lowest mean value of 38.58 mg kg^{-1} was recorded by T_{13}.

4. 3. 6 .7 Available Potassium

Various treatments significantly influenced the available K content of soil (Table 33).The mean value ranged from 163.33 to 388.33 mg kg^{-1}. The treatment T_8 (75 % N as EVC + cow urine 10 % soil application) registered the highest mean (388.33 mg kg^{-1}) and followed by T_{12} (285.00 mg kg^{-1}). The lowest value of 163.33 mg kg^{-1} was recorded by T_{13} (Absolute control) which was significantly inferior than all other treatments.

4. 3. 6 .8 Exchangeable Calcium

Data in Table 34. shows that exchangeable calcium content was maximum (1207.79 mg kg^{-1}) in T_4 (75 % N as EVC + fish amino acid 5 % soil application) and it was on par with T_{10} (1183.33 mg kg^{-1}). The lowest mean value of 517.41mg kg^{-1} was recorded by T_{13} (Absolute control) which was significantly inferior than all other treatments

Table 33. Available N P K status (mg kg $^{-1}$) in soil as effected by different on-farm liquid organic manures on bhindi (Anjitha)

Treatments	Nitrogen	Phosphorus	Potassium
T_1	87.73	53.78	190.00
T_2	91.46	39.36	183.33
T_3	115.73	54.92	208.33
T_4	123.20	69.68	273.33
T_5	125.06	56.96	216.66
T_6	128.80	65.22	258.33
T_7	76.53	47.87	216.66
T_8	98.93	54.25	388.33
T_9	76.53	42.44	203.33
T_{10}	76.53	52.07	213.33
T_{11}	85.86	42.32	203.33
T_{12}	115.73	46.24	285.00
T_{13}	59.73	38.58	163.33
SE±	11.08	1.56	8.46
CD (0.05)	32.26	4.40	24.60

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4. 3. 6 .9 Exchangeable Magnesium

The results revealed that the applied treatments had significant effect on the exchangeable magnesium status of the soil (Table.34).The mean values ranged from 116.87 to 324.29 mg kg^{-1} The highest value was recorded by T_8 (324.29 mg kg^{-1}) and was followed by T_6 (272.91 mg kg $^{-1}$) .The lowest mean value of 116.87 mg kg^{-1} was recorded by T_{13} ,which was significantly lower than all other treatments.

4. 3. 6 .10 Available Sulphur

The data on the available S content in soil is given in the table 34. The treatments could produce significant effect on the available S status in the soil. The mean sulphur content in the soil ranged from 13.87 to 49.92 mg $kg^{-1}$and the highest value (49.92 mg kg^{-1}) was recorded in T_4 where 75 % N as EVC + fish amino acid 3 % soil application. Treatment T_{13} registered the lowest mean value of 13.87 mg kg^{-1} and was significantly inferior to all other treatments.

4. 3. 6 .11 Available Iron

Table.35 revealed that Fe content in the soil was significantly influenced by the treatments. Mean values ranged from 14.20 to 91.53 mg kg^{-1}.Treatment T_{10} (75 % N as EVC + jeevamrutha 10 % soil application) recorded the highest available Fe content (91.53 mg kg^{-1}) followed by T_{12} (80.88 mg kg $^{-1}$). The lowest mean value was recorded by T_{13} (Absolute control).

4. 3. 6. 12 Available Manganese

A perusal of the data revealed that the treatments significantly influenced the available manganese content in the soil (Table 35). T_8 (75 % N as EVC + cow urine 10 % soil application) recorded the highest Mn content in the soil (4.10 mg kg^{-1}) and was found to be on par with T_7 (3.89 mg kg^{-1}). The lowest value was recorded by T_{13} (1.16 mg kg^{-1}).

Table 34. Influence of liquid organic manures on soil available secondary nutrients, mg kg $^{-1}$

Treatments	Calcium	Magnesium	Sulphur
T_1	711.50	217.25	14.50
T_2	946.62	206.79	14.97
T_3	1050.00	210.16	22.94
T_4	1207.79	249.50	49.92
T_5	806.58	246.81	23.77
T_6	904.33	272.91	35.15
T_7	526.62	261.62	15.98
T_8	868.95	324.29	17.95
T_9	876.95	195.58	19.95
T_{10}	1183.33	203.91	44.70
T_{11}	816.16	228.29	22.64
T_{12}	845.04	269.12	30.21
T_{13}	517.41	116.87	13.87
SE±	35.08	0.29	3.28
CD (0.05)	101.99	0.86	9.58

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 7 5% N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4. 3. 6.13 Available Zinc

Table.35 presents the zinc concentration in the soil. The mean values ranged from 6.13 to 10.22 mg kg^{-1}.The highest mean value of (10.22 mg kg^{-1}) was registered by T_4 which was 75 % N as enriched vermicompost with FAA 5 per cent in soil application and was found to be on par with T_3 (10.16 mg kg^{-1}). The lowest mean value 6.13 mg kg^{-1} was observed in treatment T_{13} which was inferior to all other treatments.

4. 3. 6 .14 Available Copper

Copper content in the soil was significantly influenced by different treatments (Table 35). The mean values ranged from 0.35 to 2.20 mg kg^{-1}. The highest mean value was recorded by T_8 (2.20 mg kg^{-1}) with the application of 75 per cent N as enriched vermicompost with cow urine 10 per cent in soil application which was on par with T_7 (2.08 mg kg^{-1}). T_{13} registered the lowest mean value of 0.35 mg kg^{-1} and was significantly inferior to all other treatments.

4.3.6.15 Dehydrogenase activity

Regarding the dehydrogenase activity, the data showed that the dehydrogenase activity significantly influenced by different treatments (Table 36). The mean values ranged from 30.53 to 166.8 4μg of TPF g^{-1}soil 24 h^{-1} and the highest mean value was recorded by the T_8 (75 % N as EVC + cow urine10 % soil application) 166.84 μg of TPF g^{-1}soil 24 h^{-1} and followed by T_7 (141.13 μg of TPF g^{-1}soil 24 h^{-1}) and was significantly superior to all other treatments. The lowest mean value was recorded by the T_{13} (30.53 μg of TPF g^{-1}soil 24 h^{-1}).

Table 35. Effect of on-farm liquid organic manures on micronutrient contents of the soil, mg kg^{-1}

Treatments	Fe	Mn	Zn	Cu
T_1	26.33	1.60	6.49	1.27
T_2	16.40	1.52	9.58	1.18
T_3	27.56	1.27	10.16	0.86
T_4	28.55	1.34	10.22	0.93
T_5	27.72	2.33	5.42	1.07
T_6	34.61	2.42	5.79	1.15
T_7	20.49	3.89	8.31	2.08
T_8	21.20	4.10	8.56	2.20
T_9	82.92	2.95	7.16	1.08
T_{10}	91.53	3.10	6.46	1.10
T_{11}	80.73	1.85	6.35	1.54
T_{12}	80.88	1.93	6.25	1.45
T_{13}	14.20	1.16	6.13	0.35
SE±	0.30	0.07	0.07	0.16
CD (0.05)	0.879	0.207	0.133	0.306

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4.3.6.16 Acid phosphatase

Activity of acid phosphatase varied significantly with different treatments (Table 36). The mean values of various treatments on acid phosphatase activity ranged from 13.66 to 38.72 μg of p-nitrophenol g^{-1}soil h^{-1}. Among the treatments, the highest activity was recorded by T_4 (75 % N as EVC + fish amino acid 5 % soil application) with 38.72 μg of p- nitrophenol g^{-1}soil h^{-1} , which was followed by T_3 (38.45 μg of p- nitrophenol g^{-1}soil h^{-1}). The lowest mean value was reported in absolute control (13.66 μg of p- nitrophenol g^{-1}soil h^{-1}) which was significantly inferior to all other treatments.

4.3.6.17 Alkaline phosphatase

It is clear from the data given in table 36, that the different treatments have significant influence on the alkaline phosphatase activity of the soil after harvest. The highest value was reported in the samples from T_4 (75 % N as EVC + fish amino acid 5 % soil) with a mean value of 8.66 μg of p- nitrophenol g^{-1}soil $h^{1}$and was on par with T_3 (8.45 μg of p - nitrophenol g^{-1}soil h^{-1}). Alkaline phosphatase activity was not detected in treatments T_1, T_{11}, T_{12} and T_{13}.

4.3.6.18 Urease

Data in table 36 indicated that different treatments significantly affect the urease activity of soil. An appraisal of the data on the influence of different treatments on urease activity, T_4 (75 % N as EVC + fish amino acid 5 % soil application) recorded the highest mean value of 87.52 urea g^{-1} soil h^{-1} followed by T_3 (82.74 urea g^{-1} soil h^{-1}). T_{13} (59.25 urea g^{-1} soil h^{-1}) had the lowest mean value among various treatments.

Table 36. Influence of liquid organic manures on soil enzyme activity

Treatments	Dehydrogenase (µg of TPF g^{-1} soil 24 h^{-1})	Acid phosphatase (µg of p- nitrophenol g^{-1} soil h^{-1})	Alkaline phosphatase (µg of p-nitrophenol g^{-1}soil h^{-1})	Urease (ppm urea g^{-1} soil h^{-1})
T_1	40.81	27.75	ND	69.19
T_2	65.38	14.63	5.86	69.10
T_3	116.71	38.45	8.45	82.74
T_4	129.87	38.72	8.66	87.52
T_5	95.46	16.87	2.47	72.58
T_6	95.68	16.93	2.63	76.13
T_7	141.13	23.93	1.10	76.13
T_8	166.84	25.90	1.22	77.69
T_9	52.09	19.32	1.46	74.08
T_{10}	52.33	22.11	1.63	74.13
T_{11}	31.79	16.74	ND	65.36
T_{12}	33.67	16.81	ND	67.52
T_{13}	30.53	13.66	ND	59.25
SE±	0.55	0.15	0.11	0.31
CD (0.05)	1.596	0.440	0.321	1.014

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic AdhocPoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

4.3.6.19 Bacteria

The influence of on-farm liquid organic manures on soil microbial populations in post harvest soil varied significantly and the mean values ranged from 7.43 to 8.47 log cfu g^{-1} soil. T_{10} (75 % N as EVC + jeevamrutha 10 % soil application) recorded the highest total bacterial count 8.47 log cfu g $soil^{-1}$ at soil and was on par with T_6 (8.20 log cfu g $soil^{-1}$). The lowest count was noticed in T_{13} (Absolute control) 7.43 log cfu g $soil^{-1}$ (Table 37).

4.3.6.20 Fungi

The analysis of the data (Table.37) inferred that the different treatments effects were significant and the mean values ranged from 3.81 to 5.05 log cfu g $soil^{-1}$. The highest mean value (5.05 log cfu g $soil^{-1}$) was reported by the T_{10} (75 % N as EVC + jeevamrutha 10 % soil application) which was on par with T_9,T_{12}, T_{11},T_4 and T_3. Absolute control with mean of 3.81 log cfu g $soil^{-1}$ recorded the lowest fungal population.

4.3.6.21 Actinomycetes

Critical appraisal of the data (Table 37.) shows that the different treatments have significant effect for the actinomycetes count. The highest mean value for different treatments effect was recorded by the T_4 (75 % N as EVC + fish amino acid 5 % soil application) with mean population of 5.53 log cfu g $soil^{-1}$ and the count was on par withT_5, T_6, T_7 ,T_8, T_9, T_{10}, $T_{11}$and T_{12} . T_{13} (Absolute control) recorded the lowest count of 1.51 log cfu g $soil^{-1}$.

4.3.6.22 Azotobacter

Maximum azotobacter population of 5.89 log cfu g $soil^{-1}$ was recorded in treatment T_4 (75 % N as EVC + fish amino acid 5 % soil application), which was par with T_3, T_5, T_6, T_7, T_8, T_9, T_{10} and T_{12}. The lowest population of 1.33 log cfu g $soil^{-1}$ was recorded in T_{13} (Table 37).

4.3.6.23 Azospirillum

Significant difference was noticed among the treatments with respects to azospirillum .T_4 (75 % N as EVC+ fish amino acid 5 % soil application) recorded the maximum azospirillum population of 5.78 log cfu g $soil^{-1}$, which was on par with T_3 (5.49 log cfu g $soil^{-1}$) and T_6 (4.82 log cfu g $soil^{-1}$). Azospirillum colonies was not detected in T_1, T_2, T_{11}, T_{12} and T_{13} (Table 37).

4.3.6.24 P solubilizers

The statistical analysis of the data (Table 37) on the count of P solubilizers inferred that the different treatments had significant influence on the population. The highest mean value of 5.58 log cfu g $soil^{-1}$ were recorded by T_4 (75 % N as EVC+ fish amino acid 5 % soil application) and was on par with T_3 (5.21 log cfu g $soil^{-1}$) and T_6 (5.03 log cfu g $soil^{-1}$), while the lowest count was seen at T_{13} (Absolute control) with 4.18 log cfu g $soil^{-1}$.

4.3.6.25 K solubilzers

It is clear from the data (Table 37.) that the different treatments influenced the K solubilzers population in the soil significantly. T_{12} (75 % N as EVC+ vermiwash 10 % soil application) recorded the highest mean value of 4.40 log cfu g $soil^{-1}$ and was on par with T_{11}, T_8 ,T_7, T_6 and T_5. Zero colonies of K solubilizers were recorded by T_1, T_2, T_3, T_4 and T_{13}.

Table 37. Influence of on-farm liquid organic manures on soil microbial population of post harvest soil, log cfu g soil $^{-1}$

Treatments	Bacteria	Fungi	Actinomycetes	Azotobacter	Azospirillum	P solubilizer	K solubilizer	*Pseudomonas sp.*
T_1	7.84	3.94	1.83	1.81	0.00	4.72	0.00	1.89
T_2	7.98	3.89	1.75	1.71	0.00	4.41	0.00	1.89
T_3	7.66	4.61	5.45	5.86	5.49	5.21	0.00	4.89
T_4	7.81	4.65	5.53	5.89	5.78	5.58	0.00	5.90
T_5	7.62	4.36	4.43	5.46	2.11	4.98	2.46	6.05
T_6	8.20	4.46	4.58	5.61	4.82	5.03	2.81	6.05
T_7	7.71	4.19	4.72	5.39	1.79	4.96	3.69	6.30
T_8	7.96	4.33	4.75	5.21	1.81	4.97	4.14	6.52
T_9	8.04	4.80	4.95	5.05	1.23	4.89	1.23	7.06
T_{10}	8.47	5.05	5.07	5.20	1.43	4.91	1.23	7.16
T_{11}	7.74	4.66	3.89	2.76	0.00	4.80	4.38	7.39
T_{12}	7.92	4.72	4.37	4.68	0.00	4.89	4.40	7.54
T_{13}	7.43	3.81	1.51	1.33	0.00	4.18	0.00	0.00
SE±	0.11	0.11	0.81	0.91	1.07	0.20	0.75	0.93
CD(0.05)	0.33	0.46	2.53	2.68	3.10	0.57	2.19	2.71

4.3.6.26 Pseudomonas sp.

Treatment differed significantly with respect to the *pseudomonas sp.* in the soil The highest population of *pseudomonas sp.* of 7.54 log cfu g $soil^{-1}$ was registered in the treatment 75 per cent N as enriched vermicompost with vermiwash 10 per cent soil application (T_{12}) which was found to be statistically on par with T_{11}, T_{10}, T_9, T_8, T_7, T_6, T_5, T_4 andT_3. Zero number of colonies was recorded in T_{13} (Table 37).

4.3.7 Plant uptake

Perusal of data on plant nutrient uptake revealed that different treatments significantly influenced the uptake of nutrients (Table 38-40).

4.3.7.1 Nitrogen uptake

Significant difference was observed among the treatments in plant N uptake (Table 38). Available N content varied from 14.01 to 364.33 mg plant $^{-1}$. The uptake of N was maximum (364.33 mg plant $^{-1}$) in T_5 (75 % N as EVC + panchagavya 3 % foliar spray) which, significantly superior. The treatment T_7, T_9 and T_3 was found to be on par and these treatments represented the foliar applications of liquid organic manures. With respect N uptake, the performance of soil applications of liquid organic manures were found to be inferior compared to foliar applications. The lowest value of 14.01 mg $plant^{-1}$ was observed in T_{13} (Absolute control).

4.3.7.2 Phosphorus uptake

The details of plant P showed that there was significant difference among treatments (Table 38). For the P uptake the highest value (5.58 mg $plant^{-1}$) was observed in T_5 (75 % N as EVC + panchagavya 3 % foliar spray) which was found to be on par with T_3. The lowest value of 0.24 mg plant $^{-1}$ was observed in T_{13}.

4.3.7.3 Potassium uptake

Significant differences in potassium content between the treatments were recorded in Table 38. Maximum value (1055.76 mg plant^{-1}) for potassium uptake was noticed in T_5 (75 % N as EVC + panchagavya 3 % foliar spray) which was on par with T_6 and T_{12} .The lowest value (32.29 mg plant $^{-1}$) was noticed in T_{13} .

4.3.7.4 Calcium uptake

Plant calcium uptake showed significant difference between the treatments (Table. 39). For the uptake of calcium the highest value of 209.37 mg plant^{-1} was observed in T_3 (75 % N as EVC + fish amino acid 5 % foliar spray) which was significantly superior. The T_{13} recorded the lowest value of 20.36 mg plant $^{-}$.

4.3.7.5 Magnesium uptake

Significant difference was noticed in magnesium uptaket of the plants with different treatments (Table 39). For magnesium uptake, T_3 (75 % N as EVC + fish amino acid 5 % foliar spray) recorded the highest value (79.43 mg plant $^{-1}$). Absolute control recorded the lowest value of 7.63 mg plant^{-1}.

4.3.7.6 Sulphur uptake

Significant differences in sulphur uptake between the treatments were presented in Table 39.The highest value for S uptake was 106.08 mg plant^{-1}in T_3 (75 % N as EVC fish amino acid 5 % foliar spray) which was on par with T_4. The Treatment T_{13} was recorded the lowest value (9.54 mg plant^{-1}).

4.3.7.7 Iron uptake

The values from the data (Table 40) make it clear that the Fe uptake by the plants showed significant difference among treatments.The highest value (41.50 mg plant $^{-1}$) of Fe uptake was noticed in T_{11} (75 % N as EVC + vermiwash10 % foliar spray) and was on par with T_3 (34.96 mg plant^{-1}). With respect to Fe uptake, foliar application of vermiwash, FAA and panchagavya were found to be superior than soil application of respective liquid organic manures. There was no signficant difference in Fe uptake in treatments received foliar and soil application of cow urine and jeevamrutha. The lowest value was in T_{13} (6.49 mg plant^{-1}).

4.3.7.8 Manganese uptake

The values from the table.40, clearly showed the significant variation among treatments. For the uptake of Mn, significant differences among treatments were observed. T_3 (75 % N as EVC + fish amino acid 5 % foliar spray) recorded the highest value of 0.78 mg plant^{-1}.T_{13} recorded the lowest value (0.19 mg plant $^{-1}$).

4.3.7.9 Zinc uptake

Data in table 40, clearly indicated that there was a significant difference between treatments with respect to zinc uptake. Maximum uptake of Zn was registered by T_{11} (75 % N as EVC + vermiwash 10% foliar spray) with value of 4.48 mg plant^{-1} which was on par with all treatments except treatment T_4 and absolute control. T_{13} recorded the lowest value (0.57 mg plant^{-1}).

4.3.7.10 Copper uptake

Copper uptake by plant was presented Table 40. There was significant difference between different treatments with respect to Cu uptake. The highest value of Cu uptake was noticed in T_1 KAU PoP with 4.20 Mg plant $^{-1}$ .The lowest value was in T_{13} (0.60 mg plant^{-1}).

4 .4. 1 Economic analysis

Table.41, presents the data regarding economics of cultivation of bhindi. It was observed that cost benefit ratio was found the highest for treatment T_5 (2.83)

(75 % N as EVC + panchagavya 3 % foliar application) followed by T_7 (2.09) (75 % N as EVC + cow urine 10 % foliar spray). The lowest B:C (0.37) was recorded by T_{13}.

Table 38. Plant uptake of major nutrients effected by different on-farm liquid organic manures on bhindi (Anjitha), mg plant^{-1}

Treatments	Nitrogen	Phosphorus	Potassium
T_1	304.75	2.16	539.80
T_2	167.37	1.48	406.38
T_3	329.15	4.14	1033.63
T_4	179.34	1.60	607.48
T_5	364.33	5.58	1055.76
T_6	241.37	2.55	855.20
T_7	339.79	2.77	674.16
T_8	146.12	3.59	615.35
T_9	339.17	1.50	682.42
T_{10}	279.14	2.77	643.37
T_{11}	223.17	1.73	701.41
T_{12}	133.75	3.83	895.18
T_{13}:	14.01	0.24	32.29
SE±	16.59	0.97	72.74
CD(0.05)	48.25	1.65	211.47

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

Table 39. Effect of on -farm liquid organic manures on plant uptake of secondary nutrients, mg plant^{-1}

Treatments	Calcium	Magnesium	Sulphur
T_1	106.33	46.03	23.15
T_2	116.16	35.32	42.64
T_3	209.37	79.43	106.08
T_4	145.54	48.84	95.57
T_5	143.42	60.87	36.47
T_6	128.97	54.27	29.62
T_7	173.29	68.32	63.85
T_8	129.85	42.60	73.96
T_9	130.93	47.75	61.52
T_{10}	102.61	52.58	74.61
T_{11}	86.13	43.29	21.05
T_{12}	167.19	41.90	40.84
T_{13}	20.36	7.63	9.54
SE±	10.91	3.75	3.95
CD(0.05)	31.73	10.91	11.48

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)
T_2 : Organic Adhoc PoP
T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)
T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)
T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)
T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)
T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)
T_8 : 75 % N as EVC + Cow urine 10 % (soil application)
T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)
T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)
T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)
T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)
T_{13} : Absolute control

Table 40. Plant uptake of micronutrients (mg plant^{-1}) as effected by different on-farm liquid organic manures on bhindi (Anjitha)

Treatments	Fe	Mn	Zn	Cu
T_1	26.87	0.48	2.11	4.20
T_2	12.33	0.42	2.03	0.42
T_3	34.96	0.78	4.02	1.29
T_4	25.88	0.51	1.06	0.99
T_5	28.03	0.47	1.79	0.95
T_6	20.33	0.42	1.85	2.11
T_7	16.03	0.46	3.66	0.84
T_8	18.45	0.36	1.78	2.56
T_9	21.11	0.39	4.34	2.43
T_{10}	24.44	0.41	4.02	1.35
T_{11}	41.50	0.30	4.48	1.86
T_{12}	16.54	0.28	2.80	1.20
T_{13}	6.49	0.19	0.57	0.60
SE±	2.30	0.08	1.03	0.15
CD(0.05)	6.69	0.25	3.01	0.46

T_1 : KAU PoP (FYM 12 t/ha NPK 110 :35:70 kg/ha)

T_2 : Organic Adhoc PoP

T_3 : 75 % N as EVC + Fish amino acid 5 % (foliar spray)

T_4 : 75 % N as EVC + Fish amino acid 5 % (soil application)

T_5 : 75 % N as EVC + Panchagavya 3 % (foliar spray)

T_6 : 75 % N as EVC + Panchagavya 3 % (soil application)

T_7 : 75 % N as EVC + Cow urine 10 % (foliar spray)

T_8 : 75 % N as EVC + Cow urine 10 % (soil application)

T_9 : 75 % N as EVC + Jeevamrutha 10 % (foliar spray)

T_{10} : 75 % N as EVC + Jeevamrutha 10 % (soil application)

T_{11} : 75 % N as EVC + Vermiwash 10 % (foliar spray)

T_{12} : 75 % N as EVC + Vermiwash 10 % (soil application)

T_{13} : Absolute control

Table 41. Effect of different on- farm liquid organic manures on B:C ratio of bhindi (Anjitha)

Treatments	B:C ratio
T_1 : KAU PoP	2.05
T_2: Organic Adhoc PoP	1.22
T_3: 75 % N as EVC + fish amino acid 5 % (foliar spray)	1.46
T_4: 75% N as EVC + fish amino acid 5 % (soil application)	1.35
T_5: 75 % N as EVC + panchagavya 3 % (foliar spray)	2.83
T_6: 75 % N as EVC + panchagavya 3 % (soil application)	1.56
T_7:75 % N as EVC + cow urine 10 % (foliar spray)	2.09
T_8 :75 % N as EVC +cow urine 10 % (soil application)	1.14
T_9:75 % N as EVC + jeevamrutha 10 % (foliar spray)	1.72
T_{10}:75 % N as EVC +jeevamrutha10 % (soil application)	1.46
T_{11}: 75 % N as EVC + verrmiwash 10 % (foliar)	1.69
T_{12}:75 % N as EVC + verrmiwash 10 % (soil application)	1.40
T_{13}:Absolute control	0.37

Discussion

5. DISCUSSION

An investigation entitled "Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition" was undertaken at College of Agriculture, Vellayani. The study was envisaged to characterize on-farm liquid organic manures *viz.,* cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these liquid manures on soil health and crop nutrition using bhindi as test crop.

The experimental findings detailed in the previous chapter have been briefly discussed here in the light of published information and fundamental theoretical knowledge.

PART I

5.1 PREPARTION AND CHARACTERIZATION OF ON-FARM LIQUID ORGANIC MANURES

5.1.1 Preparation and analysis of different on-farm liquid organic manures

Five types of on-farm liquid organic manures *viz.*, cow urine, panchagavya, jeevamrutha, vermiwash and fish amino acid were included in the present study. Cow urine was collected from Department of Animal Husbandary, College of Agriculture, Vellayani and other four liquid manures *viz.* panchagavya, jeevamrutha, vermiwash and fish amino acid were prepared as per standard procedures. Characterization study was conducted to determine the physical, chemical, biological and biochemical properties of these liquid manures.

5.1.2 Characterization of on-farm liquid organic manures

The on-farm liquid organic manures were characterized by analysing the different physical, chemical, biological and biochemical properties. Colour and odour are the physical properties included in the study. Chemical properties such as pH, EC, OC, total N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu are analysed. Biochemical properties *viz.,* dehydrogenase, acid and alkaline phosphatase, urease activity, hormone such as IAA, GA, cytokinin and ascorbic acid content were determined. Similarly biological properties such as Bacteria, Fungi, Actinomycetes, *E .coli,* N fixers, P solubilizers, K solubilizers and *Pseudomonas sp.* were estimated.

5.1.2 .1 Physical properties

Colour of liquid organic manures varies from pale yellow to honey brown. Colour of cow urine, jeevamrutha, panchagavya, FAA and vermiwash were pale yellow, moderate green, light brown, dark brown and honey brown respectively. Venugopal (2004) described that dark deep brownish colour of manure is an indication of good quality. Odour of these liquid organic manures varies from odourless to fermented odour. Odour of cow urine, jeevamrutha, panchagavya, FAA and vermiwash were ammonical smell, mild foul odour, fermented odour and odourless respectively. Harison and McAllan (1980) reported that fermented odour of manures might be due to the production of volatile fatty acid and methane *etc.* during fermentation

5.1.3 Chemical properties

5.1.3.1. pH, EC and OC

Table.6 shows that among the liquid organic manures studied, FAA and panchagavya showed acidic pH and other three liquid organic manures *viz.,* cow urine, jeevamrutha and vermiwash recorded neutral pH. The acidic nature may be attributed to the presence of high level of organic acids like lactic acid, acetic acid, buturic acid etc. Because of acidic pH, FAA and panchagavya can be suitably recommended for foliar application for crops grown in acid soil and soil application in alkaline soil. The increase in soil pH also might have contributed favourable environment for the multiplication of microbes in treatments receiving organic manures. Regarding EC, jeevamrutha recorded the lowest value (1.53 dSm^{-1}) which was found to be in the safe limit. The increased EC of other liquid organic manures might be due to the release of different mineral salts in available form such as phosphate, ammonia, potassium etc. Level of EC was found to be the highest in panchagavya (10.20 dSm^{1}) followed by vermiwash (9.65 dSm^{-1}). Even though electrical conductivity values are above the safe limit for crop production, dilution of these liquid organic manures before application may reduce the EC to the safe limit. Regarding the OC content, FAA was found to be superior (39.96%) to any other liquid organic manures included in the study. This might be due to less degradation of C in FAA, which was prepared under anaerobic condition. Nwite *et al.* (2015) reported that higher total N, available P, Ca, Mg, orgnic carbon, pH, exchangeable, K and Na were obtained under human and cattle urine treatments as compared to control .

5.1.3.2. Major, Secondary and Micronutrients in liquid organic manures

Among the major nutrients, the highest N content was found in panchgavya followed by FAA (Table 7). The highest P content was estimated in FAA. This might be due to the source of feed intake of fish. Maximum K content was recorded in cow urine followed by panchagavya, vermiwash and jeevamrutha. Estimation of microbial population of in these manures indicated that panchagavya and FAA contain N fixing microorganism (Azotobacter), whereas these are absent in cow urine, jeevamrutha and vermiwash. Presence of azotobacter in panchagavya and FAA might have enhanced the N content. K content in these liquid manures varied from 0.01 per cent in jeevamrutha and 0.17 per cent in cow urine. The highest content was in cow urine followed by panchagavya and vermiwash. Microbial analysis of these liquid manures indicated the presence of K solubilizing organisms in cow urine, panchagavya and vermiwash which might have enhanced the K content. Ramalingam *et al.* (2014) studied the potential use of trash fish manures in agricultural fields. Nutrient and minerals were analysed in trash fish samples. High amount of nitrogen (6%), phosphorous (5%) and potassium (4%) were present in trash fish and used for plant growth study. Another findings were reported by Jasmine (1999) that vermiwash contained 0.05 per cent N, 0.03 per cent P and 0.04 per cent K.

With respect to secondary nutrients, the highest content of Ca (324 mg kg $^{-1}$), Mg (49.00 mg kg $^{-1}$) and S (565 .00 mg kg $^{-1}$) were recorded by FAA. S content of all other liquid manures were higher compared to Ca and Mg content. The highest S content was recorded by FAA which might be due to S containing amino acid. As S being the fourth element of plant nutrition these liquid manures especially FAA can be recommended as organic S source. Cow urine is a good source of nitrogen, phosphate, potassium, calcium, magnesium, chloride and sulphate (Khanal *et al.*, 2011) and it was reported that cow urine contained 0.9-1.2 per cent N, 0.2-0.5 per cent P and 0.5-1 per cent K (Bertram, 1999).

Table 8 shows that iron content recorded the highest value in jeevamrutha. Cow urine registered the highest manganese and copper content. In addition, increased iron content of soil has tendencies to lower the manganese content. For Zn, the highest value was recorded in FAA. Application of cow urine has also been reported to correct the micronutrient deficiency, besides improving the soil structure and working as a plant hormone. Hatti *et al.* (2010) opined that the analysis of vermiwash showed high level of macro and micronutrients like Ca, K, S, P, organic carbon, Fe, Mn, Cu and Zn. Therefore, it may be concluded that significant increase in the growth of vermiwash treated plants and their grain yield is due to high level of macro and micronutrients available in the vermiwash. Analysis of nutrient composition of Jeevamruthan (Sreenivasa *et al.*, 2011) revealed the presence of N (0.077 - 0.10 %), P (0.016 - 0.017 %), K (0.01- 0.019 %), Fe (29.7 1282 mg kg^{-1}) Zn (1.27- 4.29 mg kg^{-1}), Cu (0.38 - 1.58 mg kg^{-1}) and Mn (1.8 -10.7 mg kg^{-1}).

5.14 Biochemical properties

Fish amino acid was registered the highest enzyme activities *viz.,* acid and alkaline phosphatase activities and urease activities. Dehydrogenase activity was found to be maximum in cow urine followed by FAA. Presence of microbial activity increased the content of enzyme activities in FAA.

Outcome indicated in Table.10, shows that FAA recorded the highest value of IAA and GA. From the results it can be inferred that among the liquid organic manures studied panchagavya recorded the highest cytokinin content. The similar findings were reported by Selvaraj *et al.*,2007 that panchagavya contained vitamins, essential amino acids, growth promoting factors like IAA, GA and beneficial microorganism like azatobacter, phosphobacteria and pseudomonas in abundant numbers. It also contained some useful fungi and actinomycetes. Fathima and Sekar (2014) observed that by the application of 10 per cent vermiwash, the germination percentage and seedling growth was maximum in treatment received 10 per cent vermiwash.

The data regarding the ascorbic acid content indicated that vermiwash registered the highest value.

5.15 Biological properties

The maximum population of bacteria was observed in vermiwash and jeevamrutha. Fungal population was present in all liquid organic manures except cow urine. The highest actinomycetes population was observed in jeevamrutha. Devakumar *et al.* (2014) noticed higher colony forming units of bacteria, N-fixers, fungi and actinomycetes in jeevamrutha which revealed that the formulation is a rich consortia of naturally occurring soil microbes. The highest azotobacter population was observed in fish amino acid. K solubilizers were found to be the highest in vermiwash, whereas *E.coli*, P solubilizers, *azospirillum* and *pseudomonas sp.* were not detected in any of the liquid organic manures (Table 11).The highest microbial population in the case of all organic treatments could be attributed to favourable effects of manures by providing carbon as a source of energy for microbes and also protection to enzyme fraction due to increase in the humus content (Martens *et al.*, 1992).

PART 11

5.2 LABORATORY INCUBATION STUDY

Laboratory incubation study was conducted to monitor the nutrient release pattern from soil treated with the on-farm liquid organic manures for a period of two months. The study consisted of 6 treatments, which included soil alone and soil treated with 10 per cent dilution of all the liquid organic manures *viz.*, panchagavya, fish amino acid, cow urine, jeevamrutha and vermiwash separately and all the treatments were maintained at 60 per cent moisture level.

5.2.1 Changes in pH and EC

From Fig.4, it was clear that there was an increasing trend in pH of incubated soil in all treatments compared to their initial values. All the treatments exhibited a similar pattern of increasing pH on 7^{th} day of incubation and maximum pH of 5.82 was recorded by T_4 (Soil 5 kg + cow urine 10 %) which indicated an initial pH of 5.08 on 0^{th} day. From the characterization study of liquid organic manures it was found that cow urine registered the maximum pH (7.40) among the liquid organic manures studied. Increase in pH may be due to increase in bases by active degradation of organic matter and suppression of Fe and Al oxides and hydroxides activity which play vital role in protonation and deprotonation mechanisms controlling H^+ ion concentration in soil solution and the beneficial influence of liquid organic manures that provide favourable environment for nutrient availability. On 15th day of incubation all treatments expressed slight decline in soil pH .This may be due to the production of organic acids during the decomposition of manures. The treatments received organic manure registered higher pH values than soil alone treatments. This might be due to the release of bases by active degradation of organic matter. The soil pH significantly affects the availability of most of the nutrients required for plants, and optimum availability of all nutrients are at near neutral pH (Brady, 1990).

Contrary pattern of variation in soil EC, exhibited a general increase throughout the incubation period (Fig 5). EC in soil gives an indirect estimation of soluble salt concentration. Increase in salt content and EC resultant in decomposition of compost have been reported by many works (Gill *et al*., 2016: Roy and Kashema, 2014) Sarwar *et al.*(2008) opined that acids and acid forming compounds release during decomposition of organic manures reacted with sparingly soluble salt present in soil and converted them into soluble salt. This increased the electrical conductivity. Electrical conductivity of incubated soil was increased by the addition of liquid organic manures. This might be due to faster release of bases and soluble organic fractions to the soil system by mineralization. However it should be noted that values of EC in all the treatments were well with in the safe limits prescribed (Table .13). This is similar to the findings of Thompson *et al*. (1989), who reported that organic amendments with ionic concentration increased to higher ionic mobility gave high EC value.

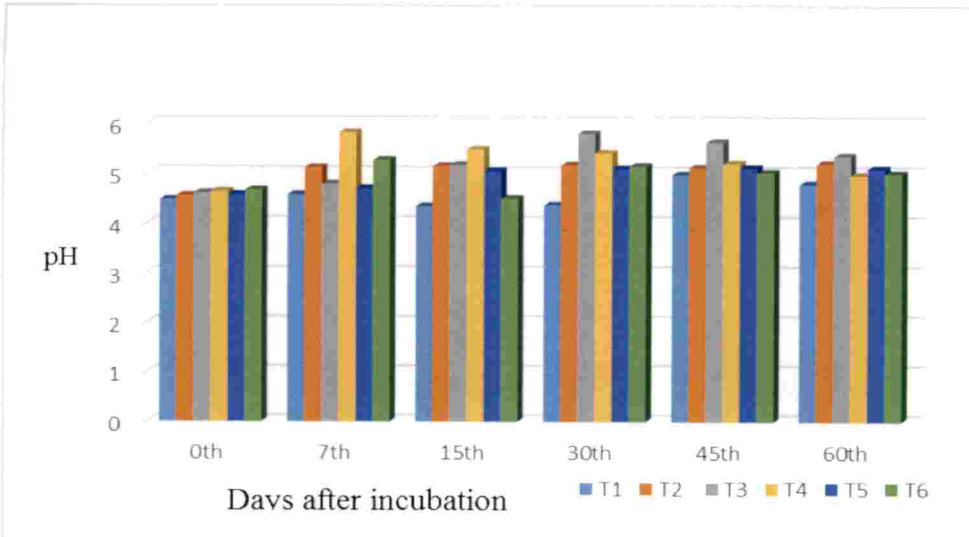


Fig.4 Effect of on-farm liquid organic manures on pH of soil during the incubation period

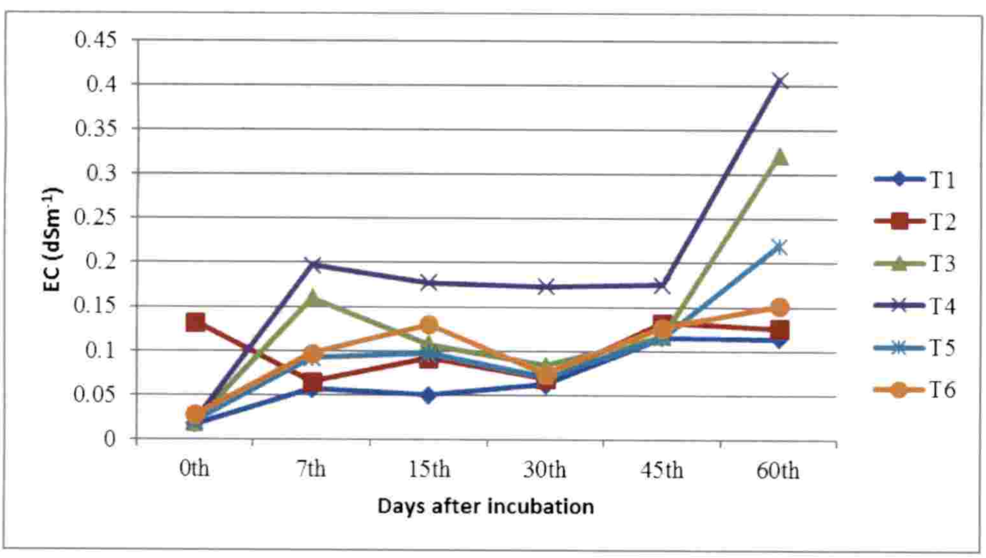


Fig. 5 Effect of on –farm liquid organic manures on EC (dSm^{-1}) of soil during the incubation period

5.2.2 Changes in major and secondary nutrients

The significant difference was observed in available N content of soil during incubation. A high N availability was recorded on 30th day of incubation thereafter showed slight decline in available nitrogen. The available N during incubation period (Fig.6) increased due to mineralisation of organic matter through high microbial activity. The soil treated with liquid manures might have active aminisation, ammonification and oxidative deamination due to high microbial mediated system. Thus N is more available in the soil. In general comparatively higher N content recorded by soil treated with FAA 10 per cent throughout the incubation period. This may be due to the active mineralization of organic manure and N fixation by azotobacter present in the FAA. In the case of vermiwash, available N content was found to be increased from 152.39 kg ha $^{-1}$ on 0th day of incubation to 343.33 kg ha^{-1} on 60th day of incubation indicating sharp increase in available N content. Arancon *et al.* (2006) observed more of nitrogen in vermiwash treated crop because it could provide a large source of nitrogen for mineralization. In most cases net available N increased with the increasing incubation period due to microbial activity. Additions of organic materials can increase microbial pool sizes and activity, C and N mineralization rates and enzyme activities (Smith *et al*., 1993).

The available nitrogen content declined after 45 days after incubation in control alone, it may be due to stabilized nature of organic matter (Dinesh and Dubey, 1999). Similar results were reported by Maerere *et al.* (2008) who observed that the increase in soil available levels of N with application rates could be attributed to increased microbial activities as a result of increased concentration of nutrients. This could have resulted in enhanced decomposition of organic forms of N hence increased availability of N.

In case of available P release during incubation period, (Fig.7) increased trend was observed upto 30th day of incubation and thereafter showed a declining tendency

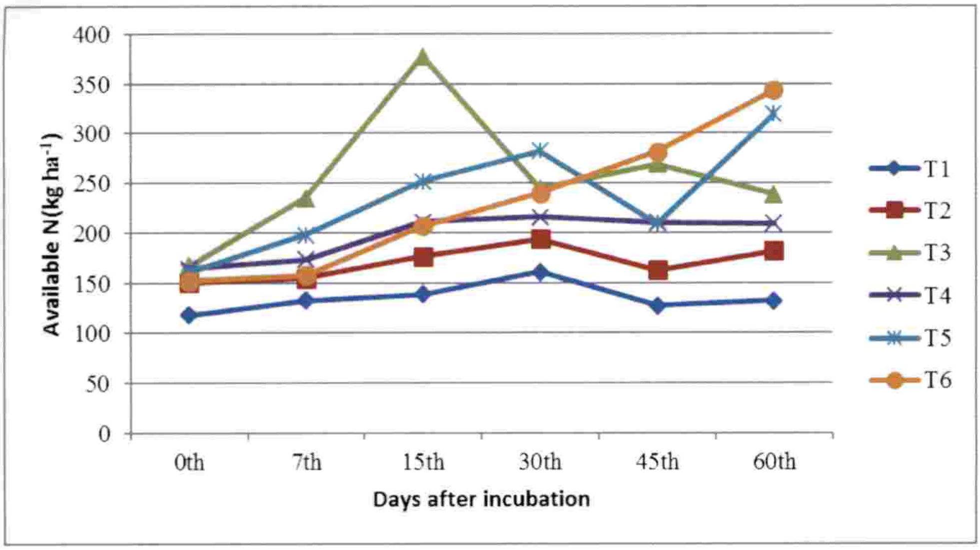


Fig.6 Effect of on –farm liquid organic manures on available N status (kg ha^{-1}) of soil during the incubation period

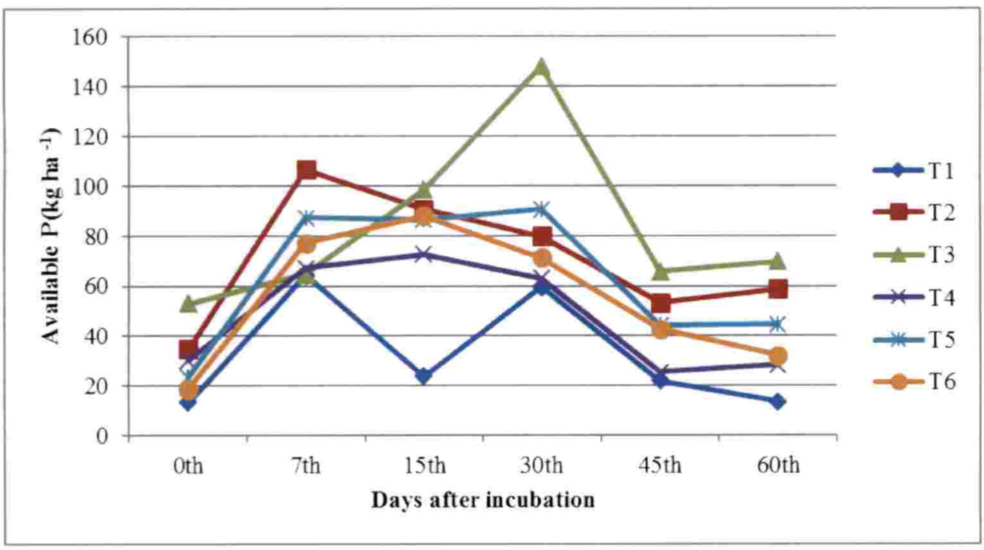


Fig.7 Effect of on -farm liquid organic manures on available P status (kg ha^{-1}) of soil during the incubation period

upto 60th days. The release of available P from soil alone treatment was found to be the lowest throughout the incubation period. In general P release from soil treated with FAA 10 per cent found to be higher. This may be due to the increased acid and alkaline phosphatase activity in FAA and high P content in FAA with the help of microorganism and greater mineralization of organic matter. Vyas and Mothiramani (1971) reported a positive effect of organic matter and soil humus on P availability.

There was a significant variation among treatments and all organic manures registered higher content of available P_2O_5 as compared to control (soil alone). This might be due to the significant addition of phosphorus through organic matter incorporation coupled with the improved solubility of P due to intense microbial activity as reported by Bijulal (1997).

The data given in Table.16 revealed the significant influence of various treatments and periods of incubation on available potassium content. In general, available K_2O increased progressively upto 15th day of incubation thereafter showed slight decrease. The available potassium content (Fig.8) in the soil ranged from 101.77 to 704.42 kg ha^{-1}. During incubation period, soil treated with cow urine 10 per cent was maximum among the treatments. It might be due to the highest content of K in cow urine as indicated in the characterization study. The highest release of K was observed due to accelerated mineralisation by the interaction of organic matter with clay (Tan, 1982).

All treatments received liquid organic manures recorded higher K_2O content than soil alone. This might be due to an addition of potassium through organic manures. More over organic amendments usually have a large cation exchange capacity enabling them to retain K ions effectively. Also decomposition of organic manures produces organic acids, which cause the dissolution of insoluble K minerals and increase the available K_2O content (Hue and Silva, 2000).

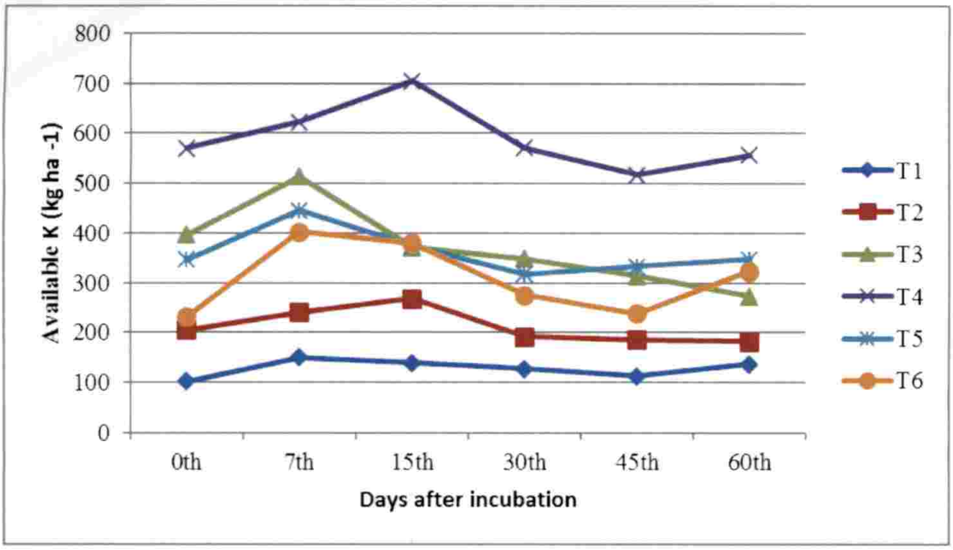


Fig.8 Effect of on-farm liquid organic manures on available K status (kg ha^{-1}) of soil during the incubation period

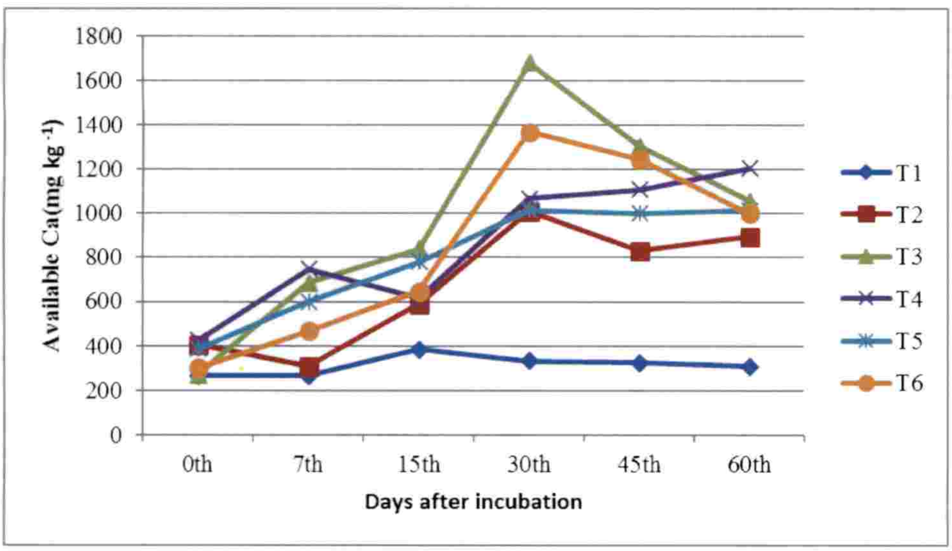


Fig.9 Effect of on –farm liquid organic manures on exchangeable Ca content (mg kg $^{-1}$) of soil during the incubation period

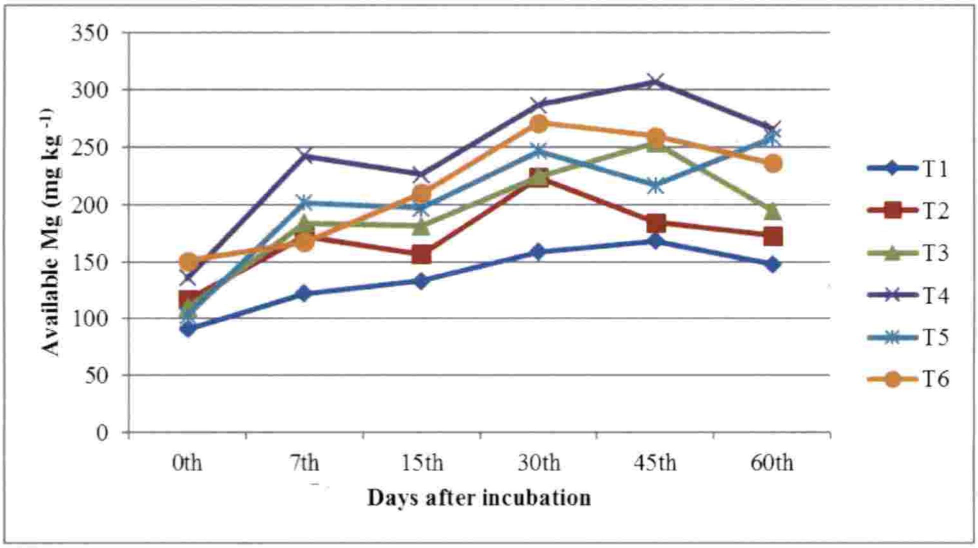


Fig.10 Effect of on -farm liquid organic manures on exchangeable Mg content (mg kg^{-1}) of soil during the incubation period

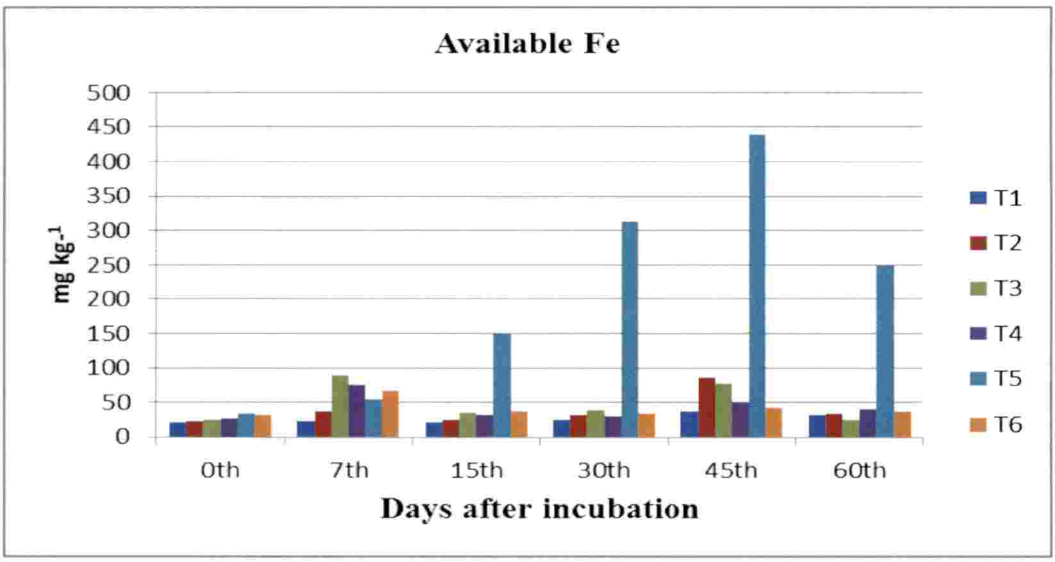


Fig.11 Effect of on-farm liquid organic manures on available Fe content (mg kg^{-1}) of soil during the incubation period

Changes in exchangeable calcium content of soil during laboratory incubation study indicated that the release of Ca was high upto 30th day of incubation thereafter it showed slight decreasing tendency (Fig.9). It was observed that soil treated with cow urine 10 per cent showed better release of Ca throughout the period. The release of Ca from soil treated with FAA 10 per cent was on par with soil treated with cow urine 10 per cent. This may be due to the presence of high Ca content in FAA (Table 17). In the case of exchangeable magnesium (Fig.10) the increasing trend was observed throughout the period. There was a significant difference in magnesium content between treatments at different intervals. Soil treated with cow urine 10 per cent indicated a better release of Mg. Olsen *et al.* (1954) inferred that the application of manures increased the exchangeable Ca and Mg particularly at higher rates of their application.

5.2.4 Changes in micronutrient content

There was a significant variation among treatments in micronutrient release (Fig 11-14). Gradual increase in available Fe content upto 45th day of incubation thereafter showed a decline. Regarding release of Zn it was found to be decreased on advancement of incubation. In the case of Mn, maximum release was obtained at 7th day of incubation thereafter indicated a declining tendency. Cu content showed an increased release upto 60th day of incubation. Soil alone treatment recorded the lowest value with respect to all micronutrients throughout the incubation period. The available Fe and Zn content showed that the highest value was recorded by soil treated with jeevamrutha 10 per cent. Soil treated with cow urine 10 per cent was found to be the best with respect to Mn and Cu content. Rostami and Ahangar (2013) reported an increase in exchangeable Fe and Mn with application of cow manure. In general, it was noted that availability of Zn was reduced on advancing incubation. This might be due to strong bonding of inorganic soil colloids mainly Fe and Al oxides by specific adsorption.

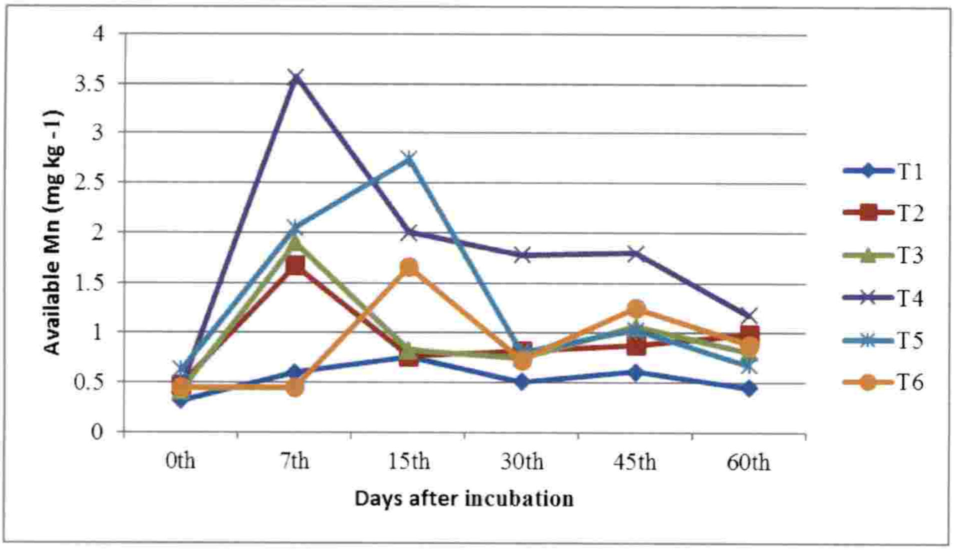


Fig. 12 Effect of on-farm liquid organic manures on available Mn content ($mg\ kg^{-1}$) of soil during the incubation period

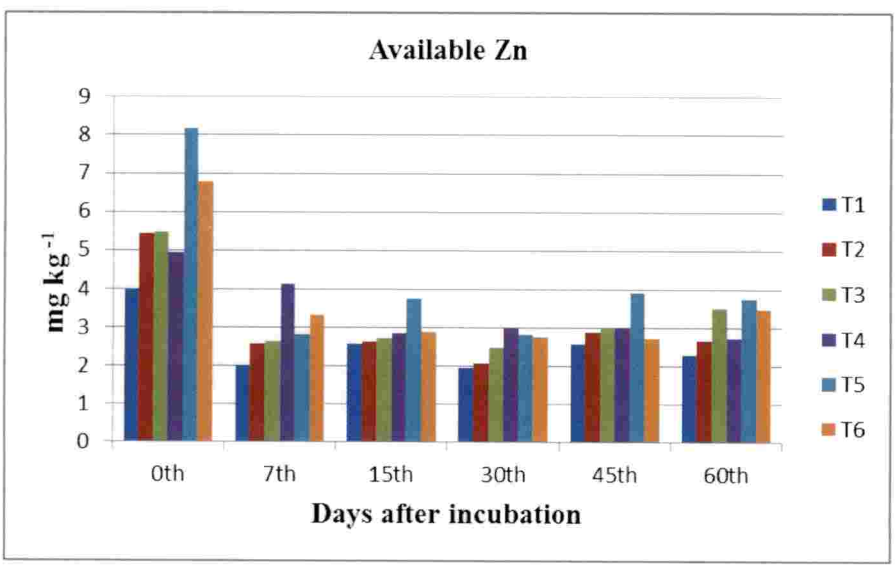


Fig.13 Effect of on –farm liquid organic manures on available zinc content ($mg\ kg^{-1}$) of soil during the incubation period

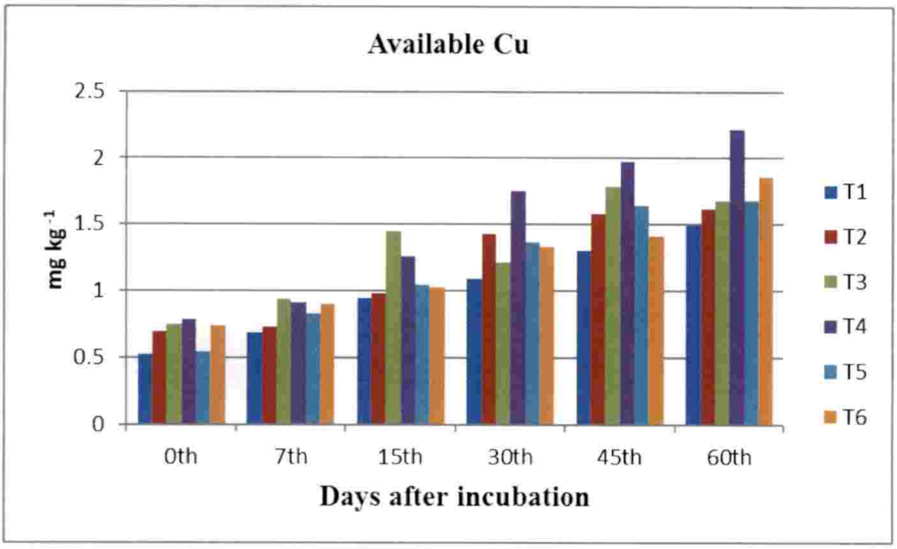


Fig. 14 Effect of on -farm liquid organic manures on available copper content ($mg\ kg^{-1}$) of soil during the incubation period

PART III

5.3 POT CULTURE EXPERIMENT

5.3.1 Effect of on-farm liquid organic manures on biometric characteristics of bhindi (Anjitha)

Important biometric observations recorded were plant height, internodal length at first harvest, number of branches per plant and LAI. Among those observation internodal length at first harvest was found significantly different whereas rest of the observations were found to be non significant.

Plant height at first and final harvest were presented in (Fig.15). The critical evaluation of the data in Table.25, revealed that the treatment T_5 was significantly superior to all other treatments with respect to plant height at all stages. The increased plant height might be due to increased uptake of nutrients supplied through 75 per cent N as enriched vermicompost as soil application along with panchagayva 3 per cent foliar spray. Enhanced vegetative growth of the plant might be due to the favourable effects of IAA, GA_3, major and micronutrients and microorganisms (Somasundaram and Sankaran, 2004) present in panchagavya resulted in stimuli in the plant system and in turn increased the production of growth regulator in the cell system. Role of panchagavya as growth promoter was also reported by Manjunatha *et al.* (2004) and Sundararaman (2004). Increased plant height by the addition of 75 per cent N as EVC with panchagavya 3 per cent as foliar spray is in conformity with above findings. Rajesh and Jayakumar (2013) reported that the highest morphological parameters of (*Abelmoschus esculentus* L.) Moench. *viz.*, plant height and number of leaves at harvest stage with 3 per cent concentration of panchagavya when compared with control.

Number of branches per plant was significantly influenced by various treatments (Table 26). Maximum number of branches per plant was recorded by the treatment T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and was on par with T_7 (75 % N as EVC + cow urine 10 % foliar spray), T_{11} (75 % N as EVC + vermiwash 10 % foliar spray) and T_8 (75% N as EVC + cow urine 10 % soil application). This indicates that application of 75 per cent N as enriched vermicompost with panchagavya 3 per cent as foliar spray can give more number of branches. Application of 75 per cent N as enriched vermicompost and panchagavya 3 per cent produced more vegetative growth, thereby enhanced more number of primary branches. According to Muthuvel (2002) four sprays of panchagavyam at 3.0 per cent and moringa leaf extract spray at 25 ml plant^{-1} in bhindi var. Varsha Upahar resulted in higher plant height and number of branches plant^{-1}.

Leaf area index is a function of leaf size and number. Regarding leaf area index (Fig 16.), the highest value was observed for the plants treated with enriched vermicompost in unification with panchagayva 3 per cent foliar spray. It was also found that plants treated with other liquid organic manures showed better leaf area when compared to control. This might be because of higher level of N in soil. Russel (1973) reported that as the nitrogen supply increases, the protein content also increases that allows plant leaves to grow larger and hence more surface area for photosynthesis. Thus the increased leaf area index might have helped in achieving more photosynthetic efficiency by providing larger leaf area for harvesting maximum sunlight.

In an experiment it was reported that foliar application of 3 per cent panchagavya increased plant height, LAI and dry matter production which was close to 0.05 per cent humic acid application in increasing the plant height, LAI, dry matter production, maximum weight of mother rhizomes and highest yield (Satish *et al.*, 2006).

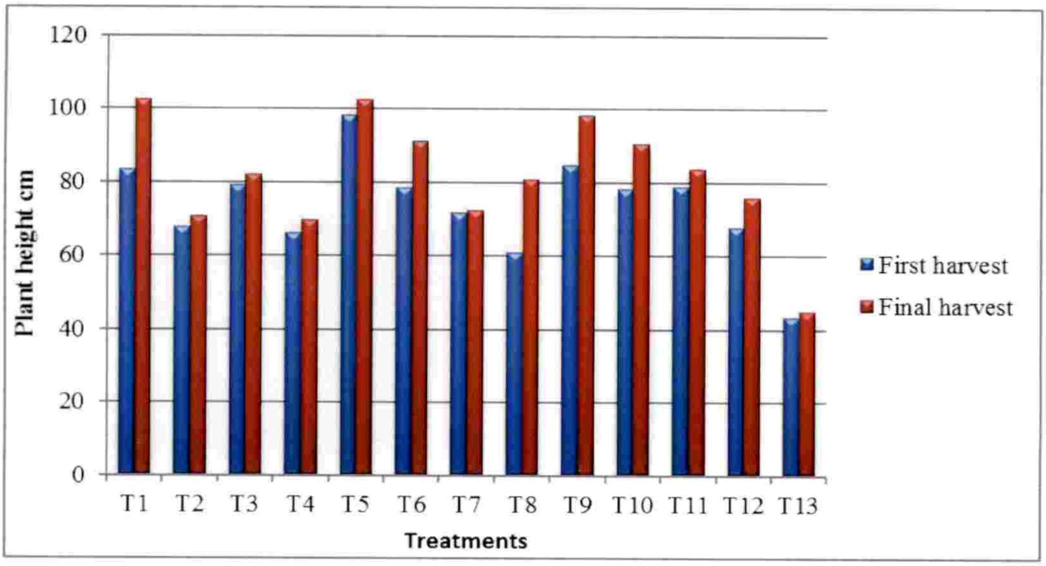


Fig.15 Effect of different on-farm liquid organic manures on plant height (cm) at different growth stages of bhindi (Anjitha)

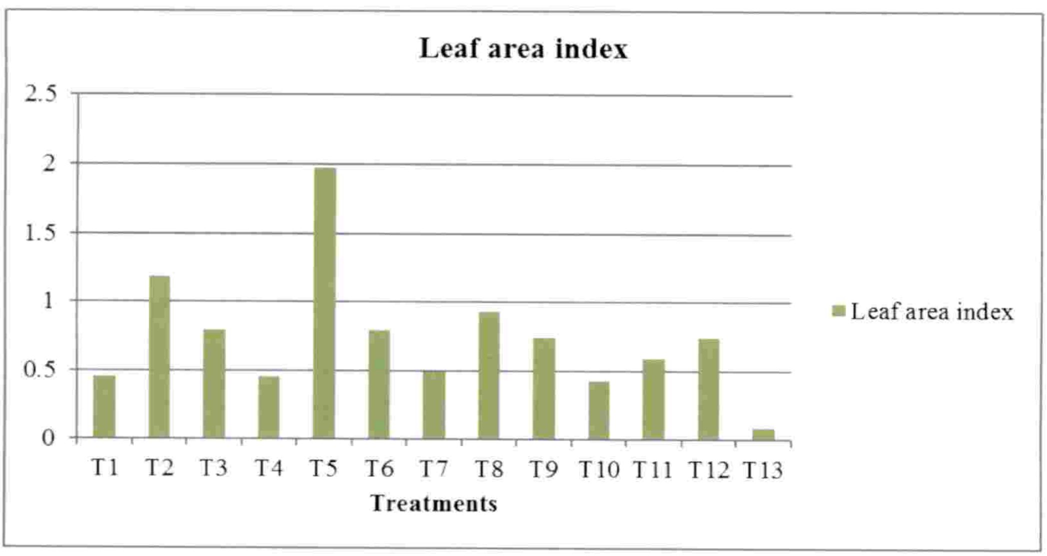


Fig.16 Effect of on-farm liquid organic manures on leaf area index

5.3.2 Effect of on-farm liquid organic manures on physiological characteristics of bhindi (Anjitha)

The data of various physiological characters were presented in the Table 28.Various physiological characters of crop *viz.*, chlorophyll a, chlorophyll b and total chlorophyll content production were recorded and presented. In these observations the highest values were recorded by the treatment T_{10} (75 % N as EVC + jeevamrutha 10 % soil application) significantly superior to all other treatments. Chlorophyll content was also more in plants receiving liquid organic manures. This might be due to the increased availability of nutrients from soil which might have enhanced the multiplication of microbes in soil which inturn enhanced the mineralization. N application through liquid organic manures increased chlorophyll content because N is present in the chlorophyll structure. The findings of Gathala *et al.*(2007), where the application of organic inputs especially foliar spray of liquid organic manures showed accumulation of nutrients in leaf tissues, which in turn ensured better photosynthetic efficiency causing greater synthesis, translocation and accumulation of carbohydrates and chlorophyll.

5.3.3 Effect of on-farm liquid organic manures on yield and yield attributes of bhindi (Anjitha)

Yield and yield characters showed significant variation due to the treatments. In general the treatment that received 75 per cent N as EVC along with panchagavya 3 per cent foliar spray showed better performance in terms of yield and yield attributes.

Important yield and yield attributes recorded were days to first flowering, length and girth of fruit, number of flowers formed, number of fruits per plant, average fruit weight, dry matter production and total fruit yield. Among those observation days to first flowering, length and girth of fruit were found significantly different, whereas rest of the observations were found non significant.

With respect to the number of flowers formed (Table .30), different treatments showed significant differences and maximum number of flowers was recorded by the treatment of T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and it was on par with T_7 (75 % N as EVC +cow urine 10 % foliar spray) and T_{11} (75 % N as EVC + vermiwash 10 % foliar spray). The result showed that enriched vermicompost along with panchagavya 3 per cent foliar spray induced more flower production. This might be due to the presence of readily available nutrients, natural hormones and enzymes present in panchagavya.

Regarding the number of fruits per plant (Table 30), the highest mean value was recorded by the treatment T_5 (75 % N as EVC + panchagavya 3% foliar spray) and was on par with the treatment T_6 (75 % N as EVC + panchagavya 3 % soil application) and T_7 (75 % N as EVC + cow urine 10 % foliar spray). It is evident that plants supplied with panchagavya is efficient in producing more number of fruits, provided it is applied along with sufficient quantity of organic manure. Number of fruits is closely associated with growth parameters like plant height, number of branches per plant, leaf area index and dry matter production. It was also attributed to the maximum uptake of N, P and K (Chandrakala, 2008; Gangamrutha, 2008). Since 75 per cent N as enriched vermicompost along with panchagavya 3 per cent foliar spray was significantly superior to all other treatments with respect to all these parameters, similar effect was produced in number of fruits per plant also. The plant can absorb nutrients about 20 times faster through the leaves than if they are applied through the soil (Agro Chadza, 2011).

Average fruit weight (Table. 30) was significantly influenced by different treatments. The highest value was recorded by the treatment of T_1 (KAU PoP) and was significantly superior to all other treatments. Average fruit weight was maximum for T_1 (KAU PoP), was due to the lesser number of fruits compared to organic treatments. Second highest value for average fruit weight was recorded by T_5 (75 % N as EVC + panchagavya 3% foliar spray). This shows the beneficial influence of panchagavya in increasing the fruit weight.

From this Fig.17, it is clear that total fruit yield significantly varied among treatments. The best treatment was T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and was found to be on par with T_7 (75 % N as EVC + cow urine 10 % foliar spray) and T_1 (KAU PoP). The treatment T_5 recorded the maximum value and this indicated that application of enriched vermicompost along with panchagavya as foliar spray is essential to get higher crop yield in organic farming and inorganics can be substituted with foliar spray of panchagavya along with quality organic manures. Reddy (2004) reported that promoting the use of panchagavya as a nutrient and a hormone can help to get better yield at very cheap cost. Similar findings were reported by Somasundaram *et al.* (2003); Manjunatha et *al.*(2004); Satish *et al.* (2006); Venkataramana *et al.* (2009) and Sangeetha and Thevanathan (2010). The fruit yield is the manifestation of various growth and yield attributing characters and higher yield could be traced back to significant differences in dry matter production and its accumulation. The highest accumulation of assimilates reflected in higher number of flowers formed, number of fruits per plant and ultimately yield. According to Ravikumar *et al.* (2011), foliar spray of panchagavya facilitated easy transfer of plant nutrients due to the stimuli caused by the presence of growth regulators such as IAA and GA, which in turn increased the crop production.

The organic manures increases the availability of native nutrients to the crops and also improves the soil environment, which stimulated proliferous root system subsequent in better absorption of water and nutrients from lower layers resulting in higher uptake and yield (Thenmozhi and Paulraj,2009).

The highest availability and uptake of nutrients might have enabled the plant to produce more number of flower buds which in turn increased the number of fruits. Increased fruit yield per plant might be due to improved vegetative growth, better availability of nutrients, greater synthesis of carbohydrates and their proper translocation (Dar *et al.*, 2009). It is well known that photosynthetic activity of the plant is modified by the nutritional status of the plant, since the N content in the plants increased with increasing levels of nutrients in the media. Moreover application of nutrients in organic form reduces the loss of nutrients from the media.

Better nutrient availability and uptake during vegetative and fruiting phase might have increased the production, translocation and assimilation of photosynthates to growing points and stimulated the plants to produce more number of fruits and better fruit characters.

The data pertaining to the dry matter production were presented in Fig 18. The growth parameters recorded at different stages of crop were significantly higher with the treatment T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and hence dry matter yield (Table. 27) was also highest for T_5. Dry matter production and its accumulation accomplished only with the development of sound vegetative growth *viz.*,plant height, number of branches per plant and LAI. Production of photosynthesis and its effective utilization might be another reason for the increased biomass. Improved performance might be due to faster decomposition of organic manures, thereby increasing the availability of nutrients, especially nitrogen, which helps in protein synthesis and ultimately resulting in more DMP (Subbaiah and Asija, 1956). Similar results were obtained by Babalad (2005), Dhananjaya (2007) and Shijini (2010). Patil *et al.* (2012) recorded an increase in dry matter accumulation in chickpea at various growth stages by the application of organic manures and foliar source such as 3 per cent panchagavya. Shashikumar *et al.* (2013) also reported that application of 3 per cent panchagavya along with RDF could improve the height of

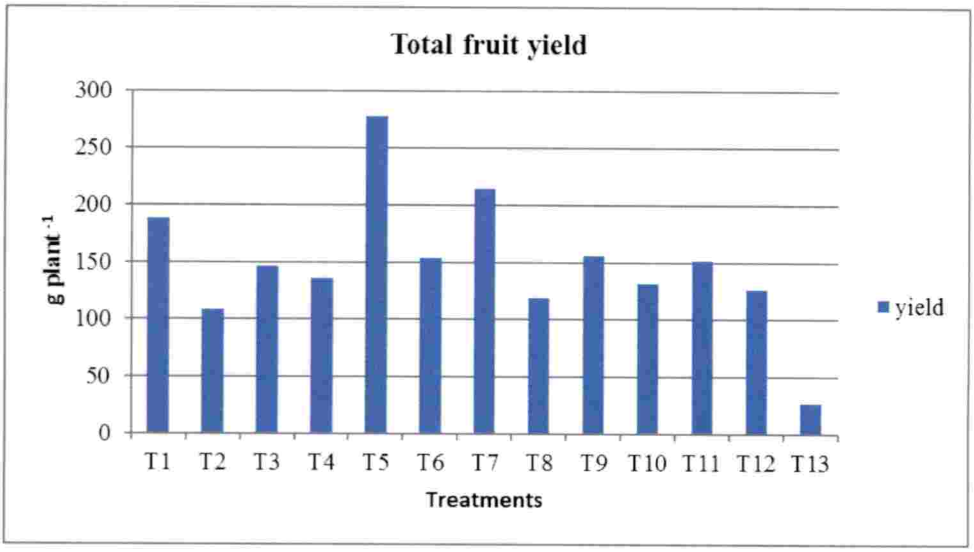


Fig. 17 Effect of on –farm liquid organic manures on total fruit yield ,g plant^{-1}

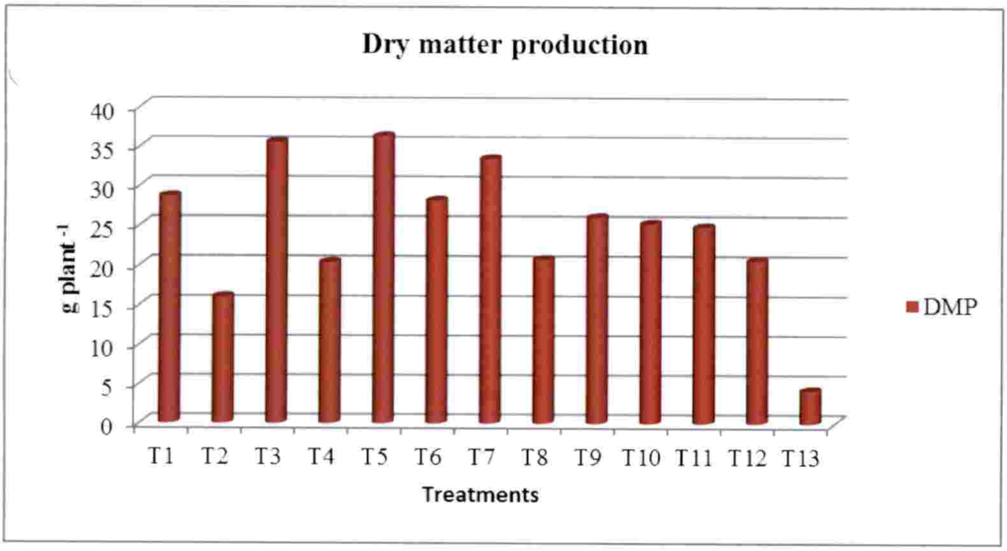


Fig.18 Effect of liquid organic manures on dry matter production (g plant $^{-1}$) of bhindi (Anjitha)

plants, number of branches, dry matter production and yield in black gram compared to the RDF alone.

Sakr (1985) reported the increase of dry weight of plants after organic manure application. This was due to the production of humus substances which improve the physical and chemical properties of soil and also increased the nutrient release which in turn enhanced the ability of growing parts.

5.3.4 Effect of on-farm liquid organic manures on quality parameters of bhinidi (Anjitha)

From the Table.31, the highest protein content was observed by plants treated with enriched vermicompost with fish amino acid 5 per cent soil application and was on par with T_7 (75 % N as EVC + cow urine 10 % foliar spray) followed by T_5 (75 % N as EVC + panchagavya 3 % foliar spray. This might be due to better translocation of N to the fruits. 75 per cent enriched vermicompost with panchagavya 3 per cent foliar spray of fruit showed higher N content that directly contribute to build up of protein content in fruit because panchagavya which consisted of N fixers make N more available to plant. Nitrogen thus obtained was metabolized via ammonia into alpha-ketoglutamic acid. Carbon skeleton provided by photosynthesis was incorporated in the process of amino acid synthesis which were converted as protein and is in confirmity with the findings of Sheeba (2004). Vennila and Jayanthi (2008) also reported that water regulation in developing fruits of okra can be controlled by the auxin present in panchagavya and it resulted in increased ascorbic acid and crude protein content.

From the Fig.19, it was clear that crude fibre contents of bhindi were significantly influenced by the different treatments. The lowest fibre content, was found as desirable quality of fruit that was observed in treatment T_7 (75 % N as EVC + cow urine 10 % foliar spray) and all other treatments which, received organic

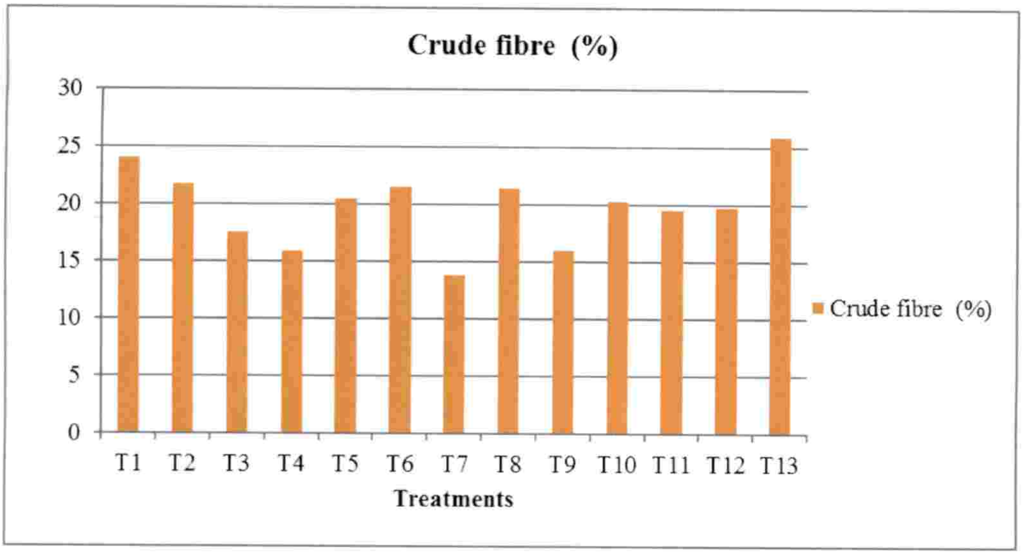


Fig. 19 Effect of on -farm liquid organic manures on crude fibre content, %

nutrition had lower fibre content when compared with control. This might be due to the production of growth hormones which might have decreased the crude fibre content especially plants received with enriched vermicompost with cow urine 10 per cent foliar spray. IAA is a phytohormone which is known to be involved in root initiation, cell division and cell enlargement (Salisbury, 1994). Increased N uptake also have resulted in increasing the succulence and there by decreasing crude fibre content. Similar results were obtained by Raj (1999). Tiwanan *et al.* (1975) reported that the decrease in crude fibre content in Napier bajra hybrid fodder was due to N application.

Ascorbic acid content of fruit was greatly influenced by different treatments (Table 31). Treatment T_9 (75 % N as EVC + jeevmrutha 10 % foliar spray) registered the highest value was on par with T_{10} (75 % N as EVC + jeevamrutha 10 % soil application). The results revealed that jeevamrutha play a vital role in enhancing the ascorbic acid content of the fruit. The increase in ascorbic acid content might be due to better availability and uptake of plant required nutrients and also favourable conditions resulted by the applied panchagavya which help in the synthesis of chlorophyll and increased ascorbic acid conent (Kaminwar and Rajagoal,1973). Ascorbic acid content of fruit depends on species, genotypes and agro-climate (Rani, 1996; Singh *et al.*, 2003 and Naveen *et al.*, 2009).

5.3.5 Incidence of pest and diseases

No severe attack of pests and diseases was observed in pot culture experiment. However, the attack of semi looper, fruit and shoot borer and white flies attack noticed during study was suppressed by spraying nimbicidin. Lesser incidence of pests and diseases with the application of panchagavya and neem cake was also reported by Solaiappan (2002), Sangeetha and Thevanathan (2010) and Krishnan (2014). The secondary metabolites produced by the beneficial micro organisms in panchagavya might have helped to prevent the attack of pests and diseases.

Nileema and Sreenivasa (2011) also reported that panchagavya was an efficient plant growth stimulant that enhances the biological efficiency of crops. It was used to activate biological reactions in the soil and to protect the plants from disease incidence. Cow urine was used for control of pests and as a growth promoter for the growing crops (Sairam, 2008).

5.3.6 Effect of on-farm liquid organic manures on properties of soil after pot culture experiment

5.3.6.1 Chemical properties

There were significant differences among treatments for pH of soil. It was observed that organic adhoc PoP was recorded higher mean value (6.44). The increase in pH might be due to the fact that lime application reduced soil acidity in organic PoP treatment and decreased the activity of Fe and Al. Application of organic manures including liquid manures might have contributed to the increase in pH (Lal *et al.*, 2000). Olsen (1972) also observed that addition of manures increased the soil pH. The treatment T_4 (75 % N as EVC + fish amino acid 5 % soil application) registered the lowest pH (5.17) among the treatements except T_{13}. This might be due to the low pH of the FAA applied in the soil.Treatement T_3 (75 % N as EVC + fish amino acid 5 % foliar spray) recorded higher pH (5.92) compared to soil application. So it is better to apply FAA as foliar spray than soil application.

Different treatments influenced the electrical conductivity of soil. The treatment T_4 (75 % N as EVC + fish amino acid 5 % soil application) registered the maximum value for EC of soil but within the safe limit.The EC of the soil was considerably enhanced by the application of organic manures and liquid organic manures. Addition of organic manure generally increases EC of soil which might be due to the fast release of bases and soluble organic fractions to the soil system by mineralisation. This is in agreement with the findings of Thompson *et al.* (1989). EC of the soil was comparatively low in treatments which received liquid organic manures as foliar spray.

In case of organic carbon, the highest value was recorded for the soil treated with 75 per cent N as EVC + fish amino acid 5 per cent soil application and was on par with T_{12} (75 %N as EVC + vermiwash 10 % soil application). This might be due to high OC content of FAA (39.96 %). The increase in organic carbon content of soil under organic farming is quite obvious since the carbonaceous materials contribute to soil organic carbon after their decomposition. Halvorson *et al.* (1999) reported that the addition of organic matter to soil increased the root biomass production which, in turn increases the carbon content in soil. More (1994) reported that addition of farm waste and organic manures increased the status of organic carbon and available NPK of the soil. Manyuchi *et al.* (2013) observed that the vermiwash applied over time increases the organic matter of soil.

Table.32 shows that the labile carbon content of soil after the harvest of crop. The result indicated that the treatment T_8 (75 % N as EVC + cow urine 10 % soil application) recorded the highest mean value and which, was on par with T_2,T_1, T_6, T_4, T_{10},T_9, T_{12} and T_5. Lowest value was recorded by T_{13} (Absolute control). Labile carbon means active pool of carbon. Light fraction organic carbon is characterized by the rapid mineralization due to the labile nature of its constituents and to the lack of protection by soil colloids (Turchenek and Oades, 1979). Labile carbon fractions *ie,* particulate organic carbon, hot water extractable carbon and permanganate oxidizable carbon respond more quickly to changes in management practices than SOC and are thus used as early and sensitive indicators of SOC changes (Haynes *et al.*,2000). Changes in carbon stocks following land use change can be more pronounced in labile fractions (Turchenek and Oades, 1979).

Highest value for available N (Fig. 20) was recorded by the treatment T_6 (75 % N as EVC + panchagavya 3 % soil application). The significant increase in available nitrogen content of soil was due to the increased multiplication of microbes which, mineralize the nitrogen contained in the applied organic manures and the presences of panchagavya also enhanced the availability of nitrogen. Similar to panchagavya, vermiwash also contains macro and micro nutrients and growth promoting substances essential for plant growth (Thangavel *et al.*, 2003). Several reports supporting this observation had been made by Shield and Earl (1982), Tomati and Galli (1995), Pramoth (1995); Kale (1998), Giraddi *et al.* (2003) and Ismail (2005).

For P (Fig 21.), T_4 (75 % N as EVC + fish amino acid 5 % soil application) recorded the highest mean value and this treatment is found to be superior to all other treatments. Increase in available P content of soil might be due to greater decomposition of native soil P by organic acids released during the decomposition of organic matter by vigorous root proliferation and contribution through biomass. Characterization study of different organic liquid manures indicated that among the liquid organic manures, FAA registered the highest total P content (0.41%). The significant increase in available P content could also be attributed to the organic manure mediated complexation of cations like Cu, Mg and Al responsible for fixation of P in soil (Sushma *et al.*, 2007). Similar results were reported by Fragstein and Vogtmann (1987); Chattopadhyay *et al.* (1993), Rasal *et al.* (1996) Korcak (1996), Zayed and Abel-Motaal(2005).

For K (Fig.22) the treatment T_8 (75 % N as EVC + cow urine 10 % soil application) showed the highest mean value for available K content in soil. This might be due to high content of K in cow urine as indicated by the characterization study. The increase in available potassium in soil is due to the decomposition products of organic matter which contain various organic acids, might have aided in release of non-exchangeable K to the water soluble forms (Chitra and Janaki, 1999).

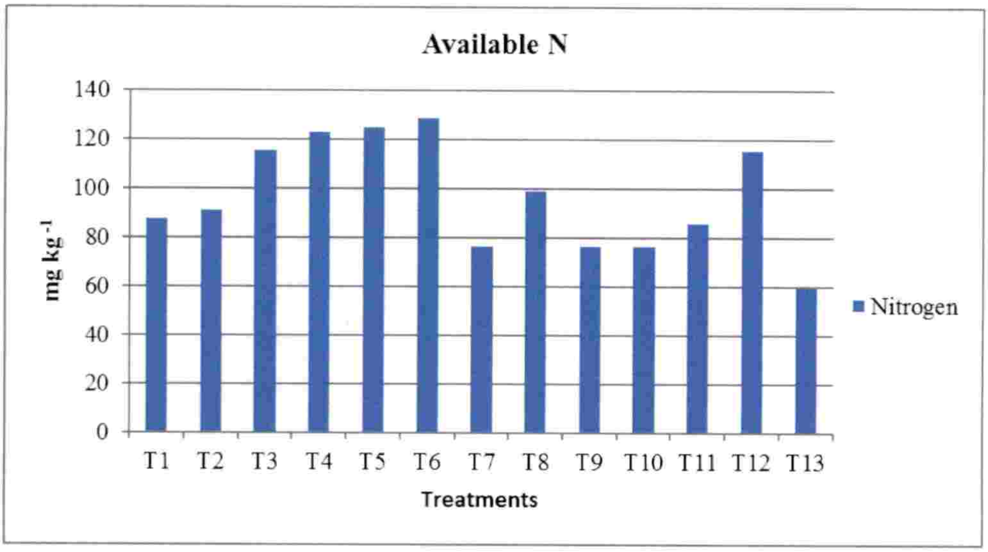


Fig.20 Influence of different liquid organic manures on soil available N content of soil, (mg kg^{-1})

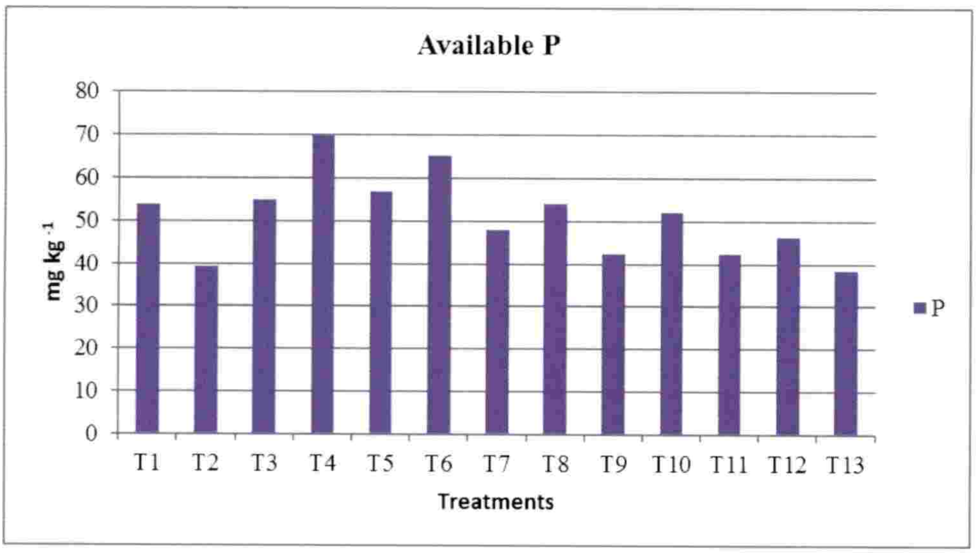


Fig. 21 Influence of different liquid organic manures on soil available P content of soil, mg kg^{-1}

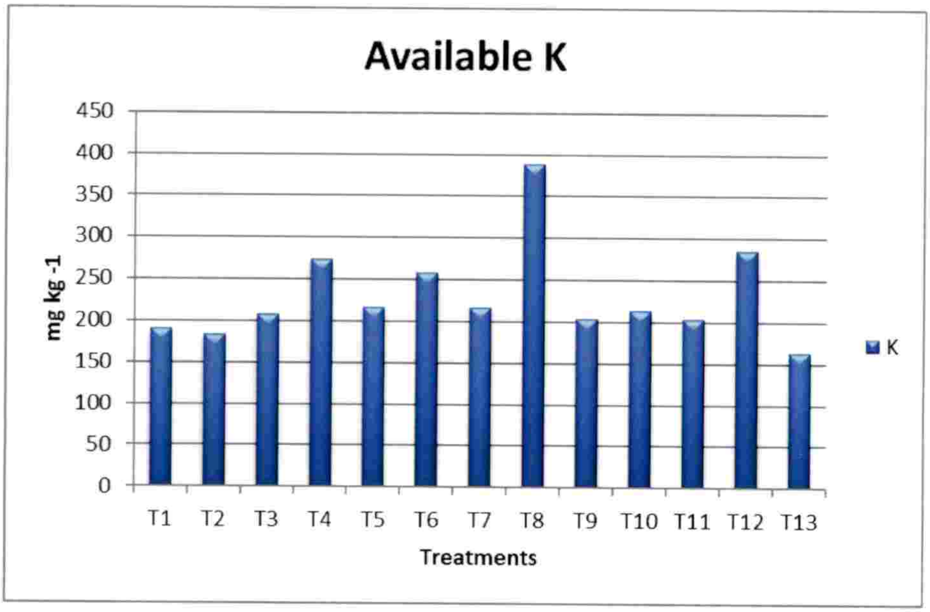


Fig.22 Influence of different liquid organic manures on soil available K content of soil, mg kg^{-1}

Greater concentration of Ca, S and Zn was observed in soils treated with T_4 (75 % N as EVC + fish amino acid 5 % soil application). Among enriched vermicompost with cow urine 10 per cent soil application reported to be the best for Mg, Mn and Cu. For Fe the treatment T_{10} (75 % N as EVC +jeevamrutha 10 % soil application) recorded the highest value. The increase in available Fe, Cu, Mn and Zn upon addition of organic matter might be due to intensified microbial and chemical reduction, pH of soil and also formation of stable complexes with organic ligands. This might have decreased the susceptibility of micronutrients to adsorption, fixation or precipitation reaction in soil resulting in greater availability it also noticed that Ca, Mg and S .Apart from these highest content of Cu and Mn noticed in cow urine, high content of Ca, Mg and S were present in FAA and highest Fe content in jeevamrutha. Manjunatha *et al.* (2009) noticed that application of jeevamrutha maintains soil health and productivity by improving physical, chemical and biological properties of soil.This was similar with the findings of Palekar (2006) that jeevamrutha, a promising liquid manure could act as a good soil tonic which enhanced the soil physical, chemical and biological properties.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.

The role of microorganism in mineralization of organic matter has been well established. The microorganisms present in FAA enhanced the microbial activity of the soil thereby increased the availability of macro and micronutrients in soil.

5.3.6.2 Biochemical properties

Enzymes produced by the proliferating micro-organisms mediate many processes occurring in soil. The variation in the microbial population might result in an alteration of the enzyme activity. Enzymes have biological significance as they participate in the biological cycling of elements. They play a very important role in the initial phases of the decomposition of organic residues and transformation of some of the mineral compounds and under unfavourable conditions for the proliferation of micro-organisms (Kiss *et al.*, 1975). Some of the important soil enzymes are dehydrogenase, urease and phosphatase.

Regarding the dehydrogenase activity, the data showed that the dehydrogenase activity varied significantly influenced by different treatments (Fig 23.) The highest mean value was recorded by the treatment T_8 (75 % N as EVC + cow urine 10 % soil application) and followed by T_7 (75 % N as EVC + cow urine 10 % foliar spray) and was significantly superior to all other treatments. This might be mainly due to highest dehydrogenase activity in cow urine as indicated from the characterization study.

Activity of acid phosphatase varied significantly with different treatments (Fig.24). Among the treatments, the highest activity was recorded by T_4 (75 % N as EVC + fish amino acid 5 % soil application) which was followed by T_3 (75 % N as EVC + fish amino acid 5 % foliar spray).

Table.36, data showed that the different treatment influenced the urease activity of soil. An appraisal of the data on the influence of different treatments on urease activity at soil sample, the T_4 (75 % N as EVC + fish amino acid 5 % soil application) recorded the highest value and followed by T3.

From the characterization study it was noticed that acid and alkaline phosphatase activity and urease activity were found to be highest in FAA. This might be the reason for highest acid and alkaline phosphatase activity and urease activity in the soil treated with FAA as soil or foliar application.The study of microbial biomass, dehydrogenase and alkaline phosphatase activity to obtain a more complete and precise definition of soil fertility was suggested by Beyer *et al.* (1992).

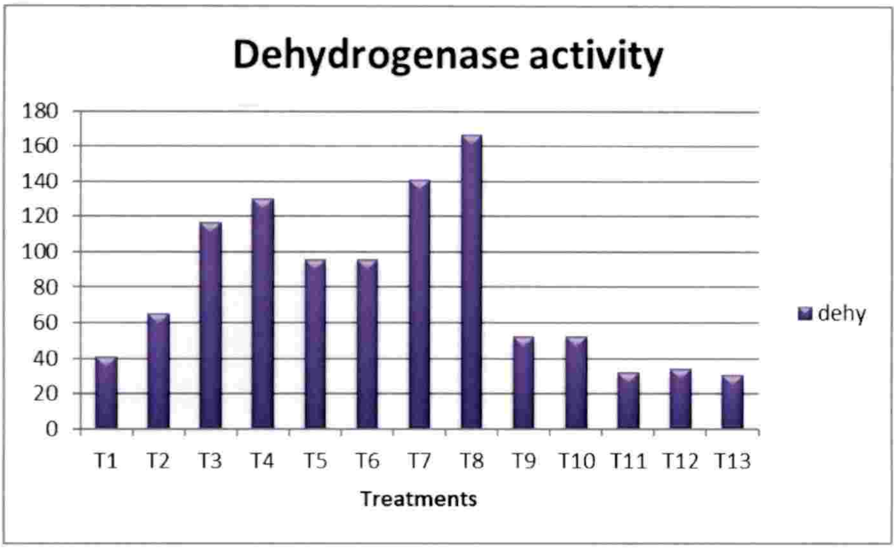


Fig. 23 Effect of different types of on-farm liquid organic manures on soil dehydrogenase activity, µg TPF g^{-1} h^{-1} soil

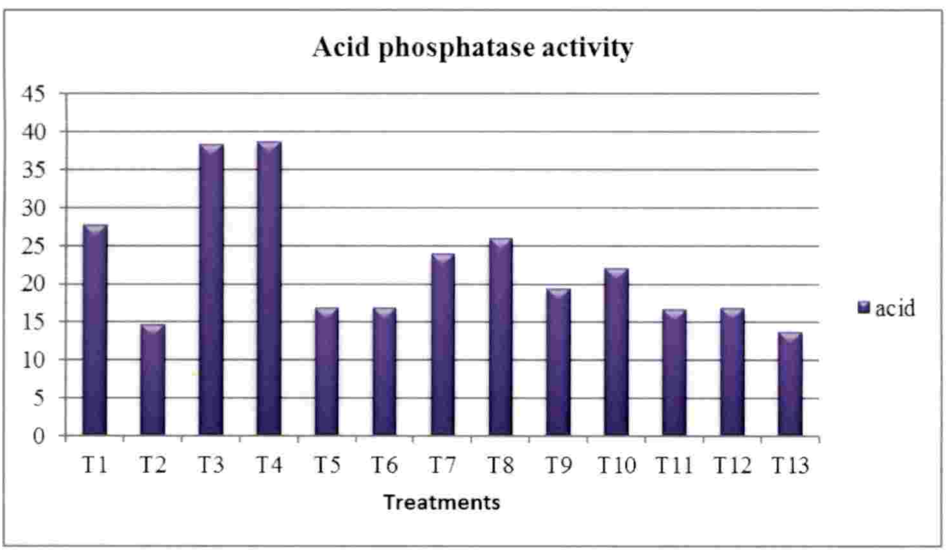


Fig. 24 Effect of on- farm liquid organic manures on soil acid phosphatase activity, µg of p- nitrophenol g^{-1} soil h^{-1}

5.3.6.3 Biological properties

Table .37, shows the microbial population of the soil after the harvest of crop and was found varied among treatments.

T_{10} (75 % N as EVC +jeevamrutha 10 % soil application) recorded the highest total bacterial count at soil and was on par with T6. The highest fungal population of mean value was reported by the T10 (75 % N as EVC + jeevamrutha 10 % soil application). Critical appraisal of the data (Table 37) shows that the different treatments have significant effect for the actinomycetes count. The highest mean value for different treatments effect was recorded by the T_4 (75 % N as EVC + fish amino acid 5% soil application). Maximum azotobacter population was recorded in T_4. The treatment T_4 (75 % N as EVC+ fish amino acid 5 % soil application) recorded the maximum azospirillum population which was on par with T_3 and T_6 .The statistical analysis of the data (Table 37) on the count of P solubilizers inferred that the different treatments had significant influence on the population. Regarding the analysis of the sample highest mean value was recorded by T_4. It was observed from the data (Table 37) that the different treatments influenced the K solubilzers population in the soil significantly. The highest mean value for different treatments effect was noticed by the sample from T_{12} (75 % N as EVC+ vermiwash 10 % soil application). The highest population of pseudomonas sp. was registered in 75 per cent N as enriched vermicompost with vermiwash10 per cent soil application (T_{12}). Vermiwash play a vital role in enhancing the microbial population of the soil (Kale *et al.*, 1992 and Somasundaram and Sankaran, 2004). The highest microbial population in the case of all organic treatments could be attributed to favourable effects of manures by providing carbon as a source of energy for microbes and also protection to enzyme fraction due to increase in the humus content (Martens *et al.*, 1992).

Microbial biomass and enzyme activities are closely related to soil organic matter content. Added organic amendments stimulated the biological activity preferably due to synergism of soil organic material and microorganism (Gaind and Nain, 2010).

5.3.7 Effect of on-farm liquid organic manures on nutrient uptake

Uptake of major nutrients affected by different treatments were shown in Fig 25. In case of N, P and K, the highest mean values were recorded by treatment T_5 (75 % N as EVC + panchagavya 3 % foliar spray). From the results it can be inferred that application of enriched vermicompost with 10 per cent azolla and along with liquid manures can increase the uptake of NPK by the crop. The foliar spray of liquid formulations facilitated instant uptake of nutrients which might have led to the effective conversion of vegetative phase to reproductive phase which the growth and yield.The increased N uptake may be due to the fact that vast portion of non oxidisable N in organics could be available to plants through microbial activity and also through biological N fixation.The increased mineralization of soil P and added P as a result of production of organic acid during decomposition is one reason for high P uptake (Niranjana,1998).

However , the increase in uptake of nutrients in foliar spray of panchagavya was due to increased availability of nutrients due to build up of soil microflora resulting in increased enzymatic activity and biological efficiency of crop plants creating greater source and sink in the plant system (Boomathi *et al.*, 2005) that might have helped in absorption of the nutrients. It might also be due to increased leaf area index in panchagavya treatments indicating increased photosynthetic efficiency of plants leading to increased uptake of nutrients (Chandrakala,2008).

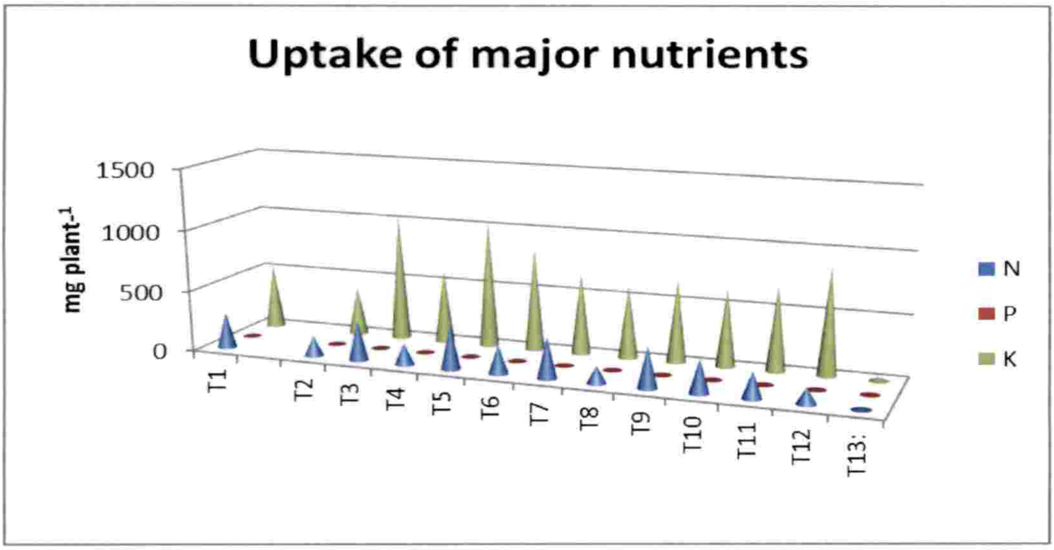


Fig.25 Effect of different on-farm liquid organic manures on plant uptake of major nutrients, mg plant^{-1}

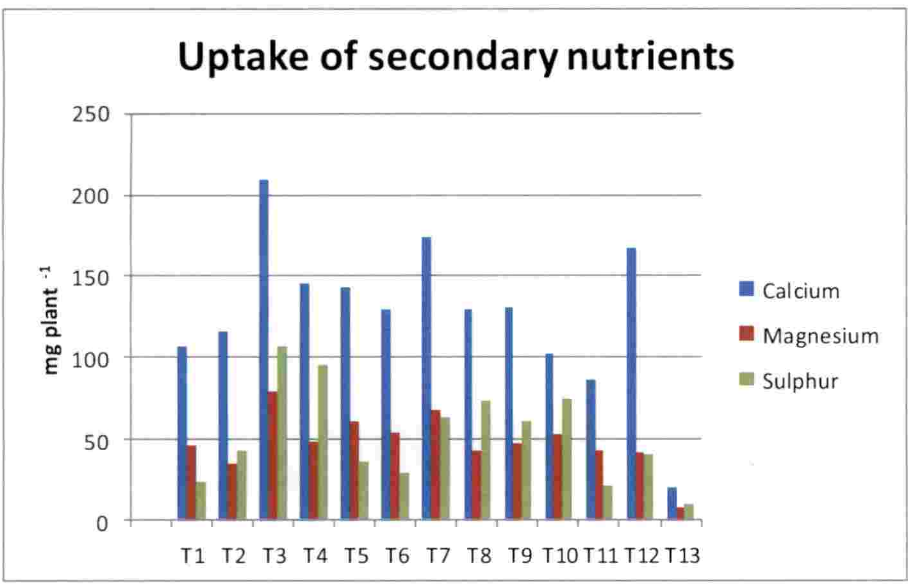


Fig. 26 Effect of different on-farm liquid organic manures on plant uptake of secondary nutrients, mg plant^{-1}

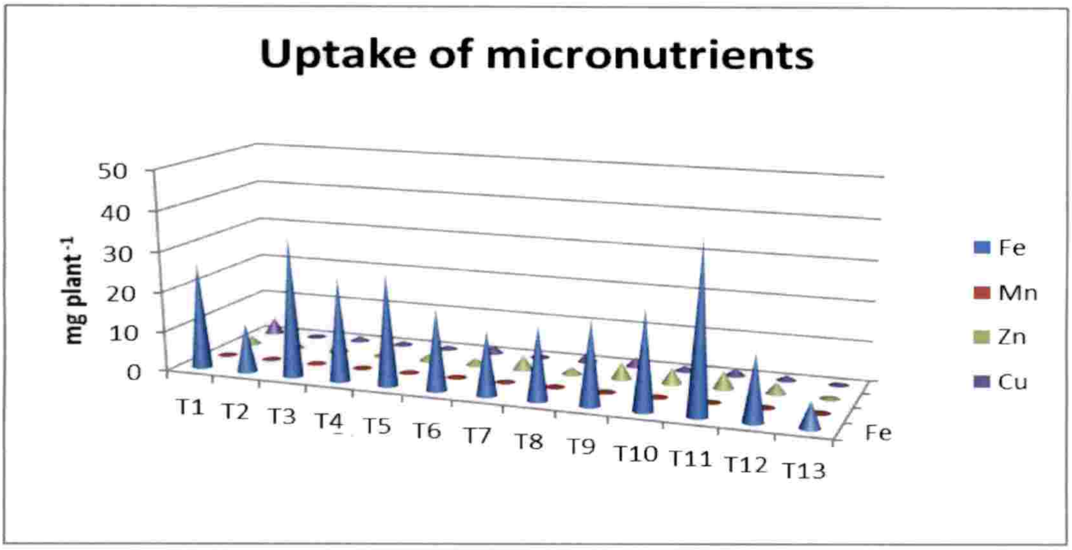


Fig. 27 Effect of different on-farm liquid organic manures on plant uptake of micronutrients, mg plant^{-1}

Higher uptake of nutrients would have increased the number of leaves and LAI. Similar results of enhancement in growth characters of bhindi due to increased nutrient levels have been reported by Karthikeyan (2010).

The importance of liquid manures on secondary nutrients uptake was clear from the Fig.26. For all the secondary nutrients, treatment T_3 (75 % N as EVC + fish amino acid 5 % foliar application) was found to be the best. The superiority of FAA for supplying calcium, magnesium and sulphur to the crop was due to the presence of high content of Ca, Mg and S in FAA as indicated from characterization study.

Regarding micronutrient uptake (Fig.27), the highest value of Fe and Zn uptake was noticed in T_{11}.(75 % N as EVC + vermiwash 10 % foliar spray). The highest value of Cu was noticed in T_1 (KAU PoP). The highest value of Mn was noticed in T_3 (75 % N as EVC + FAA 5 % foliar spray). The lowest plant uptake with respect to all micronutrients was recorded by T_{13} (Absolute control).

Soil organic matter have the ability to hold micronutrients in stable combination. The organic ligands can keep the micronutrients cations as soluble chelates and are plant available. Microorganisms assimilate these metal ions for many microbial transformation reactions and temporarily immobilize the micronutrients in their body which, however are released after the death of microorganism through mineralization process and are made available to plants (Deb and Sakal, 2002).

5.3.8 Economic of cultivation

Table.41, presents the data regarding economics of cultivation of bhindi. It was observed that cost benefit ratio was found to be the highest for treatment T_5, 75 % N as EVC + panchagavya 3 % foliar application (2.83) followed by T_7, 75 % N as EVC + cow urine 10 % foliar spray (2.09). The lowest B: C ratio (0.37) was recorded by T_{13}. The highest B: C ratio recored by T_5 might be due to highest LAI which inturn enhanced the photosynthetic efficiency and resulted in highest gross yield. Since the organic produce fetch premium price in the market compared to non organics produce and the use of on-farm organic manures reduced the cost of cultivation, which might have resulted in high B: C ratio. These results are in accordance with those of Madhuri *et al.* (2006). Shwetha (2008) reported that the net return in soybean was significantly higher with combined application of organic and fermented liquid manures over non fermented liquid manures. Similarly Yadav and Christopher (2006) reported significantly higher net returns with panchagavya spray over no panchagavya spray. However benefit cost ratio was also higher with combined application of RDF and panchagavya (2.28) over RDF in rice.

In a study conducted by Somasundaram *et al.* (2003), it was found that the increase or decrease in the levels of panchagavya from 3 per cent level decreased the yield at higher concentrations, scorching was observed resulting in reduced photosynthetic activity and yield. They also observed that increased number of seeds pod^{-1}, higher grain weight and grain yield by the application of panchagavya in green gram. Additional revenue and higher B: C was also reported. The economics of organic farming cannot be worked out merely based on yield. It encompasses the entire process and effects of organic farming in terms of benefits to human society.

Summary

5. SUMMARY

The study entitled "Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrtion" was undertaken during August 2015 to March 2017 at College of Agriculture, Vellayani with the objective of characterization of on-farm liquid organic manures *viz.*, cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these manures on soil health and crop nutrition using bhindi as test crop.

The investigation comprised of three parts. The first part of the experiment was the preparation and characterization of different on-farm liquid organic manures. Laboratory incubation study was carried out as second part of the experiment by utilizing the above mentioned on- farm liquid organic manures to monitor nutrient release pattern. The third part of the experiment was pot culture experiment to evaluate the efficacy of soil and foliar applications of these liquid manures on soil health and crop nutrition using bhindi (Anjitha) as test crop. A summary of the salient results of the study are presented.

PART I

Characterization of on-farm liquid organic manures

- The colour and odour of the cow urine were pale yellow and ammonical smell respectively. Colour of jeevamrutha was moderate green with mild foul odour. Panchagavya had a light brown colour and fermented odour. FAA was dark brown in colour and odourless. The colour and odour of the vermiwash were honey brown and odourless.

- Among the liquid organic manures studied, FAA and panchagavya showed acidic pH and other three liquid organic manures *viz.*, cow urine, jeevamrutha and vermiwash recorded near neutral pH. The pH was the highest for cow urine (7.40) followed by vermiwash (7.30), jeevamrutha (7.00), panchagavya (5.70) and FAA (4.26).

- Panchagavya registered the highest EC (10.20 dSm^{-1}) followed by vermiwash (9.65 dSm^{-1}), cow urine (7.80 dSm^{-1}), FAA (5.63 dSm^{-1}) and jeevamrutha (1.53 dSm^{-1}).
- FAA recorded the highest organic carbon content of 39.96 per cent followed by panchagavya (0.84%), cow urine (0.46%), vermiwash (0.23%) and jeevamrutha (0.09%).
- The highest nitrogen content (0.45%) was found in panchgavya followed by FAA (0.13 %).
- The highest P content (0.41 %) was recorded in FAA.
- Maximum K content (0.17%) was recorded in cow urine followed by panchagavya, vermiwash and jeevamrutha.
- S content of all the liquid organic manures were higher compared to Ca and Mg content. The highest contents of Ca, Mg and S were recorded by FAA.
- The Fe content (39.92mg L^{-1}) was highest in jeevamrutha and lowest in FAA.
- Cow urine was found to be rich in Mn (0.400 mg L^{-1}) and Cu (21.21 mg L^{-1}).
- The maximum zinc content (2.00 mg L^{-1}), IAA (6.00μg ml^{-1}) and GA (35.00 μg ml^{-1}) were found in FAA.
- Panchagavya was rich in cytokinin (2.82 mg L^{-1}) whereas ascorbic acid content (37.50 mg $100g^{-1}$) was highest in vermiwash.

- FAA was registered the highest urease activity and acid and alkaline phosphatase activity whereas dehydrogenase activity was found to be maximum in cow urine followed by FAA.

- The maximum population of bacteria was observed in vermiwash and fungal population was present in all liquid organic manures except cow urine. *E.coli*, P solubilizers, azospirillum and *pseudomonas sp*. were not detected in any of the liquid organic manures.

PART II

Laboratory Incubation Study

- There was an increasing trend in pH and EC of incubated soil in all treatments compared to their initial values.

- In case of release of available N, P during incubation, the increased trend was observed upto 30^{th} day of incubation . Phosphorous release from soil treated with FAA 10 per cent was found to be higher due to the increased acid and alkaline phosphatase activity.

- Available K_2O increased progressively upto 15^{th} day of incubation. Maximum release of potassium was recorded from soil treated with cow urine 10 per cent.

- Release of Ca was high upto 30^{th} day of inubation. Higher release of Ca was noted in soil treated with FAA 10 per cent or cow urine 10 per cent.

- Exchangeable magnesium showed increasing trend throughout the incubation period. Soil treated with cow urine 10 per cent indicated a better release of magnesium.

- Gradual increase in release of available Fe content upto 45th day of incubation. Maximum Zn contents were observed in all treatments during intial period of incubation.

- In the case of Mn and Cu, maximum release was obtained at 7th day and 30th day of incubation respectively.

PART III

Pot Culture Experiment

Pot culture experiment was laid out in CRD with 13 treatments and 3 replications. Enriched vermicompost was (enriched with azolla 10%) used for supplying 75% N and diluted liquid organic manures *viz.,* cow urine, panchagavya, vermiwash, fish amino acid and jeevamrutha were given as foliar or soil applications at 10 days intervals. Salient findings of the experiment are listed below.

- Tallest plant was found in T_5 (75 % N as EVC + panchagavya 3 % foliar spray).

- Maximum number of branches per plant was recorded by the treatment T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and was on par with T_7, T_{11} and T_8. Application of 75 per cent N as enriched vermicompost and panchagavya 3 per cent as foliar spray produced more vegetative growth, thereby enhanced more number of primary branches.

- LAI and dry matter production were found to be the maximum in T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and was on par with T_8, T_3, T_6, T_{12}, T_9, T_{11} and T_7.

- Physiological characters of crop *viz*., chlorophyll a, chlorophyll b and total chlorophyll content were found to be maximum for the treatment T_{10} (75 % N as EVC + jeevamrutha 10 % soil application) and significantly superior to all other treatments.

- For yield characters like days to first flowering, number of flowers formed, number of fruits per plant and total fruit yield, T_5 (75 % N as EVC + panchagavya 3% foliar spray) recorded the highest value.
- Average fruit weight was highest for T_1 (KAU PoP)
- Highest crude protein was recorded by T_4 (75 % N as EVC + fish amino acid 5 % soil application) and was on par with T_7.
- The lowest crude fibre content was found in treatment T_7 (75 % N as EVC + cow urine 10 % foliar spray).
- The ascorbic acid content was found to be the highest in T_9 (75 % N as EVC + jeevmrutha 10 % foliar spray) and was on par with T_{10} (75 % N as EVC + jeevamrutha 10 % soil application).
- The highest mean value (6.44) of pH was recorded by treatment T_2 (Organic Adhoc PoP).
- The highest EC value was recorded by the treatment T_4 (75 % N as EVC + fish amino acid 5 % soil application) with 0.30 dSm^{-1}
- The highest OC value (15.6 g kg^{-1}) was recorded for the soil treated with 75 per cent N as EVC + fish amino acid 5 per cent soil application.
- T_8 (75 % N as EVC +cow urine 10 % soil application) recorded the highest mean value of labile carbon content after harvest of crop and which was on par with T_2,T_1 T_6, T_4, T_{10},T_9, T_{12} and T_5.

- The highest value for available N content was recorded by the treatment T_6 (75 % N as EVC + panchagavya 3 % soil application).

- The highest mean value of available P was recorded by treatment T_4 (75 % N as EVC+ fish amino acid 5 % soil application)

- The treatment T_8 (75 %N as EVC + cow urine 10 % soil application) recorded the highest mean value of K content.

- Exchangeable Ca content was maximum in T_4 (75 % N as EVC+ fish amino acid 5 % soil application) and exchangeable magnesium was maximum in T_8 (75 %N as EVC +cow urine 10 % soil application).

- Available S content was maximum in T_4 (75 % N as EVC+ fish amino acid 5 % soil application).

- The highest Fe content in the soil was observed in T_{10} (75 % N as EVC + Jeevamrutha 10 % soil application). The highest Zn content was registered by T_4. Cu and Mn content in T_8 (75 % N as EVC + cow urine 10 % soil application).

- Maximum dehydrogenase activity was recorded by the T_8 (75 % N as EVC + cow urine 10 % soil application) followed by T_7 (75 % N as EVC + cow urine 10 % foliar spray) .

- Acid and alkaline phosphatase activity and urease activity were found to be maximum in T_4 (75 % N as EVC+ fish amino acid 5 % soil application).

- Maximum azotobacter and actinomyctes count were recorded by T_4 (75 % N as EVC+ fish amino acid 5 % soil application).

- P solubilizers were found to be maximum in T_4 and was par with T_3.

- Total bacteria count was found to be maximum in T_{10}

- K solubilizer population was the highest in T_{12} and was on par with T_{11}, T_8, T7, T6 and T_5.

- The highest population in *Pseudomonas sp* registered in T_{12} which was found to be statically on par with T_{10},T_{11},T_9 ,T_8 T_6 and T_3

- Azospirillum, K solubilizers and *Pseudomonas sp.* were absent in T_{13}.

- Regarding uptake of primary nutrients the highest NPK uptake was observed in T_5 (75 % N as EVC +panchagavya 3 % foliar spray)

- Maximum uptake of secondary nutrients were found to be in T_3 (75 % N as EVC + fish amino acid 5 % foliar spray). This indicated the superiority of fish amino acid in supplying calcium, magnesium and sulphur for crop.

- The highest values of Fe uptake in T_{11}, Mn uptake in T_3, Zn uptake in T_{12} and Cu uptake in T_1 were registered.

CONCLUSION

Physical, chemical, biological and biochemical characters of on-farm liquid organic manures indicated that these manures were potent nutrient source to improve soil health, crop productivity and quality. These can be used as potential alternatives for readily available nutrient sources for organic farming and good agriculture practices.

Among different liquid organic manures studied, fish amino acid recorded the best values for the parameters *viz.,* organic carbon, secondary nutrients, enzyme activities, IAA and GA in the characterization study.These liquid organic manures are rich sources of beneficial micro flora which support and stimulate the plant growth and yield and quality.

Fish amino acid followed by cow urine has given the best result with respect to nutrient release. 75 per cent N as EVC + panchagvya 3 per cent foliar application followed by FAA 5 per cent foliar spray and cow urine 10 per cent foliar spray was superior to all other treatments in promoting yield and quality of bhindi. The recommended dose of inorganics (KAU PoP) can be substituted with combined application of enriched vermicompost (enriched with azolla 10%) to get 75 per cent N and foliar application of 3 per cent panchagavya or foliar spray of 10 per cent cow urine or 5 per cent fish amino acid at 10 days intervals. Soil health was enhanced in all the treatments compared to control.

Organic liquid manures *viz.*, cow urine ,panchagavya, jeevamrutha, fish amino acid and vermiwash supply much needed organic and mineral matter to the soil and play a vital role in promoting growth and providing immunity to plant system. They are easily preparable in the farmers' farm, biodegradable, less expensive, eco-friendly and non-hazardous for human health and environment.

FUTURE LINE OF WORK

1. Response of different vegetables and other crops to different organic liquid manures should be studied at field level.

2. Exploration of other organic sources for use as alternative sources to chemical fertilizers should also be evaluated.

3. Evaluate the commercially available liquid organic manures for organic farming and good agricultural practices.

4. Protocol for quality parameters of organic liquid manures are to be developed.

5. Detailed microbial and enzymatic studies need to be conducted to explain the nutrient mineralization pattern of other organic liquid manures.

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Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition

by

SREYA U PARVATHI

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VELLAYANI, THIRUVANANTHAPURAM-695522

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ABSTRACT

The experiment entitled "Characterization and evaluation of on-farm liquid organic manures on soil health and crop nutrition" was undertaken at College of Agriculture, Vellayani during 2014-2017.The study was envisaged to characterize the on-farm liquid organic manures *viz.,* cow urine, panchagavya, fish amino acid, vermiwash and jeevamrutha, to monitor the nutrient release pattern under laboratory conditions and to evaluate the efficacy of soil and foliar applications of these liquid manures on soil health and crop nutrition using bhindi as test crop.

The study consisted of three parts. The first part comprised the preparation and characterization of above said on-farm liquid organic manures. These manures were prepared as per standard procedures and characterization study was conducted to determine the physical, chemical, biological and biochemical properties.

Physical properties *viz.,* colour and odour of different on-farm liquid organic manures were recorded. Among the liquid organic manures studied, fish amino acid and panchagavya showed acidic pH and other three liquid organic manures *viz.,* cow urine, jeevamrutha and vermiwash recorded neutral pH. Regarding EC, jeevamrutha recorded the lowest value (1.53 dSm^{-1}).The highest OC content (39.96%) was recorded by fish amino acid followed by panchagavya. Among the major nutrients, the highest N content (0.45%) was found in panchgavya followed by fish amino acid. The highest P content was recorded by FAA (0.41%). Maximum K content (0.17%) was recorded in cow urine followed by panchagavya, vermiwash and jeevamrutha. S content of all the liquid organic manures were higher compared to Ca and Mg content. The highest contents of Ca, Mg and S were recorded by fish amino acid. The Fe content (39.92mg L^{-1}) was highest in jeevamrutha and the lowest in fish amino acid. Cow urine was found to be rich in Mn (0.400 mg L^{-1}) and Cu (21.21 mg L^{-1}).The maximum zinc content

(2.00 mg L^{-1}), IAA (6.00µg ml^{-1}) and GA (35.00µg ml^{-1}) were found in fish amino acid. Panchagavya was rich in cytokinin (2.82 mg L^{-1}) whereas, ascorbic acid content (37.50 mg $100g^{-1}$) was the highest in vermiwash. Fish amino acid was registered the highest enzyme activities, except for dehydrogenase activity which was found to be maximum in cow urine (371.27 µg of TPF g^{-1}soil 24 h^{-1}) followed by fish amino acid (336.98 µg of TPF g^{-1}soil 24 h^{-1}). The maximum population of bacteria was observed in vermiwash and fungal population was presented in all liquid organic manures except cow urine. The highest azotobacter population was observed in fish amino acid. K solubilizers were found to be the highest in vermiwash whereas *E.coli*, P solubilizers, *azospirillum* and *pseudomonas sp.* were not detected in any of the above liquid organic manures.

The second part of the experiment was laboratory incubation study to monitor the nutrient release pattern from soil treated with the on-farm liquid organic manures for a period of two months. The study consisted of 6 treatments which included soil alone and soil treated with 10 per cent dilution of all the liquid organic manures separately and all the treatments were maintained at 60 per cent moisture level. In general increased pH and EC values were observed in all the treatments received diluted liquid organic manures compared to control. Regarding the release of major, secondary and micronutrients, there was significant difference in available nutrient contents between treatments during the periods of incubation. Regarding the release of N and P during incubation study, soil along with FAA 10 per cent recorded the highest release pattern whereas soil along with cow urine 10 per cent recorded the highest K release throughout the incubation period. There was increased release of Ca in the treatments received liquid organic manures. The highest Mg release throughout the incubation period was registered by the treatment received cow urine 10 per cent. Available iron content was higher in T_5 (soil 5 kg + jeevamrutha 10 %) compared to other treatments. A significant difference was found among treatments with respect to available Zn content. Initially (0^{th} day of incubation), all the treatments were recorded higher values compared to values recorded on 7^{th} ,15^{th} ,30^{th} , 45^{th} and

60^{th} days of incubation. There was increasing trends in the Cu content of soil from 0^{th} day of incubation to 60^{th} day of incubation except in the case of T_3 (soil 5 kg + FAA 10 %). Treatment T_1 (soil without treatments) recorded the lowest values for all nutrients throughout the incubation period.

The third part of the experiment was to evaluate the efficacy of soil and foliar applications of on-farm liquid organic manures in a pot culture experiment using bhindi as test crop. The treatments included were 75 per cent N as enriched vermicompost along with diluted liquid organic manures separately as soil and foliar applications. Plant height, LAI, dry matter production, number of flowers, number of fruits per plant and total fruit yield were found to be the highest in T_5 (75 % N as EVC + panchagavya 3 % foliar application). Chlorophyll a, b and total chlorophyll content were the highest in T_{10} (75 % N as EVC + jeevamrutha 10 % soil application). T_1 (KAU PoP) recorded the highest average fruit weight. T_4 (75 % N as EVC + FAA 5 % soil application). registered the highest crude protein content while crude fibre content was lowest in T_7 (75 % N as EVC + cow urine 10 % foliar spray). Ascorbic acid content was the highest in T_5 (75 % N as EVC + panchagavya 3 % foliar spray) and was on par with T_7, T_2,T_9 and T_{11}.

The results of the post harvest analysis of soil revealed that pH, EC, organic carbon and labile carbon contents varied significantly among the treatments. The highest organic carbon content of soil was recorded by T_4 (75 % N as EVC + FAA 3 % soil application) and T_{12} (75% N as EVC + vermiwash 10 % soil application). The maximum labile carbon was recorded by T_8. T_5 (75 % N as EVC + panchagavya 3 % foliar spray) was rich in available N. Soil enzyme activities were influenced by the application of liquid organic manures. The treatment T_5 registered the highest plant uptake of major nutrients. The treatment T_3 registered the highest plant uptake of secondary nutrients. The highest value of Fe and Zn uptake was noticed in T_{11}.(75 % N as EVC + vermiwash 10 % foliar spray). The highest value of Cu uptake was noticed in T_1 (KAU PoP). The highest value of Mn uptake was noticed in T_3 (75 % N as EVC + FAA 5 % foliar spray) . The lowest plant uptake of all nutrients were recorded by T_{13} (Absolute control). Economics of cultivation of bhindi indicated that cost benefit ratio was found higher for treatment T_5, 75 per cent N as EVC + panchagavya 3 per cent foliar application (2.83) followed by T_7, 75 per cent N as EVC + cow urine 10 per cent foliar spray (2.09).

From the above study, it was concluded that the recommended dose of inorganics (KAU PoP) can be substituted with combined application of enriched vermicompost (enriched with azolla 10 %) to get 75 per cent N and foliar application of 3 per cent panchagavya or soil application of 10 per cent cow urine or 5 per cent fish amino acid at 10 days intervals. Soil health, in terms of physical, chemical, biological and biochemical properties of soil was more enhanced in the treatments received soil application of liquid organic manures. Liquid organic manures *viz.*, cow urine, panchagavya, jeevamrutha, fish amino acid and vermiwash were easily preparable in the farmers' farm, biodegradable, less expensive, eco-friendly and non-hazardous for human health and environment. From the study it was found that above liquid organic manures were very good organic sources for organic farming and sustainable agriculture.

Appendices

Appendix I

Composition of media for microbial enumeration

1. Enumeration of Bacteria

Media : Nutrient Agar

Composition :

1. Peptone - 5 g
2. NaCl - 5 g
3. Beef Extract - 3 g
4. Agar - 20 g
5. pH - 7.0
6. Distilled water - 1000 ml

2. Enumeration of Fungi

Media : Rose Bengal Agar

Composition :

1. Glucose - 3.0 g
2. $MgSO_4$ - 0.2 g
3. K_2HPO_4 - 0.9 g
4. Rose Bengal - 0.5 g
5. Streptomycin - 0.25 g
6. Agar - 20 g
7. Distilled water - 1000 ml

3. Enumeration of Actinomycetes

Media : Kenknight's Agar

Composition :

1. Dextrose - 1.0 g
2. KH_2PO_4 - 0.1 g
3. $NaNO_3$ - 0.1 g
4. KCl - 0.1 g
5. $MgSO_4$ - 0.1 g
6. Agar - 15 g
7. Distilled water - 1000 ml

4. Enumeration of K solubilizers

Media : Aleksandrow Agar

Composition

1) $MgSO_4$ - 0.50g
2) $CaCO_3$ - 0.10g
3) $KAlSi_3O_8$ - 2.00g
4) Glucose - 5.00g
5) $FeCl_2$ - 0.005g
6) CaH_2PO_4 - 2.00g
7) Agar - 20.00 g
8) Distilled water – 1000 ml

5. **Enumeration of Nitrogen Fixers**

Media : LGI Agar

Composition :

1. K_2HPO_4 - 0.2 g
2. KH_2PO_4 - 0.2 g
3. $MgSO_4$ - 0.6 g
4. $CaCl_2$ - 0.2 g
5. Na_2MoO_4 - 0.02 g
6. $FeCl_2$ - 0.002 g
7. Agar - 15 g
8. Distilled water : 1000 ml

6. **Enumeration of Phosphorus Solubilizers**

Media : Phosphate Solublizers Differential Agar

Composition :

1. Yeast extract - 0.5 g
2. Dextrose - 10 g
3. $Ca_3(PO_4)_2$ - 5.0 g
4. $(NH_4)_2SO_4$ - 0.5 g
5. KCl - 0.2 g
6. $MgSO_4$ - 0.1 g
7. $MnSO_4$ - 0.0001 g
8. $FeSO_4$ - 0.0001 g
9. Agar - 15 g
10. Distilled water : 1000 ml

7. Enumeration of *Pseudomonas sp.*

Media : Kings B media

Composition

1) Peptone : 20g
2) K_2HPO_4 : 1.5 g
3) $MgSO_4$: 1.5 g
4) Glycerol : 10 ml
5) Distilled water : 1000ml

8 .Enumeration of EMB agar

Media : Eosin Methylene Blue Agar

Composition

1) Peptone - 10 .00g
2) K_2HPO_4 - 2.00 g
3) Lactose - 5.00g
4) Sucrose - 5.00 g
5) Eosin – Y - 0.40 g
6) Methylene blue - 0.065 g
7) Agar - 13.50 g
8) Distilled water -1000ml

Appendix II

Weather data for the cropping period

(26th April to 26th August 2016)- weekly average

Standard week	Temperature(^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
17	35.2	26.9	86.10	0.0
18	35.7	26.0	86.30	21.3
19	34.8	24.8	86.65	12.0
20	32.5	24.1	86.59	55.0
21	33.1	24.7	86.38	24.3
22	32.7	24.8	86.71	0.0
23	31.5	25.9	87.09	48.0
24	31.1	23.1	86.75	17.0
25	31.5	24.4	86.22	6.50
26	31.3	24.2	85.80	11.0
27	32.4	25.0	85.47	7.0
28	31.3	24.3	84.45	10.0
29	32.0	24.9	83.51	0.0
30	31.2	24.9	83.15	6.0
31	32.3	25.2	82.00	1.0

Appendix III

Varietal characters of bhindi var. Anjitha

Name of variety	Anjitha
Institution responsible for developing the variety	Department of Plant Breeding and Genetics, College of Agriculture, Vellayani
Breeding methodology adopted with parentage	Interspecific hybridization between *Abelmoschus esculentus* var .Kiran x *A.manihot* followed by mutation breeding
Season	Summer
Situation	Summer rice fallows
Duration	94.3 days
Productivity	14.6 t/ha
Special features	Long, smooth, green fruits with prominent ridges
Reaction to stresses	Resistant to yellow vein mosaic and tolerant to shoot and fruit borer
Released by	23rd State Seed Sub Committee on 30-10-2006
Habit	Annual ,Erect
Stature	135 cm
Branching habit	1.3 branches
Leaf shape	Lobed
Leaf size	Normal
Flowering	Moderate
Days to first flowering	39
Flower colour	Bright yellow
Flower size	Big
Days to first harvest	45
Immature fruit colour	Light green
Mature fruit colour	Green
Fruit number per plant	16.6
Fruit length	19.3cm
Fruit weight	25-30 gm
Fruit size	Long
Fruiting period – first to last picking	50 days