CHARACTERIZATION AND EVALUATION OF HERBAL AND NON-HERBAL *KUNAPAJALA* ON SOIL HEALTH AND CROP NUTRITION.

by

KAVYA S R

(2017-11-014)

THESIS

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VELLAYANI, THIRUVANANTHAPURAM - 695 522

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<u>**DECLARATION**</u>

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

Vellayani

Date: 2/8/19

Kavya S R

(2017-11-014)

CERTIFICATE

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Vellayani
Date: 2/8/2019

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

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Kavya S R** (2017-11-014), a candidate for the degree of **Master of Science in Agriculture** with major in **Soil Science and Agricultural Chemistry**, agree that the thesis entitled **"CHARACTERIZATION AND EVALUATION OF HERBAL AND NON-HERBAL *KUNAPAJALA* ON SOIL HEALTH AND CROP NUTRITION"** may be submitted by **Ms. Kavya S R** (2017-11-014), in partial fulfilment of the requirement for the degree.

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

Dr. B. Aparna
(Member, Advisory Committee)
Assistant Professor (Sr. Scale)
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani

Dr. Naveen Leno
(Member, Advisory Committee)
Assistant Professor
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani

Dr. Meenakumari K. S.
(Member, Advisory Committee)
Professor and Head
Department of Agricultural
Microbiology
College of Agriculture, Vellayani

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST of APPENDICES

LIST OF ABBREVIATIONS

@	-At the rate of
^{0}C	-Degree Celecius
AAHF	-Asian Agri History Foundation
AAS	-Atomic Absorption and Spectrum
ANOVA	-Analysis of Variance
Avg	-Average
B:C	-Benefit : Cost ratio
CD	-Critical Difference
cfu	-Colony forming units
cm	-Centimeter
CRD	-Completely Randomised Block Design
DAS	-Days After Sowing
DMSO	-Diemethyl sulphoxide
dS m^{-1}	-deci Siemens per meter
DTPA	-Diethylene Triamine Penta Acetic acid
EC	-Electrical Conductivity
EDTA	-Ethylene- Diamine-Tetra- Acetic acid
EBDLM	-Enriched Biodigested Liquid Manure
et al.	-And others
EVC	-Enriched vermicompost
FAA	-Fish Amino Acid
Fig.	-Figure
FYM	-Farm Yard Manure
g	-gram
GA	-Gibberellic acid
h	- hour
ha	-hectare
HAU	-Haryana Agricultural University

IAA	-Indole Acetic Acid
i.e.,	-That is
KAU	-Kerala Agricultural University
K_2O	-Potassium oxide
kg	-kilogram
kg ha^{-1}	-kilogram per hectare
L	-Litre
L ha^{-1}	-Litre per hectare
LAI	-Leaf Area Index
LC–MS	-Liquid Chromatography Mass Spectrometry
μg	- Micro gram
Max	-Maximum
MOP	-Muriate of potash
mg kg^{-1}	-milligram per kilogram
ml	-Milli litre
mm	-Milli meter
MSL	-Mean Sea Level
MT	-Megatonne
nm	-Nano meter
NS	-Non significant
P_2O_5	-Phosphorus pentoxide
PGPR	-Plant Growth Promoting Rhizobacteria
POP	-Package of Practices
ppm	-parts per million
PSB	-Phosphorus Solubilizing Bacteria
RBD	-Randomized Block Design
RDF	-Recommended Dose of Fertilizers
Rf	-Rainfall
RH	-Relative Humidity

rpm	-rotation per minute
sp	-Species
SE	-Standard Error
t ha^{-1}	-tonnes per hectare
TPF	-Triphenyl Formazan
TTC	-Triphenyl Tetrazolium Chloride
Var.	-Variety
Viz.,	-Namely
v/v	-Volume of solute/ volume of solution
UV	-Ultra violet

Introduction

1. INTRODUCTION

Agriculture is the past, agriculture is the present, and agriculture is the future. History of the world shows that evolutionary processes are based on analysis and have less side effects, while revolutionary processes are based on synthesis and have more side effects. The best example was the evolution in traditional agriculture and green revolution in agriculture. Green revolution promoted the production and consumption of hybrid seeds, chemical fertilizers and pesticides. Intensive use of chemicals, over exploitation of natural resources, unscientific cultivation practices and deforestation are exhausting soil nutrients thus cause severe environmental problems.

Continuous consumption of chemical fertilizers has hardened the soil, reduced fertility, polluted air and water, and released harmful gases, thus bringing threat to soil, plant and ultimately human health. There are evidences justifying the above facts. According to Devasanapathy *et al.* (2008), soil organic carbon content in India has confronted with a drastic reduction from 1.2% to 0.6% in 2000 and is declining further. Natural soil microorganisms like *Rhizobium* and *Phosphorus Solubilizing Bacteria* (PSB) have been adversely affected and are destroyed by the unscientific and indiscriminate use of agrochemicals resulting in depletion of soil as well as crop productivity (Dademal and Dongale 2004). In order to pertain the ecological diversity for future generations and to maintain a balance, the human race should be more responsible0 to take up ecofriendly measures of agriculture. This increasing responsibility demands our nation to propose, promote and perpetuate organic farming. Thus, organic farming will pave the way for sustainable production.

Organic farming is an effort to adjust the exponential trends of our population without compromising on the integrity of the environment. This holistic production management system has gained wide recognition by providing safe food and balancing the integrity of the agro ecosystem. Use of organic manures can satisfy the food and nutrition needs of the society. Long back itself Indians had remarkable awareness and knowledge of the importance of organic manures. We are on the verge of adopting the essential principles and practices of our traditional way of farming.

We, the Indians have medical science for plants, called *Vrikshayurveda*, an ancient literature, where the diverse plant states are viewed through the prism of Ayurveda. '*Vrikshayurveda*', by Surapala, a 1000 years old science of plant life, deals with healthy growth of plants and their productivity. The wide spectrum of this book also emphasizes pest and disease management of plants. This Sanskrit literature was translated and published in English by Asian Agri History Foundation (AAHF), after which farming based on this literature got popularized known as *Vrikshayurveda* farming (Nene, 2018). The text provides knowledge of plant disorders, organic farming, organic manures, liquid formulations, their preparation, application and even the effect of each formulation. According to *Vrikshayurveda*, plant disorders are similar to Vata, Pitta and Kapha. This also emphasised on gardening, raising and managing herbs, flowers, fruits and vegetables by adopting the practices such as soil drenching, foliar spraying and seed treatment which are widely practiced now a days. The most remarkable innovation depicted was the development of fermented organic liquid manures from organic wastes.

Organic liquid manures are aqueous products prepared from the plant or animal derivatives that can serve as nutrient sources and bio pesticides. They are able to add nutrient elements for rapid availability to boost the plants as chemical fertilizers do. It can be used as a suitable substitute to manure, which cannot be spread uniformly even in liquid form, while organic liquid manure can be applied so. Organic liquid fertilization is considered as a viable means for enhancing crop growth and production both in conventional and modern farming system. The liquid manures can be applied as foliar as well as in soil. They play a key role in promoting growth, providing immunity to plant system and protect the crop from harmful soil-borne and seed borne pathogens. The foliar application of organic liquid manures has the inherent capacity to supply many essential nutrients rapidly than root application for a balanced nutrition of the crop. The plant can absorb nutrients about

20 times faster through the leaves (Pathak and Ram, 2013). They are helpful to overcome temporary nutrient shortage. Bio degradable, less expensive, and eco-friendly liquid organic manures are easily preparable and safe to environment. Cow urine, Panchagavya, *Kunapajala*, Biogas slurry, Fish Amino Acid, Egg Amino Acid, Compost tea, Vermiwash, Jeevamrutha are the widely used liquid organic manures.

The liquid bio fertilizer, *kunapambu* or *Kunapajala* (*kunapa*= corps, *jala*=water), was appropriately named because non-herbal *Kunapajala* involved fermentation of the animal remains, such as flesh, marrow, etc. and was used since ancient times in India. The complex molecules like proteins, fats, carbohydrates get broken down into simpler molecules during fermentation, thus becoming readily available to plants. Herbal *Kunapajala* is commonly available and widely used by the farmers in organic farming.

Kunapajala can be applied to any crop at any growth stage. The threat of passing on dormant pathogens to fields with plant-based compost is averted by the way of *Kunapajala* due to the fact that, the ingredients are cooked and fermented. Usage of *Kunapajala* conserves natural count and enhanced the microbial population in soil. *Kunapajala* also avoids the nitrogen loss through volatilization, since, during decomposition, it liberates organic acid, which mix to form ammonium salts.

It has been claimed that *Kunapajala* application enhances the growth and yield of crops like chilli, cowpea (Sarkar *et a.*,2013); tomato (Deshmukh *et al*, 2012a); and rice (Mishra ,2007).

Nene, (2006) reported that there was no fixed proportion for the ingredients of *Kunapajala* and further research is required to standardize the procedure. Few works have been carried out on application of *Kunapajala*, but characterization has not been studied till date. So, the present investigation was to fulfill this shortfall.

Vegetables are important part of healthy eating and provide a source of many vitamins and minerals. The nutrients in vegetables are vital for health and maintenance of human body. Eating a diet rich in vegetables may reduce risk for stroke, cancer, heart diseases and diabetes. Among the different vegetables cultivated in Kerala, bhindi *(Abelmoschus esculentus* L. Moench.) gained its own place because of its nutritional value and benefits. Bhindi is rich in vitamin A, B, C, E, and K. It also contains calcium, iron, magnesium, potassium, and zinc. India rank first in bhindi production with 11.6 MT/ha productivity and that of Kerala was 9.74 MT/ha (Horticultural Statistics 2016-17). Varsha Uphar is the most accepted and widely cultivated variety in India. Varsha Uphar is the variety developed by Haryana Agricultural University (HAU), which is resistant to yellow vein mosaic and field tolerant to leaf hopper.

Considering the challenges and importance of vegetable production without compromising environmental safety, we are at the border to adopt organic means of cultivation. Use of liquid organic manures such as *Kunapajala* ensures rapid availability of nutrients and sustainable production.

In the light of above facts, present investigation entitled "Characterization and evaluation of herbal and non- herbal *Kunapajala* on soil health and crop nutrition" was undertaken with the following objectives;

- ❖ Characterization and evaluation of traditional liquid organic manures herbal and non-herbal *Kunapajala*
- ❖ To monitor the nutrient release pattern under laboratory conditions
- ❖ To evaluate their comparative efficacy of foliar and soil application on soil health and crop nutrition using bhindi as a test crop.

Review of Literature

2. REVIEW OF LITERATURE

Organic farming is an age-old agriculture practice of great pertinenance even in this 21st century. Organic farming greatly relies on organic manures and biofertilizers. Organic manures enhance soil fertility and plant growth. Among them application of liquid organic manures is gaining popularity among farmers due to its rapid effect on plant growth. *Kunapajala* is one such fermented liquid organic manure mentioned in *Vrikshayurveda* and is widely used by farmers nowadays to achieve maximum yield, in turn leading to sustainable production. The main objective of the study was to characterize and evaluate the efficacy of *Kunapajala* on soil health and crop nutrition.

Since the information regarding the effect of *Kunapajala* on soil and plant growth is limited, an endeavour has been made here to review the available information on various liquid organic manures presently accessible and is been used by farmers.

2.1 Effect of organic liquid manures on crop growth and yield

2.1.1 Nutrient and microbial characterization of liquid organic manures

Foliar application of mineral nutrients mitigates the nutrient deficiency problems in crops. Application of enriched liquid organic manures from locally available biodegradable materials results in better crop growth and they provide both macro and micro nutrients. 1: 20 ratio is best for preparing liquid organic manures. They are a boon for sustainable crop production (Masih *et al.*, 2009). Liquid organic manures play a vital role in plant growth. Liquid organic manures such as panchagavya, Jeevamrutha, Beejamrutha, and biodigester are rich source of macro, micro nutrients and different microflora. The nutrient status of liquid organic manures varied with the type and quantity of material used and environmental conditions (Sreenivasa *et al.*, 2010).

Cow dung is an important constituent in almost all liquid organic manures. The microflora of cow dung is enhanced by the application of carbon and nitrogen sources like jaggery, milk and gram flour. The presence of cofactors, anti-oxidants and surfactant like biomolecules in organic manures supplemented the adhesion abilities of organic molecules and bacteria onto the plant (Tank *et al.*, 2017).

panchagavya is an effective organic manure, and the beneficial property was contributed by the constituents like milk, curd, cow urine and ghee present in it (Rajesh and Jayakumar, 2013). Amalraj *et al.* (2013) enumerated the microbial count in panchagavya as total bacteria (22×10^9 cfu ml^{-1}), actinomycetes (60×10^4 cfu ml^{-1}), phosphate solubilizers (103×10^6 cfu ml^{-1}), fluorescent pseudomonas (151×10^5 cfu ml^{-1}), and nitrifiers (5.4×10^6 cfu ml^{-1}).

Shelf life and microbial population of fermented liquid organic manures were studied by Rao *et al.* (2015) and the study shows that microbial count of panchagavya progressively increased from 31st day onwards. It is rich in nutrients like N, P, K, Mg, Fe, and organic carbon, which exceeded than other biofertilizers like Jeevamruha, *Kunapajala,* Amritpani, Sanjibani (Anandan *et al.,* 2016). The same results were discussed by Raghavendra *et al.* (2014) and reported that macro, micro nutrients, various amino acids, vitamins, growth regulators like Auxins, Gibberellins and also beneficial microorganisms like Pseudomonas, Azatobacter and Phosphobacteria are abundant in panchagavya thus acting as a growth promoter and immunity booster. Nuclear magnetic resonance spectrum of panchagavya shows that it contains plant growth hormones like IAA, GA and it is also rich in several amino acids (Ukale *et al.,* 2016).

Sreenivasa *et al.* (2012) analysed the nutrient content in Jeevamrutha and the results indicated the presence of major nutrients like nitrogen (770-1000 ppm), phosphorous (166-175 ppm), potassium (126-194 ppm) and minor nutrients like zinc (1.27-4.29 ppm),copper (0.38-1.58 ppm), iron (29.7-282 ppm) and manganese (1.8-10.7 ppm). Gore and Sreenivasa (2011) counted the microbial population in Jeevamrutha and results shows that it contain fungi (13.40×10^3 cfu ml^{-1}), bacteria (19.70×10^5cfu ml^{-1}), actinomycetes (3.50×10^3 cfu ml^{-1}), nitrogen fixers (4.60×10^2 cfu ml^{-1}) and P solubilisers (4.20×10^2 cfu ml^{-1}).

Devakumar *et al.* (2014) noticed higher colony forming units on the day of preparation of beejamrutha and between 9th and 12th day after preparation of Jeevamrutha and reported that Jeevamrutha is an enriched consortia of native soil microorganisms, which contain higher number of bacteria, N-fixers and fungi. Rameeza (2016) claimed that panchagavya and Jeevamrutha can be kept for 6 months without deteriorating the quality. 20 week old panchagavya recorded maximum nitrogen content and the nutrients and microbial population are increased due to ageing.

Nitrogen-fixing bacteria like *Azotobacter* sp, *Agrobacterium* sp. and *Rhizobium* sp. and some phosphate solubilizing bacteria were present in vermiwash (Zambare *et al.*, 2008). The chemical composition of vermiwash varied with the substrates from which it is produced. Vermiwash obtained from coconut leaf is rich in macro and micronutrients. Higher content of total sugar, reducing sugar, proteins, free amino acids, and plant growth hormones, are responsible for the effectiveness of vermiwash as a growth promoter (Gopal *et al.*, 2010). Vermiwash prepared from different biowaste present in the tea garden was rich in *Azospirillum*, *Azotobacter*, PSB, and actinomycetes (Phukan and Savapondit, 2011).

Sreenivasa *et al.* (2009) noted that beejamrutha was an effective organic product rich in beneficial microbes such as total bacteria, fungi, actinomycetes, free-living N_2-fixers and phosphate solubilising organisms (15.4 $\times 10^5$, 10.5 $\times$ 10^3, 6.8 $\times 10^3$, 3.1 $\times 10^2$ and 2.7 $\times 10^2$ cfu ml^{-1} respectively). Kumar *et al.* (2015) suggested that biogas slurry can replace synthetic fertilizers. Biogas slurry is rich in macro and micro nutrients and organic matter than FYM and compost.

According to Ingham (2005), compost tea is nutritionally rich well-balanced organic supplement containing soluble nutrients extracted from the compost and which improved the soil quality and promoted the crop growth. The nutrient content of compost tea is 0.5-0.75% N, 0.25-0.5% P and 0.5-0.75% K. An enhanced fertility is attained from compost tea as it suppliments nutrients, beneficial microbes, and the beneficial metabolites of microbes into the phyllo sphere and rhizosphere. However, at the early stage of decomposition, it may contain pathogens (Diver, 2002). The microbial population of aerated compost tea can be enhanced by the addition of yeast extract and humic acid as the microbial starter (Naidu *et al.*, 2010).

Dhanalakshmi (2017) reported that 6 weeks old egg extract is rich in bacteria and fungal population, similarly the highest microbial count was observed in 10 weeks old fish jaggery extract also.

Parvathy (2017) conducted an experiment to study the efficacy of different on-farm liquid manures such as cow urine, panchagavya, Fish Amino Acid (FAA), vermiwash and Jeevamrutha. These findings suggested that the FAA was the highest in organic carbon, phosphorus, Ca, Mg. S, Zn, IAA, GA, and enzymatic activities.

2.1.2 Effect of liquid organic manures on growth and yield of crops

Organic manures such as Cow urine, panchagavya, Vermiwash, Jeevamrutha, and Compost tea were widely used and was found effective for the sustainable production of crops.

Muthuvel (2002) studied the effect of panchagavya and moringa leaf extract on the growth and yield of Varsha Uphar, and observed an increase in plant height, number of branches, number of fruits and fruit yield.

According to Natarajan (2008), panchagavya was used in different means such as foliar spray, soil application along with irrigation water, seed or seedling treatment. Sumangala and Patil (2009) reported that seed treatment with panchagavya enhances rice seed germination with 90.7 % and vigour index 1036.36. Seeds of *Jatropha curcas* and *Pongamia pinnata* fortification with panchagavya 2% and 5 % respectively, recorded the highest germination % and vigour index (Srimathi *et al.*, 2013).

An experiment conducted by Vemaraju (2014) revealed that seeds treated with panchagavya resulted in 100% germination and the highest vigour index whereas the highest shoot and root length, fresh and dry weight of plants were obtained by the combined treatment with panchagavya and *Pseudomonas*. The germination %, vigour index, number of seeds per pod, seed recovery, seedling length, and seed yield per ha of cowpea were amplified by the application of 5% panchagavya spray. Spraying also induced the highest plant growth parameters like plant height, number of branches, number of effective nodules per plant and a smaller number of days to 50% flowering (Sumalatha, 2015). Ukale *et al.* (2016) observed that seed treatment of tomato seeds with panchagavya and Jeevamrutha enhanced the germination by two folds over control and treatment resulted in the rapid development of shoot, flowers and fruits in tomato plants. A study conducted by Ananda and Sharanappa (2017) pointed out that application of enriched bio digested liquid organic manure at 25 kg N equivalent ha^{-1}+ 3 sprays of panchagavya at 3 per cent produced significantly higher pod yield, kernel yield, number of pods $plant^{-1}$, 100 kernel weight and shelling % of groundnut by providing sufficient amount of major and minor nutrients.

Jandaik and Sarma (2016) found that capsicum seeds dipped in 15% concentration of panchagavya showed 100% germination, but its 5 % concentration resulted in only 70% germination. Similarly, 2.5% panchagavya resulted in 97.5% germination in ridge gourd. It also induces maximum plant growth, root length, shoot length, fruit length, fruit width and fruit weight. (Sornalatha *et al.*, 2018).

Thangavel *et al.* (2003) reported that vermiwash was rich in nutrients and plant growth substances which enhanced the growth and yield in paddy. According to Gopal *et al.* (2010), seed treatment with diluted vermiwash increased the percentage of seed germination and growth of seedlings in cowpea and paddy. Meghvansi *et al.* (2012) conducted a field trial to study the efficacy of vermiwash on okra and Naga chilli. The study noted that a foliar spray of 20% vermiwash was effective for the growth and yield of crops.

Gadewar *et al.* (2014) found that lentil seeds soaked with Brahamastra, a liquid organic preparation made by mixing both plant and animal products, showed the highest percentage of germination and field emergence followed by Beejamrutha, Panchagava and Jeevamrutha. The seedlings applied with vermiwash manifested profuse growth of fine roots. Plumule length, radicle length, seedling dry weight, and seedling vigour were found enhanced by the application of the Brahmastra than others. Fathima and Sekar (2014) explored the growth promoting effects of vermiwash by using mung bean. They opined that maximum germination and seedling growth were achieved by the treatment with a lower concentration of vermiwash compared to gibberellic acid.

Sreenivasa *et al.* (2009) found that the treatment with Beejamrutha improved seed germination, seed vigour and seedling length in soybean by the production of plant growth promoters like IAA and GA by the beneficial microorganisms present in it. The efficiency of Beejamrutha on seed germination was also explained by Palekar (2006). Singh *et al.* (2018) reported that Jeevamrutha enhances the seed germination in *Ocimum basilicum* L. and found that it promotes seed germination under salinity stress due to the presence of growth promoting substances.

Improved root growth, root length density, leaf area index and yield were observed in wheat crops applied with flyash and biogas slurry (Garg *et al.*, 2005). Significant growth in soybean was observed in terms of number of root nodules, effective root nodules and branches producing pods per plant when liquid extract of sugarcane pulp waste and skin was applied (Herawati *et a*l., 2017).

According to Anbukkarasi and Sadasakthi (2011), an increased yield and yield attributes like number of seeds per plant, fruit girth, fruit length and fruit weight of bhindi could be imputed to timely application of green leaf manures and leaf extracts.

Integrated application of poultry manure and extracts of *Tithonia diversifolia, Gliricidia sepium* recorded significantly higher growth performance in *Abelmoschus esculentus* and *Alternanthera sessilis* than the other treatments (Jayasundara *et al.*, 2016).

The favourable effect of cow urine application has been recorded in enhancing the productivity of different crops viz., maize, mustard and rice etc. It can also be used for the control of pests and as a growth promoter for the growing crops (Sairam, 2008). Six foliar sprays of 55% cattle urine solution resulted in the highest fruit weight, volume, number of fruits, fruit yield (kg plant^{-1}) and yield (t ha^{-1}) of mango compared to control (Damodhar and Shinde, 2010). Patil *et al.* (2012) observed that application of cow urine at 10% concentration at flower initiation and 15 days after flowering contributed a higher plant height, number of branches, number of pods per plant, and grain yield in chickpea.

An experiment conducted by Sobhana (2014) at Cashew Research Station in jasmine concluded that vegetative growth and yearly flower production can be achieved by the application of GA, cycocel and 15 times diluted cow's urine. The phenotypic characters of bhindi and methi were enhanced by the application of cow urine. Plant height, shoot length and root length, number of leaves, and leaf length and breadth were increased with increase in concentration as it increases mitotic index (Jandaik *et al.*, 2015). A study conducted by Tamarkar (2016), showed that all vegetative and post-harvest parameters of gladiolus viz., earlier 50 % emergence of corms, increased emergence of plants, plant height, number of leaves, length and width of leaves improved significantly with cow urine at 5 and 10% concentration.

Sangeetha and Thevanathan (2010a) analysed the effect of seaweed based panchagavya. The study shows that soil amended with seaweed based panchagavya at a concentration of 1: 100 (panchagavya: soil v/v) supplemented the linear root and shoot growth of seedlings of crops *like Vigna radiata, Vigna mungo, Arachis hypogea, Cyamopsis tetragonoloba, Lablab purpureus, Cicer arietinum* and the cereal *Oryza sativa* var. Ponni. Increase in number of lateral roots, leaves or leaflets, increased leaf area and nodule formation by Rhizobium was also observed.

Foliar and media application of diluted panchagavya registered the highest growth and flowering parameters of *Cymbidium* orchids. The number of spikes per plant, floret per spike, spike length and rachis length were recorded the highest in the media application of panchagavya at 1: 30 dilution (Naik *et al.*, 2013). A study conducted by Patel *et al.* (2013) pointed out that foliar spray of 3% panchagavya at vegetative and flowering stage resulted in the quantitative, qualitative and sustainable production of cowpea by enhancing the growth and yield parameters.

Application of 3% panchagavya also increased the morphological and yield performance of black gram. It is efficient in restoring the yield level of all crops when the land is converted from inorganic system to organic from the very first year and it induces early harvest in crops (Rajesh and Jayakumar, 2013; Ram, 2017).

Ali *et al.* (2011) claimed that application of panchagavya and Sanjibani recorded the maximum yield contributing characters in green gram, mustard and chilli. panchagavya through flow irrigation system positively influences the growth and biochemical contents in rice var. Ponni (Krishnapriya and Padmadevi, 2011).

Choudhary *et al.* (2014) inferred that integrated application of panchagavya and neem leaf extract accounted for significantly higher number of nodules, root nodule weight, number of pods per plant, pod weight, pod yield, haulm yield, harvest index, 100 kernels weight and shelling % of groundnut.

Vijayakumari *et al.* (2012) found that mixture of panchagavya, humic acid and micro herbal fertilizer enhanced the yield parameters like number of pods per plant and number of seeds per plant in soybean. According to Jayachithra and Abhirami (2016), foliar application of panchagavya at 3% in horse gram resulted in increased plant height, fresh weight and dry weight both at seedling and yielding stage.

Alagesan *et al.* (2009) noticed that phenotypic characters of tomato plants were enhanced by the combined application of panchagavya and egg lime mix.

Growth and yield of French bean were improved by the application of FYM, panchagavya and Jeevamrutha by increasing beneficial microbes, growth promoting substances and nutrient availability (Kumbar *et al.*, 2015).

Foliar application of 5% panchagavya significantly boosted the growth and yield of green gram by improving the plant height (cm), no of leaves per plant, no of pods per plant, 1000 grain weight (g) and yield (Kulkarni *et al.*, 2016).

Choudhary *et al.* (2017) noticed that application of 4% panchagavya at branching and flowering stages recorded the highest seed yield, stover yield and biological yield in black gram.

Field experiments conducted at Kerala Agricultural University by Jasmine *et al.* (2003) found that vermiwash at 50% concentration significantly increased the yield of tomato. Correspondingly Nishana (2005) revealed that soil and foliar application of vermiwash @ 50 ml $plant^{-1}$ provided maximum growth in bhindi. The combined use of vermiwash and vermicompost increased the growth and yield parameters of bhindi (Ansari and Sukhraj, 2010).

Gopal *et al.* (2010) found that application of appropriately diluted vermiwash increased the biomass and yield of bhindi, cowpea, maize and paddy. Vermiwash produced from the several biowastes collected from tea garden contain sufficient amounts of plant nutrients and this induced significant increase in growth and productivity of young and unpruned mature tea (Phukan and Savapondit, 2011). Sundararasu and Jeyasankar (2014) revealed that application of vermiwash significantly enhances the growth and yield parameters of brinjal.

Elumalai *et al.* (2013) conducted an experiment to study the influence of vermiwash on the exomorphological characters of bhindi, and the study showed that foliar application of 15% vermiwash increased the plant height, length and diameter of the internode, number of leaves, leaf surface area, root length, wet and dry weight of the shoot and root as compared to other plant growth regulators. Saranraj and Thiruppathi (2015) noticed that foliar application of 5% vermiwash at tillering and flowering stages had resulted in significantly better plant growth in terms of plant height, number of tillers and dry matter production, higher number of yield attributes, grain and straw yield in rice.

Rudragouda *et al.* (2014) opined that vermicompost, compost and liquid organic manures complemented each other and produced higher yield in crops. Glyricidia along with Jeevamrutha brings higher kapas yield in cotton. Organic manures are able to accelerate the weathering process and make the nutrients easily available to plants and also modified the physical, chemical and biological environment of soil for superior plant growth.

Amareswari and Sujathamma (2014) opined that Jeevamrutha is a better alternative for chemical farming in the cultivation of rice. The grain yield and gross return through NPK farming are 5% less than Jeevamrutha application and net return is 37% lower than that of chemical farming. They also reported that organically cultivated French bean shows the highest B:C ratio than NPK cultivation (Amareswari and Sujathamma, 2015). Similarly, in field bean Jeevamrutha at 1500 L ha^{-1} also recorded significantly higher growth and yield parameters like plant height, number of branches, leaf area index and dry matter production. Apart from this, higher number of pods, pod weight, number of seeds, total seed weight $plant^{-1}$ and hundred seed weight of field bean was also observed (Siddappa, 2015).

Gore and Srinivasa (2011) reported that integrated application of RDF + Beejamruth + Jeevamruth + panchagavya resulted in higher growth parameters like plant height, fruit yield and dry matter production of tomato at both flowering and crop harvesting stage.

According to Ramesh *et al.* (2018) foliar application of 5% Jeevamrutha on 20, 40 and 60 DAS in maize showed the highest growth and yield attributes like plant height, leaf area index, dry matter production, cob length, cob diameter, number of grains cob^{-1}, test weight, grain and stover yield. Borai *et al.* (2018) found that application of Jeevamrutha resulted in higher fruit yield per hectare in chilli.

Masih *et al.* (2009) suggested that liquid organic manures are beneficial for crop production and protection. A ratio of 1: 20 ratios was found to be optimum for the preparation and which can be used for drenching, fertigation and foliar spray.

The growth and yield of cucumber can be augmented by the foliar spraying of aged liquid organic manures. An increased yield and yield attributes was recorded by the application of 20-week-old 100% Jeevamrutha (Rameeza, 2016)

FAA is produced by fermenting fresh fish by-products (bones, head, skin, and other tankage parts) with brown sugar, which have been documented to promote seedling growth, fruiting, and microbial action in the soil (El-Tarabily *et al.,* 2003).

Foliar application of fish waste extract @ 40cc per 20 litre of water on soybean crop enhanced the growth and yield attributes like plant height (74.83cm), leaf length (11.87), dry weight (4740.83 kg ha^{-1}) and seed yield (3850.83 kg ha^{-1}) (Myint *et al.*, 2009). Similarly, Abhilash (2011) reported that foliar application of fish amino acid enhanced the growth, better colour and yield in red Amaranthus.

According to Garcia (2016), different rates of fish amino acid had a highly significant effect on the length of fruits, diameter of fruits, correlation of number of flowers, fruit set, weight of non-marketable fruits per solanum plant and total yield. Study shows that expensive inorganic fertilizer can be substituted by the combined use of FAA and organic fertilizer. Gunapaselam (fermented fish waste) is very effective liquid organic manure in increasing the growth parameters of brinjal like; leaf area, plant height, stem diameter, root length, fresh and dry plant weight. It also increased the thickness of phloem and xylem conducting tissues (Balraj *et al.*, 2014). Foliar spray of Fish amino acid resulted in the maximum length of vine, the highest number of leaves at 45 DAS, early flowering and harvest (Vemaraju,2014).

Srikumaran *et al.* (2017) conducted an experiment to compare the different concentration of Gunapaselam on the growth of okra, and the results showed that 10% concentrated Gunapaselam have proven distinctive results in all parameters, and the plants appear healthy, green and attractive. Similarly, soil application of 2 weeks old preparation of fish jaggery extract @ 10% in okra recorded the highest number of leaves, total dry matter production, fruit yield per plant, total yield and B: C ratio of 2.33 (Dhanalakshmi, 2017).

Foliar application of compost tea was found to provide macro and micronutrients for growth in readily available form. Non aerated compost tea is an effective amendment for the growth of Strawberry (Hargreaves *et al.*, 2009).

Pillai (2012) reported that, foliar application of liquid manures prepared from composite manures of groundnut cake, neem cake and poultry manure (1:0.5:0.5 ratio) enriched with PGPR resulted in the maximum yield attributing characters like plant height, functional leaf number, fruit number and weight of fruits/ plant at different growth stages of bhindi.

The combined use of biogas slurry and synthetic fertilizers boost the C: N transformation on the crop and supplement the yield of crops (Kumar *et al.*, 2015) by effecting yield contributing characters. Number of fruits per plant, individual fruit weight, fruit weight per plant and yield of tomato crop plant were positively influenced by bio slurry treatments (Ferdous *et al.*, 2018)

Muhmood *et al.* (2015) revealed that the application of biogas slurry along with inorganic fertilizers had a profound increase in yield in okra and the combination were also cost effective.

Synthetic fertilizers along with either cow dung or poultry bio-slurry affect yield contributing characters. Bio-slurry is a potential source for nutrients and amplifies the economic returns of the farmers (Ferdous *et al.*, 2018).

Herawati *et al.* (2017) noticed that liquid organic fertilizers from sugarcane pulp waste and sugarcane skin were able to cause noticeable difference in production parameters such as number of pods per plant and the dry weight of seed per ha of soybean when compared with basic fertilizer doses.

Nandhakumar and Swaminathan (2011) noticed that foliar spraying of leaf extracts resulted in maximum plant height, LAI and dry matter production in maize and an increase in soil microbial population.

2.1.3 Effect of liquid organic manures on soil quality

According to Ravusehab (2008), liquid organic manures sustain soil health by improving physico chemical and biological properties of soil.

Since cow urine is a rich source of nutrients, its application in soil could alleviate the micronutrient deficiency (Khanal *et al.,* 2011). Veeresha *et al.* (2014) found that application of FYM 12.5 t ha^{-1} + cattle urine at 34300 L ha^{-1} was found to be superior in giving higher soil organic carbon (0.58%), available nitrogen (272.4 kg ha^{-1}), phosphorus (23.5 kg ha^{-1}), and potassium (199.9 kg ha^{-1}), as it was able to improve the activity of beneficial microorganisms and thus soil NPK become available. Cattle urine and human urine treatments resulted in higher total nitrogen, available phosphorus, Ca, Mg, organic carbon, pH, exchangeable K and Na (Nwite, 2015).

A decreased C: N ratio was observed by amending the soil with seaweed based panchagavya (Sangeetha and Thevanathan, 2010a). Post-harvest analysis of soil in the experiment conducted by Vijayakumari *et al.* (2012) pointed out that combined application of panchagavya, humic acid and micro herbal fertilizer improved the soil fertility and increased the soil NPK content. Ninan *et al.* (2013) claimed that PSB present in Jeevamrutha enhanced the availability of phosphorus ions in the soil.

Foliar spray of extracts of seaweed significantly improved the NPK content in potato tubers and haulm (Dwivedi *et al.*, 2016).

Soil fertility status was improved by the application of panchagavya which increases macronutrients, micronutrients and microorganisms in the soil thus increasing soil health. It also improves the water holding capacity of soils (Ram, 2017). Similar results were observed by Sailaja *et al.* (2014). They recorded the percentage increase of soil N, P and K content over control.

Application of coconut leaf vermiwash induced the highest rhizodeposition, which increases soil organic carbon content (Gopal *et al.,* 2010). Sundararasu and Jeyasankar (2014) reported that application of vermiwash in brinjal elevated the levels of total soil macro (N, P, K, Mg and C) and micronutrients (Fe, Cu and Zn). The physico-chemical properties of the soil, biochemical characteristics and soil micronutrient content were amplified by the combined use of vermiwash and vermicompost (Ansari and Sukhraj, 2010).

Palekar (2006) opined that Jeevamrutha is promising liquid manure and can act as a good soil tonic. Gore and Srinivasa (2011) reported that Jeevamrutha is a low-cost improvised preparation that enriches the soil and helps in soil mineralization. An experiment conducted by Siddappa (2015) also revealed that application of Jeevamrutha at 1500 L ha^{-1} was found to be significant with respect to available N, P, and K. Increased nutrient uptake and better translocation of nutrients, was the outcome of application, and it enhances the nutrient availability and physico chemical and biological properties of the soil.

According to Sreenivasa *et al.* (2009) inoculation of bacterial isolates from beejamrutha could boost the nitrogen fixation and P solubilisation capacity of the soil.

The integrated application of biofertilizers, panchagavya, vermicompost and recommended dose of fertilizers resulted in a higher availability of major nutrients N (324.9 kg ha^{-1}), P (29.7 kg ha^{-1}) and micronutrients, Zn (0.63 mg kg^{-1}), Fe (3.88 mg kg^{-1}), Cu (0.68 mg kg^{-1}) and Mn (2.94 mg kg^{-1}) in soil (Naidu *et al.*, 2009).

Application of Gunapaselam was found to enhance the soil physical, chemical and biological properties. It decreased the soil pH, increased the organic matter content, N, P, K and increased the number of exchangeable cations favouring the growth of brinjal (Balraj *et al.*, 2014).

According to Garg *et al.* (2005), biogas slurry from agricultural waste treatment is a potential nutrient source for agriculture. Biogas slurry and flyash amendments improve the soil physical properties. They reduced the bulk density of soil and increased saturated soil hydraulic conductivity and moisture retention capacity.

Ryan (2007) noted that soil structure, nutrient status and soil health was improved by the application of compost tea.

2.1.4 Effect of liquid organic manures on soil microbial activity

Pathak and Ram (2002) found that nutrient transformation and its availability to crops was enhanced by the complimentary action of native microbes and the microbes found in compost tea (cow dung+cow urine+water).

Jeevamrutha and compost tea is rich in microorganisms and which positively influenced the soil microflora (Palekar, 2006; Ryan, 2007).

Coconut leaf vermiwash is rich in microorganisms. Application of this liquid manure elevated the population of soil micro flora, particularly plant beneficial microbes such as nitrogen fixers and phosphate solubilizers (Gopal *et al.*, 2010).

Remarkably higher soil microbial population viz., bacteria (47.0×10^5 cfu g^{-1}), fungi (34.6×10^4 cfu g^{-1}) and actinomycetes (40.0×10^3 cfu g^{-1}) were acquired with the application of FYM 12.5 t ha^{-1} + cattle urine at 34300 L ha^{-1} as compared to control (Veeresha *et al.*, 2014). Application of Jeevamrutham along with mulching in cucumber resulted in higher bacterial and fungal count than the chemical application (Krishanan, 2014). Foliar and soil application of diluted panchagavya increased the total actinomycetes count and total viable count of bacteria in soil (Shailaja *et al.*, 2014). Similarly, Jain *et al.* (2014), reported that application of panchagavya at 4% improves the soil microbial activity.

Gopakkali and Sharanappa (2014) claimed that enriched biodigested liquid manure (EBDLM) at 125 kg N equivalent ha^{-1} + 3 sprays of 3% panchagavya was responsible for the higher soil microbial population. Similarly, Vemaraju (2014) reported that liquid extract of composite organic manures resulted in the highest fungal population and Jeevamrutha application imparted the highest bacterial and actinomycetes count in soil.

According to Siddappa (2015), significantly higher population of bacteria, fungi, actinomycetes, P-solubilizer, and N fixer (52.93×10^6, 10.33×10^4, 38.22×10^3, 31.58×10^5 and 36.09×10^5 cfu g^{-1} of soil, respectively) were recorded by the application of Jeevamrutha at 1500 L ha^{-1}.

Chaudhari *et al.* (2013) analysed the microbial count of soil after the harvest of green gram and reported that, the combined application of panchagavya and vermicompost at 15 and 30 DAS increased the microbial population of *Azotobacter, Azospirillum, Rhizobium*, and PSB in soil. Ram (2017) opined that panchagavya was able to encourage the growth and reproduction of beneficial soil microorganisms.

According to Dhanalakshmi (2017), bacterial, fungal and actinomycetal count in the rhizosphere of okra was enhanced by the application of 6 weeks old, 4 weeks old egg extract and 4 weeks old fish jaggery extract respectively.

2.1.5 Effect of liquid organic manures on plant growth promoting hormones and enzymes

Somasundaram and Sankaran (2004) opined that panchagavya contains growth promoting substances such as IAA, GA_3 and cytokinin which was responsible for the enhanced plant growth. Similar results were obtained in vermiwash which increases growth and yield in flower, vegetable and fruit crops (Venkateswara *et al.*, 2005; Vijayananthan and Kumar, 2006).

Dehydrogenase activity was increased profoundly in organic farms compared to conventional farms (Manjunatha, 2006).

Vennila and Jayanthi (2008) reported that regulation of water in the developing okra fruits was controlled by the auxin present in vermiwash and panchagavya, which resulted in high crude protein content, Barletts index and ascorbic acid content. panchagavya enhanced the quantity of phyto hormones like Indole acetic acid, Gibberellic acid, kinetin and Abscisic acid in the soils.

According to Naik and Sreenivasa (2009), panchagavya is rich in plant growth substances producing bacteria. Seed germination, seedling length and seed vigour index might have been resulted from the beneficial microorganisms present in panchagavya which indicates that panchagavya is an efficient plant growth stimulant. Sreenivasa *et al.* (2009) opined that the highest seed germination and vigour index was obtained with beejamrutha treatment due to the production of IAA, and GA by the beneficial microbes in it.

Gopal *et al.* (2010) observed that soil dehydrogenase, urease and phosphatase enzyme activities were enhanced by the application of diluted coconut leaf vermiwash.

Kumar *et al.* (2011) found an increased production in groundnut with the application of 3% panchagavya as foliar which facilitates easy nutrient transfer with the help of growth hormones like IAA and GA.

Balraj *et al.* (2014) reported that Gunapaselam, fermented fish waste can boost the growth and development of roots by increasing the production of auxin and similar substances and also strengthened the activity of plant growth promoting rhizobacteria.

Zhang *et al.* (2014) detected and quantified the cytokinin content in aqueous extract of vermicompost by liquid chromatography– tandem mass spectrometry (LC–MS/MS) and it support the growth efficiency of vermicompost tea in plants.

Seaweed sap along with recommended dose of fertilizers promoted the growth of rice through the activity of hormones like IAA, zeatin, GA and kinetin present in it (Patel *et al.*, 2015). Application of liquid organic manures such as cow urine, fish amino acid boost the dehydrogenase, acid and alkaline phosphatase activity in soil (Parvathy, 2017).

2.1.6 Effect of liquid organic manures on quality attributes and shelf life of plant products

According to Shivamurthy and Patel (2006), seed treatment with cow's urine significantly improved the chlorophyll a and chlorophyll b content in wheat.

Chandrakala (2008) noted an increase in ascorbic acid, oleoresin and colour value by the combined application of beejamrutha + Jeevamrutha+ panchagavya and also by the application of panchagavya alone.

Lycopene content in tomato was increased by the integrated application of beejamrutha, Jeevamrutha and panchagavya at 75 DAS and 160 DAS as foliar spray (Gore, 2009).

Fangbo *et al.* (2010) observed that application of concentrated biogas slurry enhanced the protein, amino acid, soluble sugar, carotene, tannins, amino acids and

4

vitamin C content in tomato fruits. Shijini (2010) observed an extended shelf life in organic papaya.

Combined application of recommended dose of fertilizers and pancghagavya significantly improved the protein and oil content in groundnut (Kumar *et a*l., 2011).

Uppar and Rayar (2014) revealed that the application of vermiwash at 5% in mulberry significantly increased the biochemical constituents like chlorophyll, total sugar, and crude protein content.

Application of enriched biodigested liquid organic manure along with 3 sprays of panchagavya at 3% improved the protein and oil yield of ground nut (Ananda and Sharanappa, 2017).

Cow urine increased the protein and chlorophyll content of methi and bhindi with an increase in concentration (Jandaik *et al.*, 2015). Early harvesting of good quality cucumber fruits was obtained by the foliar spray of fish- jaggery extract and it produced quality fruits with a maximum shelf life of nine days (Krishnan, 2014). Similarly, Vemaraju (2014) found that the maximum shelf life of 19.66 days in oriental pickling melon was obtained by the application of FAA followed by panchagavya.

Boraiah *et al*. (2018) reported that application of Jeevamrutha increased the shelf life of capsicum (19.06 days) as compared to control (15.67 days).

According to Siddappa (2015), the crop quality parameters like moisture content, ash content, protein content, fat content, crude fibre content and carbohydrate content of field bean were enhanced by the application of Jeevamrutha at 1500 L ha^{-1}. Similarly, significantly the highest capsaicin content was observed by the application of Jeevamrutha (Boraiah *et al.,* 2018).

Decreased chlorophyll a/b ratio was observed by the application of modified seaweed based panchagavya to soil (Sangeetha and Thevanathan, 2010a). Rajesh and Jayakumar (2013) reported that the photosynthetic pigments and biochemical

4

constituents like protein, starch, amino acid and sugars in *Abelmoschus esculentus* (L.) Moench were enhanced by the application of 3% panchagavya. Application of diluted panchagavya also stimulated the vitamins, minerals and carbohydrate content of leafy vegetable *Spinacia oleracea* (Shailaja *et al.*, 2014). In ground nut, oil content and significantly higher protein content in seeds were observed by the application of panchagavya and neem leaf extract at both branching and flowering stage (Choudhary *et al.*, 2018).

The protein and ascorbic acid content in seeds of soybean were enhanced by the application of organic mixture contain panchagavya, humic acid, and micro herbal fertilizer (Vijayakumari *et al.*, 2012). Sumalatha (2015) noted that protein content and dehydrogenase activity in cowpea seed were enhanced by the application of 5% panchagavya. Jayachithra and Abirami (2016) claimed that foliar application of 3% panchagavya in horse gram increased the biochemical contents up to seedling stages like protein, starch, amino acid and sugars. panchagavya is a potential bio-organic which can alleviate salinity stress. panchagavya treated rice plants recorded higher biochemical parameters like chlorophyll a, b, total chlorophyll, total carotenoids, anthocyanin, and total protein even under salinity stress. panchagavya has renowned scavenging activity, thus acts as an antioxidant (Khan *et al.*, 2017).

2.1.7 Effect of liquid organic manures on plant nutrient uptake

The combined use of poultry manure, panchagavya, and neem cake increased the macro and micronutrient content in the leaves and pods of moringa and also resulted in the highest nutrient uptake and nutrient use efficiency in both main and ratoon crops of moringa (Beaulah, 2002). Somasundaram and Sankaran (2004) also reported that panchagavya treated green gram plants showed higher NPK uptake than the other treatments. Palekar (2006) opined that Jeevamrutha application increased the nutrient uptake by crops. The highest macro and micronutrients by chilli were observed by the combined application of organics (FYM, biofertilizers, panchagavya and vermicompost) along with recommended dose of nitrogen fertilizers (Naidu *et al.*, 2009). The combination of beejamrutha, Jeevamrutha and panchagvya also contributed to the highest nutrient uptake by plants (Gore, 2009). Gopal *et al.* (2010) observed a greater nutrient content in plants by the application of coconut leaf vermiwash.

Gore and Srinivasa (2011) revealed that the combined application of RDF + Beejamruth + Jeevamruth + panchagavya resulted in the highest nutrient concentration in plants at both flowering and final harvest stage. Similarly, Siddappa (2015) reported that application of Jeevamrutha at 1500 L ha^{-1} recorded significantly a higher plant N, P and K content than the other treatments in field bean at harvest.

According to Choudhary *et al.* (2014), significantly higher N and P uptake in kernels and haulm were accounted by the combined application of panchagavya and neem leaf extract at both branching and flowering stage. Application of panchagavya at 4 % at both branching and flowering stages of black gram resulted in maximum N, P, K, S, Zn and Fe content and their uptake in seed and straw and protein content in seeds (Choudhary *et al.,* 2017). 3% panchagavya, and 5% fish amino acid were responsible for the maximum primary and secondary nutrient uptake by okra (Parvathy, 2017).

2.1.8 Effect of organic manures on nutrient release pattern in soil

Nair (2003) conducted an incubation study with FYM, poultry manure and vermicompost. The results indicated that the availability of N and P_2O_5 progressively increased up to 90[th] day for all three manures and that of K_2O increased up to 60[th] day and thereafter decreased.

According to Sheeba (2004), the available N, P_2O_5 and K_2O content of the soil increases till 45[th] day of incubation and then decreased. The rapid availability of nutrients within 30-60 days was obtained by the treatment with poultry manure (Asha, 2006). An incubation study was carried out by Ch'ng *et al.* (2014) by using organic amendments and the findings suggest that biochar or compost can effectively fix Al and Fe instead of P, thus making P available by keeping the inorganic phosphorus in a bioavailable labile phosphorus pool for a longer period.

Sreeja (2015) noted an increasing trend in the case of available NPK throughout the incubation period, using compost enriched with rock dust and the pattern of solubilization of Fe, Mn, Zn, and Cu content were observed during 30th, 60th, 90th and 30th day of incubation respectively.

The evaluation of nutrient release pattern of different liquid organic manures by Parvathy (2017) revealed that pH, EC of soil increased throughout the incubation period. Soil treated with 10% FAA showed higher N, P and Ca content up to 30th day of incubation and then declined, whereas available K_2O content increased till 15th day of incubation. Exchangeable Mg showed an increasing trend throughout the time period.

2.1.9 Effect of organic manures on controlling pest and diseases

Bacterial blight in paddy can be controlled by the application of 5% panchagavya (Natarajan, 2008). Rana *et al.* (2016) conducted an experiment to evaluate the efficiency of organic inputs against rice blast caused by *Pyricularia oryzae*. The study shows that organic inputs are an effective means to control rice blast disease. Compost tea, biosol, Vermiwash, panchagavya, cow urine, and buttermilk: cow urine mixture is effective against rice blast. Among them fermented buttermilk: cow urine (1:1) was found to inhibit the pathogen at 10% concentration. Among the different organic inputs the highest seedling vigour index and lowest percentage of infection was recorded in case of beejamrutha treated seeds.

According to Jain *et al.* (2010), consumption of cow urine helps in curing incurable diseases as it contains sodium, nitrogen, sulphur, Vitamin A, B, C, D, E, minerals, manganese, iron, silicon, chlorine, magnesium, citric, succinic, calcium salts, phosphate, lactose, carbolic acid, enzymes, creatinine and hormones in optimum composition.

Ashlesha and Paul (2012) suggested that unsterilized biodynamic inputs are effective against R. *solanacearum* in chilli. Maximum inhibition of bacterium was resulted by unsterilized biodynamic compost followed by biosol and also reported that bacterial wilt in chilli can be controlled by the soil application of vermicompost and biodynamic compost along with drench of BIOM (Biosol + Fermented butter milk + cow urine+ vermiwash +homa ash) under protected cultivation.

Brahamastra is a liquid organic preparation having anti pathogenic properties. Lentil seed treated with Brahamastra resulted in lower invasion of pathogens like *Alternaria, Aspergillus, Cladosporium, Currvularia, Fusarium, Penicillium* and *Rhizopus* (Gadewar *et al.*, 2014).

Scheuerell (2004) reported that compost tea is a carrier to deliver plant nutrients and manage plant diseases and also opinied that compost tea is a rich source of beneficial micro flora which compete and suppress the disease-causing organisms and protect the crops from damping off. And also, foliar application of compost tea was effective against Septoria leaf spot of tomato (Gangaiah *et al.*, 2004).

Rajan (2014) found that compost tea can offer eco-friendly management of collar rot and web blight along with crop growth promotion. Study shows that 1:5 dilution and 24 hr brewing is optimum for microbial growth which suppresses web blight, collar rot and enhances the biometric and yield parameters.

Sapre (2005) found that application of cow urine and buttermilk can reduce mycelial growth of, *Rhizoctonia bataticola* and *Fusarium solani*. However, seed treatment with them only increased plant height and which did not reduce the mycelial population. Jandaik *et al.* (2015) also studied the antifungal efficiency of cow urine and he reported that vegetative growth of fungal pathogens was inhibited by cow urine. The percentage of inhibition increases with increase in concentration and maximum inhibition was shown against *Fusarium oxysporum*, followed by *Rhizoctonia solani* and *Sclerotium rolfsii*. Antifungal efficiency of cow urine was also revealed by Tiwari and Das (2011) and reported that medicinal plant extracts prepared in cow urine inhibit mycelial growth of *Rhizoctonia solani* to a greater extent than the extracts prepared in cold water and hot water. Cow urine acts as a bioenhancer and it aids in extracting the active principles from medicinal plant parts. The amazing germicidal power of cow urine was revealed by Pathak and Ram

(2013) and reported that it has disinfectant and prophylactic properties thus purifying the atmosphere and improving soil fertility.

Leaf spot and leaf feeder attack in Amaranthus can be reduced by the spraying of fish amino acid at weekly intervals (KAU, 2014).

Sumangala and Patil (2009) found that panchagavya is an effective organic weapon against plant pathogens. Seed treatment with panchagavya resulted in 86.3 % inhibition of mycelial growth of *Curvularia lunata*. panchagavya inhibits the viral infection also. Lesser viral activity, viral multiplication and higher viral inhibition was showed by panchagavya treated plants (Vallimayil and Sekar, 2012). Sireesha (2013) noted that foliar application of panchagavya caused a decline in the leaf and neck blast in rice.

Antifungal activity of panchagavya was studied by Adhao (2013). The study pointed out that antibiotics and cell wall degrading enzymes present in panchagavya was responsible for the decreased mycelial growth of soil borne pathogens. Jandaik and Sharma (2016), also revealed that vegetative growth of fungal pathogens is cutback with the utilization of higher concentrations of panchagavya. 15 % concentration of panchagavya was effective for the inhibition of fungal growth.

Fermented egg lemon juice extract completely inhibited the mycelial growth of pathogens (Sajeena *et al.*, 2015).

Onion treated with vermiwash (1: 5) and Jeevamrutha @ 2 % recorded lower thrips population than other treatments (Mallinath and Biradar, 2015).

Kumar *et al.* (2015) observed an increase in the number of predatory spiders, Oxyopes spp. with the application of 7 % diluted panchagavya in teak. It also checked the population of teak defoliators, skeletonizers, ground hopper and mealy bug effectively

2.2. Effect of *Kunapajala* on crop growth and yield

Kunapajala was a fermented liquid organic manure prepared from animal waste, dung, bones and urine, which contains proteins, amino acids, keratins, macro

4

and micro nutrients in available form. *Kunapajala* constitution was variable and no standard formulation was specified in any of the *Vrikshayurveda*.

The ingredients such as honey, milk, cow dung, cow's urine and plant leaves enhance the quality of *Kunapajala* (Nene,2012). Honey contains proline, which induces systemic resistance in plants. It is antimicrobial and antibacterial. It contains increased quantities of plant growth promoting substances like cytokinin and auxin. Likewise, milk is an amino acid rich compound which induces general disease resistance in plants (Nene,2012).

Masih *et al*. (2009) pointed out that neem leaves, neem cake and cow dung were rich sources of nitrogen, potash and phosphorus and active principles present in them are liable for the biocidal properties.

Neem is rich in anti-microbial compounds, and it modifies the biological process of harmful insects in a detrimental way. It imposes antifeedant effect, larval repellent, oviposition deterrent, growth and metamorphosis inhibiting effects, effect on fecundity and egg sterility (Nene,2012). Nahak and Sahu (2014) also inferred that neem extract promoted the growth of brinjal in terms of increasing shoot height, number of buds, number of flowers and number of fruits and induced resistance against leaf spot and wilt diseases in brinjal.

The addition of silica rich rice husk was expected to release some of the silica to Kunapajala, which enhanced the robust plant growth (Nene, 2006).

The medicinal herb *Clerodendron infortunatum* Linn have anti-microbial and anti-inflammatory activities (Mohandas and Narayanan, 2017). Parallelly Sreeletha and Geetha (2011) inferred that this herb can cause larval and pupal mortality of *O. rhinoceros*.

Kunapajala application is very effective in the growth of medicinal plants. An experiment conducted by Brajeshwar (2002) reported that *Kunapajala* treated Senna plants showed maximum plant height, leaf area index, and sennoside content per plant compared to chemical fertilizers. 'Colchicine' content become maximum in *Gloriosa superba* by the application of *Kunapajala* (Asha, 2006). *Kunapajala* application in brinjal resulted in higher number of branches, maximum yield, fruits with lesser seeds and lower susceptibility to diseases when compared with plants grown with chemical fertilizer (Bhat and Vasanthi, 2008).

Jani *et al.* (2017) reported that the physical state of *Kunapajala* as liquid, its alcohol content is 4% v/v, pH-3.5 and also the presence of carbohydrates, proteins and alkaloids.

Nutrient requirement of plants can be satisfied by composted *Kunapajala* (Savitha *et al.*, 2012). Manure break down into simpler forms by composting and their presence for long period in the soil enhances microbial action in soil allowing it to absorb and retain water and nutrients more efficiently. Since it is in liquid form, it is readily available for the roots (Prabha *et al.*, 2008).

Mishra (2007) claimed that the application of *Kunapajala* at the rate of 500 ml per pot had a significant effect on growth and development in rice plants. Plant height, leaf length and inflorescence length were remarkably increased with the treatment.

According to Sarkar *et al.* (2013), combined use of panchagavya and *Kunapajala* resulted in maximum growth and yield of vegetables like chilli, tomato and cowpea. A decreased chlorophyll a/b ratio was observed which denoted the better availability of leaf nitrogen and efficient photosynthetic activity.

An experiment conducted by Deshmukh *et al.* (2012a) observed that application of *Kunapajala* for five times at an interval of 10 days resulted in maximum number of leaves, leaf area index and total biomass in tomato plants as compared to conventional and organic farming.

Deshmukh *et al.* (2012b) reported that the application of *Kunapajala* resulted in early flowering, fruiting, yield and yield per plant in tomato.

Chlorophyll a, Chlorophyll b, Total chlorophyll stability index, Carotenoids and xanthophyll were increased with the application of *Kunapajala* to tomato plants, which resulted in maximum productivity as compared to conventional and organic farming (Deshmukh *et al.*, 2012a).

Deshmukh *et al.* (2012b) observed that *Kunapajala* treated tomato plants had maximum number of fruits per plant and fruit weight.

Ali *et al.* (2012) noticed that *Kunapajala* @ 5 and 10% and Shasyagavya @ 20% spray produced a better plant growth in black gram than the other treatments. The yield attributes like number of pods per plant, number of seeds per pod, 1000 seed weight, pod length and yield per m^2 were increased with the application of *Kunapajala* and Shasyagavya.

Anandan *et al.* (2016) observed that *Kunapajala* showed the highest seed germination with longer roots in *Oryza sativa* when compared with other biofertilizers like panchagavya, Sanjibani, Amrithpani, Jeevamrutha

According to Ankad *et al.* (2017) *Kunapajala* reported a pH of 5.793 and EC of 2.653 dS m^{-1} , with the highest content of macro and micro nutrients except P, followed by panchagavya, Humic acid and FYM.

Catalase, peroxidase, polyphenol oxidase, IAA oxidase, and super oxide dismutase activity were enhanced by the application of *Kunapajala* on tomato plants. These enzymes bring about growth and development in plants. Similar experiments were conducted on tomato fruits and reported that the activity of peroxidase, polyphenol oxidase, IAA Oxidase, and Super oxide dismutase were enhanced by the application of *Kunapajala.* The study also revealed that the plants treated with *Kunapajala* showed more acidity, which leads to better canning and more shelf life of the produce. *Kunapajala* application on tomato plants increases the lycopene, proline and ascorbic acid content of the fruits, which makes them tastier and healthier (Deshmukh *et al.*, 2012b).

Seeds soaked with 0.5% *Kunapajal*a resulted in maximum seed germination which significantly reduced the number of days to first flowering and 50% flowering. Length, width, weight and shelf life of fruits were maximum in *Kunapajala* treated plants and also reported that ascorbic acid content in stem and leaf, proline content in root and stem, glycine betaine in leaf, and activity of oxidative enzymes are enhanced by the application of *Kunapajala* in tomato. Nutritional and biochemical constituent of fruits exhibited the highest value as compared to vermicompost and NPK treatment (Deshmukh, 2013).

Nene (2018) detected the presence of species of Azotobacter, Pseudomonas, Azospirillum, Rhizobium, and phosphate solubilizing bacteria and substantial amount of total organic carbon, GA and IAA in *Kunapajala.*

Materials and Methods

3. MATERIALS AND METHODS

The study entitled "Characterization and evaluation of herbal and non-herbal *Kunapajala* on soil health and crop nutrition" was carried out at College of Agriculture, Vellayani during 2017-2019. Field experiments were conducted to evaluate the comparative efficacy of foliar and soil applications of *Kunapajala*. The study was carried out in three phases.

Part - 1: Preparation and characterization of organic liquid manures.

Part - 2: Laboratory incubation study to monitor the nutrient release pattern from herbal and non- herbal *Kunapajala.*

Part - 3: Evaluation of comparative efficacy of soil and foliar applications of herbal and non-herbal *Kunapajala* on soil health and crop nutrition using bhindi as a test crop.

The materials used and method adopted for the execution of the research work are presented in this chapter.

Part –I Preparation and Characterization of organic liquid manures

3.1. Preparation and characterization of organic liquid manures

3.1.1 Preparation of organic liquid manures

3.1.1.1 Preparation of herbal *Kunapajala*

Materials required

- Plant leaves (non-milky and non-grazing) : 20 kg
- Cow dung : 10 kg
- Sprouted black gram : 2 kg
- Jaggery : 2 kg
- Cow's urine : 15 L

- Water : 80 L

The leaves (non-milky and non-grazing) of *Adathoda vasica*, *Vitex negundo, Azadirachta indica*, *Ocimum tenuiflorum*, *Chlerodendron infortunatum*, *Eupatorium odoratum*, *Cassia fistula*, *Glyricidia maculata*, *Mimusops elengi*, and *Pongamia pinnata* were used. The leaves were cut into small pieces shearing the veins. The above items were mixed in 4-5 layers in a barrel. 80 litres of water were added. The content was mixed well with a bamboo pole twice a day, three minutes each, in both directions, for 15 days. After 15 days the preparation was ready for use (Plate 1).

3.1.1.2 Preparation of non-herbal *Kunapajala*

Materials required

- Fish : 2kg
- Bone meal : 1 kg
- Rice husk : 1 kg
- Coconut oil cake : 1 kg
- Sprouted Black gram : 500g
- Water : 85L
- Fresh Cow dung : 10 kg
- Cow's Urine : 15 L
- Honey : 250g
- Ghee : 250g
- Jaggery : 2kg
- Milk : 1L

Two kg fish was taken and cut fish into small pieces. Fish, bone meal, rice husk, coconut oil cake and sprouted black gram were boiled in 10 litres of water


Plate 1. Preparation of herbal *Kunapajala*


Plate 2. Preparation of non-herbal *Kunapajala*

until it become viscous and semi solid consistency. It was cooled and poured into a plastic barrel. Cow dung and cow's urine (from native breed), honey, jaggery, ghee, milk and remaining 75 L water were added (Plate 2). The content was mixed well with a bamboo pole twice a day, three minutes each, in clockwise and anticlockwise directions, for 15 days. After 15 days the preparation was ready for use (Nene, 2012).

For comparative study, liquid organic manures such as Panchagavya and Fish Amino Acid (FAA) were also prepared.

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 (10L) 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, cow milk (3L), cow curd (2L), tender coconut water (3L), jaggery (3kg) and well ripened poovan banana (12 Numbers) were added. The contents were stirred twice a day both in morning and evening. Panchagvya was ready for use after 30^{th} day (KAU, 2017).

3.1.1.4 Preparation of FAA

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. It was kept away from direct sun light for 30 days. The end product was filtered and diluted for application (Sundararaman ,2009).

3.1.2 Characterization of organic liquid manures

Organic liquid manures such as herbal and non- herbal *Kunapajala*, FAA and Panchagavya were characterized for physical, chemical, biological, and biochemical properties as per standard procedures (Table 1).

Table 1. Analytical methods followed in the analysis of organic liquid manures

SI. No.	Properties	Methods	Reference
1	Colour	Visual observation	
2	Odour	Sniff test	
3	pH	pH meter	Jackson (1973)
4	EC	Conductivity meter	Jackson (1973)
5	Organic carbon	Loss on ignition method	Jackson (1973)
6	Nitrogen	Microkjedahl digestion and distillation	Jackson (1973)
7	Phosphorus	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer	Jackson (1973)
8	Potassium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	Jackson (1973)
9	Calcium, Magnesium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation by EDTA method	Jackson (1973)
10	Micronutrients: Fe, Mn, Zn & Cu	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)
11	Boron	Diacid digestion and estimation using azomethane-H.	Gupta (1967)
12	Microbial count (log cfu ml^{-1})	Serial dilution plate technique	Timonin (1940)

3.1.2.1 Physical and Chemical characterization

Physical properties viz colour, and odour, chemical properties like pH, EC, organic carbon, primary, secondary and micro nutrients were estimated as per standard procedures.

3.1.2.2 Biochemical activity

Important biochemical properties like dehydrogenase activity, ascorbic acid content, total sugar % of liquid organic manures were determined as per standard procedures.

3.1.2.2.1 *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 add 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 got vanished while washing with methanol. The filtrate, which is 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.

3.1.2.2.2 Ascorbic acid

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

3.1.2.2.3 Total sugar percentage

Total sugar percentage of various liquid organic manures was estimated as per standard procedure and expressed in percentage (Sadasivam and Manickam, 1996).

3.1.2.3 Biological activity

Biological properties like total bacteria, fungi, and actinomycetes (log cfu ml^{-1}) in the manure sample were determined by using specific media. (Table 2, Media composition in Appendix I)

Table 2. Media used for estimation of microbial population

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	Cappuccino and Shaman (1996)

Part - II

3.2 LABORATORY INCUBATION STUDY

To monitor the nutrient release pattern of *Kunapajala*, at periodic intervals, a laboratory incubation study was conducted for a period of two months from October 2018 to December 2018. Samplings were done at 0^{th}, 7^{th}, 15^{th}, 30^{th}, 45^{th}, and 60^{th} day of incubation to study the nutrient release pattern.

3.2.1 Collection and preparation of soil samples to conduct incubation study

The soil for the incubation study was collected from the Model Organic Farm, under Department of Soil Science and Agricultural Chemistry. Samples were collected, mixed thoroughly and sieved through 2 mm sieve. 5 kilo gram of soil mixed with 45g FYM was filled in plastic buckets and to which herbal and non-herbal *Kunapajala* were added separately as per the treatments (Plate 3). Sixty per cent moisture capacity was maintained throughout the study period by adding distilled water by considering the weight difference occurred during the study period. The details of experiments are presented below.

3.2.2 Design and Layout of the Experiment

Design	: CRD
Treatments	: 5
Replication	: 4

3.2.3 Treatment details

T_1: Soil 5kg + FYM

T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*

T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*

T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*

T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*

Quantity of FYM was fixed as per the basal dose (20 t ha^{-1}) for bhindi cultivation (KAU, 2017).

Design	**:**	**CRD**
Treatments	**:**	**5**
Replication	**:**	**4**

T_1: Soil 5kg + FYM

T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*

T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*

T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*

T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*

Plate 3. General view of laboratory incubation study

The layout of laboratory incubation study was presented in Fig 1

R_2T_2	R_1T_5	R_3T_4	R_1T_1	R_3T_2
R_3T_5	R_2T_5	R_3T_3	R_2T_3	R_4T_4
R_4T_2	R_1T_4	R_4T_5	R_2T_4	R_1T_3
R_2T_1	R_4T_1	R_3T_1	R_4T_3	R_1T_2

Fig 1. Lay out of incubation study

3.2.4 Soil sampling

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

3.2.5 Analysis of soil sample

Chemical parameters such as pH, EC, organic carbon, Available N, P, K, Ca, Mg, S, Na, Fe, Mn, B, Cu, and Zn were determined as per the standard analytical procedures (Table 3).

Part -III

3.3 FIELD EXPERIMENT

A field experiment was conducted from 5-11-2018 to 9-02-2019 to evaluate the comparative efficiency of foliar and soil applications of herbal and non- herbal *Kunapajala* on soil health and crop nutrition using bhindi as a test crop.

Herbal and non-herbal *Kunapajala* at 2% and 5 % concentrations were applied as per treatment along with FYM which was applied on 50% nitrogen basis. Panchagavya and fish amino acid were applied for the purpose of collation.

3.3.1. EXPERIMENTAL SITE

The field experiment was conducted at Model Organic Farm under the Department of Soil Science and Agricultural Chemistry, College of Agriculture,

Table 3. 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	Available N	Alkaline potassium permanganate method	Subbiah and Asija (1956)
6	Available P	Bray No.1 extraction and estimation using spectrophotometer.	Bray and Kurtz (1945)
7	Available K	Neutral normal ammonium acetate and flame photometry	Jackson (1973)
8	Exchangeable Ca	Neutral normal ammonium acetate and EDTA method	Jackson (1973)
9	Exchangeable Mg	Neutral normal ammonium acetate and EDTA method	Jackson (1973)
10	Available S	$CaCl_2$ extraction and estimation using spectrophotometer.	Massoumi and Cornfield (1963)
11	Available B	Hot water extraction and spectrophotometry (Azomethane-H method)	Gupta, (1967)
12	Micronutrients Fe, Mn, Zn and Cu	0.1N HCl extraction and AAS	Sims and Johnson (1991)
13	Dehydrogenase	Spectrophotometric method	Casida *et al.* (1964)
14	Bacteria	Nutrient Agar medium	Atlas and Parks (1993)
15	Fungi	Martin's Rose Bengal Agar	Martin (1950)
16	Actinomycetes	Ken knight's agar medium	Cappuccino and Sheman (1996)

Vellayani. Geographically the area is situated at $8^0 50'$ North latitude and $76^0 90'$ East longitude and at an altitude of 29m above MSL.

3.3.1.1 Season

The period of crop growth was from November 2018 to February 2019. 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.

3.3.1.2 Soil

The soil of the experimental site was sandy clay loam belonging to family Loamy Kaolinitic Isohyperthermic Typic Kandiustult.

3.3.1.3 Crop

Bhindi variety 'Varsha Uphar' was used for the field experiments. The seed materials were collected from Instructional Farm, College of Agriculture, Vellayani.

3.3.1.4 Fertilizers and Manures

FYM and vermicompost required for the experiment were purchased from Model Organic Farm, College of Agriculture, Vellayani. Diluted *Kunapajala* was applied at periodic intervals.

Urea (46% N), Rock phosphate (20% P_2O_5), MOP (60% K_2O) were applied as per the recommendations of KAU Package of Practices.

3.3.2 METHODS

3.3.2.1 Design and layout of the experiment

Design : RBD

Treatments : 13

Replication : 3

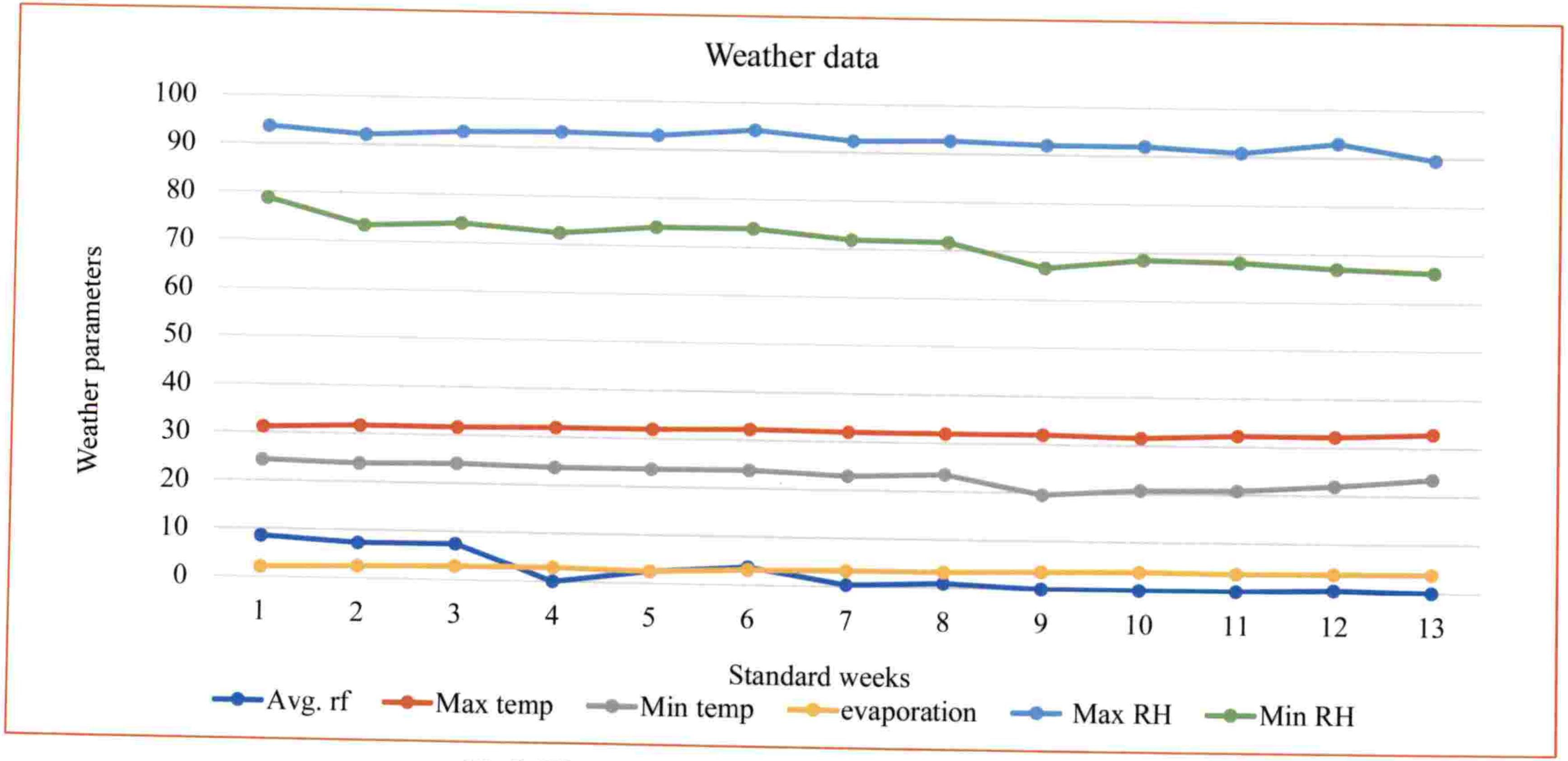


Fig 2. Weather parameters during field experiment

Avg. rf: Average rainfall (mm) Max temp: Maximum temperature (^{0}C) Min temp: Minimum temperature (^{0}C)
Max RH: Maximum Relative Humidity (%) Min RH: Minimum Relative Humidity (%)

Crop : Bhindi

Variety : Varsha Uphar

Plot size : 3 m x 3 m

Spacing : 60 cm x 30 cm

3.3.2.2 Treatment details

T_1: KAU POP (FYM 20 t ha^{-1} NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5 % herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2 % non- herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

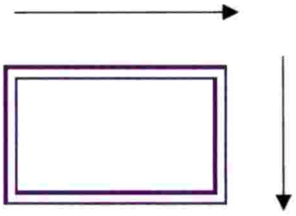
T_{13}: 50% N as FYM + 5% non- herbal *Kunapajala* foliar application

3.3.2.3 Field preparation and Layout

The main field was cleared and made into a fine tilth. Furrows at 60 cm spacing were taken within the plots having size of 3 x 3m. Three blocks with 13 plots were laid out in randomized design. Seeds were sown at 60 x 30 spacing. Irrigation was done as and when required. Lay out was presented in Fig 3.

R_1T_{10}	R_1T_{13}	R_1T_1	R_1T_{12}	R_1T_4
R_1T_9	R_1T_5	R_1T_8	R_1T_{11}	R_1T_3
R_1T_6	R_1T_2	R_1T_7	R_2T_5	R_2T_1
R_2T_9	R_2T_4	R_2T_6	R_2T_2	R_2T_7
R_2T_{13}	R_2T_3	R_2T_8	R_2T_{10}	R_2T_{12}
R_2T_{11}	R_3T_5	R_3T_2	R_3T_1	R_3T_4

Pipe		
R_3T_3	R_3T_8	R_3T_{13}
R_3T_9	R_3T_{11}	R_3T_{10}
R_3T_7	R_3T_6	R_3T_{12}



3 m x 3 m

Fig 3. Lay out of field experiment

Plate 4. Layout of the field

Plate 5. General field view

3.3.2.4 Application of fertilizers and manures

Lime was applied at 350 kg ha^{-1}. FYM was applied at 20 t ha^{-1} in all treatments. Besides this basal dose, FYM at 50% N basis were applied for the treatments T_5 to T_{13}. Chemical fertilizers such as urea, Rajphos, and MOP were applied as per the KAU POP recommendations (T_1). 5% FAA and 3% Panchagavya were added as per the treatment along with organic Adhoc POP recommendations (T_3 &T_4). Vermicompost at 1 t ha^{-1} was applied for the treatments T_2, T_3, and T_4 at 10 days interval for topdressing besides the basal dose of FYM 20 t ha^{-1} + Trichoderma @ 2.5 kg ha^{-1} + *Pseudomonas fluorescens* @ 2 kg ha^{-1}. Herbal and non- herbal *Kunapajala* was applied as per the treatments at 10 days interval.

3.3.2.5 Sowing and After cultivation

Healthy seeds after pseudomonas treatment were sown by dibbling at the rate of 2-3 seeds per hole at a spacing of 60x30 cm and covered with a thin layer of soil. Uniform plant population was maintained by gap filling and thinning. Initially irrigation was given daily, after that, watered at once in two days. Hand weeding was practised as and when required.

3.3.2.6 Harvest

Matured bhindi fruits were picked once in two days. The crop was uprooted on 9-02-2019.

3.3.3 BIOMETRIC OBSERVATIONS

Five plants in the middle rows were tagged from each plot for recording regular biometric observations.

3.3.3.1 Plant height (cm)

Height of plants was measured from base of the plant to the terminal leaf bud at first and final harvest and then expressed in centimetres.

3.3.3.2 Number of branches per plant

Number of branches per plant was recorded at first harvest.

3.3.3.3 Dry matter production (kg ha^{-1})

Fresh weight and oven dry weight of plant samples were recorded for calculating dry matter production. 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 kg ha^{-1}.

3.3.3.4 Leaf area index (LAI)

Leaf area index was estimated by measuring leaf area at 50 % flowering stage. Leaf area index was computed using the following formula

LAI = Total leaf area / Land area

3.3.4 PHYSIOLOGICAL CHARACTERS

3.3.4.1 Estimation of Chlorophyll content

0.5 g fresh leaf sample was weighed and cut into small bits and were taken into test tube which contain 10 ml DMSO and acetone mixture in 1: 1 ratio. The solution was kept overnight 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.

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

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

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

3.3.5 YIELD CHARACTERS

Yield and yield attributing characters were recorded from tagged plants.

3.3.5.1 Days to first flowering

In each plot, number of days taken for first flowering from the date of sowing was counted.

3.3.5.2 Days to 50% flowering

Number of days to reach 50% flowering from the date of sowing was noted from each plot.

3.3.5.3 Number of fruits per plant

Number of fruits harvested from tagged plant from each plot at every harvest were noted and average was worked out.

3.3.5.4 Length of fruit (cm)

Measured the length of fruits harvested from observation plants and mean length was calculated and expressed in centimetre.

3.3.5.5 Girth of fruit (cm)

For the same fruit, girth was measured by winding a thread around the centre of the individual fruits. Mean girth was calculated and expressed in centimetre.

3.3.5.6 Average fruit weight (g)

Weight of fruits from the tagged plants at every harvest was noted and mean was computed and expressed in gram.

3.3.5.7 Total fruit yield (t ha^{-1})

Total fruit yield was counted by calculating the total weight of fruits harvested from the observation plants from each plot at every harvest and the average was worked out and calculated the total fruit yield in t ha^{-1}.

3.3.6 QUALITY PARAMETERS OF FRUIT

3.3.6.1 Crude protein content

The crude protein content of the fruits was obtained from the nitrogen content of the fruits. Total nitrogen content in the fruits was determined and the value was multiplied by the factor 6.25 and expressed in percentage (Simpson *et al.*, 1965).

3.3.6.2 Crude fibre content

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

3.3.6.3 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}.

3.3.7 INCIDENCE OF PEST AND DISEASES

Incidence of pest and disease was very rare. A very few plants were infected with yellow mosaic virus. For controlling vectors and other insects Nimbicidine 5% was applied.

3.3.8 SOIL ANALYSIS

Soil samples were collected from the experimental plot before and after the experiment. Samples were air dried under shade and sieved through 2 mm sieve. The sieved soil samples were used for the analysis of pH, EC, OC, Available N, P, K, Ca, Mg, S, Fe, Mn, B, Zn, and Cu. Biochemical analysis were also done. Fresh samples were used for biological analysis. The procedures adopted for all these analyses are given in Table 3.

3.3.9 PLANT ANALYSIS

Plant and fruit samples were collected and oven dried at 70^0C. One plant from observation plant was uprooted, cleaned and chopped which was oven dried, and powdered. The powdered samples were used for analysis.

Plant uptake was perceived by analysing plant parts. Oven dried fruit samples were also powdered. 0.25 g of the powdered sample was used for the estimation of total N, P, K, Ca, Mg, S, Fe, Mn, B, Zn, and Cu by using standard procedures as given in Table 4.

Nutrient uptake = (Concentration of nutrients x Total dry matter production) / 100

Table 4. 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, Magnesium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using EDTA method	Jackson (1973)
5	Sulphur	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and turbidimetry	Massoumi and Cornfield (1963)
6	Boron	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and using Azomethane-H	Gupta (1967)
7	Micronutrients: Fe, Mn, Zn and Cu	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)

3.3.10 ECONOMICS OF CULTIVATION

The economics of cultivation was found out by considering the income derived from the plant and cost of cultivation based on the norms and rates fixed by the Instructional Farm, College of Agriculture, Vellayani.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.3.11 STATISTICAL ANALYSIS OF DATA

Statistical analysis of the experimental data was subjected to analysis of variance techniques as described by Cochran and Cox (1965). F test is followed in ANOVA for testing the significance of treatments. CD was calculated for the treatments that were found significant.

Results

4. RESULTS

The present study entitled "Characterization and evaluation of herbal and non- herbal *Kunapajala* on soil health and crop nutrition" was carried out at the College of Agriculture, Vellayani during the period from November 2018 to February 2019. The study aimed at preparation and characterization of herbal and non-herbal *Kunapajala*, analyses the nutrient release pattern under laboratory condition, and studying the efficacy of soil and foliar applications of these liquid manures on soil health and crop nutrition using bhindi as a test crop.

The organic liquid manures, viz., herbal and non- herbal *Kunapajala* were prepared and their characterization was undertaken. The physical, chemical biological and biochemical properties of the soil and chemical analysis of plant samples collected from the experimental plots were determined in the PG laboratory attached to the Department of Soil Science and Agricultural Chemistry.

The results of the various experiments conducted to fulfill the objectives of the study were statistically analyzed and are presented in this chapter.

PART I

4.1. Characterization of herbal and non-herbal *Kunapajala*

4.1.1 Physical properties

The physical properties such as colour and odour of organic liquid manures are presented in the table 5. Herbal *Kunapajala* was dark brown in colour while non-herbal *Kunapajala* was yellowish brown in colour. The colour of Panchagavya and FAA were light brown and dark brown respectively. Except for FAA, other three have a fermented odour and FAA was found to be odourless.

4.1.2 Chemical properties

4.1.2.1 pH & EC

The pH of herbal and non-herbal *Kunapajala* was in the neutral range as 7.00 and 7.70 respectively and that of Panchagavya and FAA were in the acidic range as 5.50 and 4.40 respectively (Table 5). The results revealed that Panchagavya has highest EC (7.30 dS m^{-1}) followed by FAA (3.60 dS m^{-1}). *Kunapajala* recorded a safe value for EC as compared to others (2.25 dS m^{-1} & 2.41 dS m^{-1} respectively for herbal and non- herbal *Kunapajala*).

4.1.2.2 Organic Carbon

Regarding organic carbon content (Table 5) herbal and non-herbal *Kunapajala* have higher organic carbon content (2.00% and 2.30% respectively), compared to Panchagavya (1.20%). However, the FAA recorded the highest organic carbon content of 35.67%.

4.1.2.3 Primary and secondary nutrients

The primary and secondary nutrient analysis of *Kunapajala*, Panchagavya and FAA are presented in table 6. The data revealed that FAA registered maximum nitrogen content (3.90%) followed by Panchagavya (2.30%), non-herbal *Kunapajala* (1.28%) and herbal *Kunapajala* (1.09%). The maximum phosphorus content was observed in Panchagavya (0.43%) followed by the FAA (0.31%). Among these liquid manures, herbal and non- herbal *Kunapajala* recorded the least P content (0.10% and 0.11% respectively). Regarding the potassium content, herbal and non-herbal *Kunapajala* recorded a maximum K content (0.33% and 0.44% respectively) followed by FAA (0.24%) and Panchagavya (0.14%).

It is evident from the data presented in the table 6, that the Ca, Mg & S content of *Kunapajala* is greater than that of FAA & Panchagavya. The Ca content was found to be the highest in non-herbal *Kunapajala* (380.0 mg L^{-1}), followed by herbal *Kunapajala* (340.0 mg L^{-1}), FAA (330.0 mg L^{-1}), and Panchagavya (215.0 mg L^{-1}). The highest Mg content was recorded by non-herbal *Kunapajala* (324.0

Table 5. Physical and physico-chemical characters of organic liquid manures

	Herbal *Kunapajala*	Non-herbal *Kunapajala*	Panchagavya	FAA
Colour	Dark brown	Yellowish brown	Light brown	Dark brown
Odour	Fermented odour	Fermented odour	Fermented odour	Odourless
pH	7.00	7.70	5.50	4.40
EC (dS m^{-1})	2.25	2.41	7.30	3.60
OC (%)	2.00	2.30	1.20	35.67

Table 6. Primary and secondary nutrient contents of organic liquid manures

	Herbal *Kunapajala*	Non-herbal *Kunapajala*	Panchagavya	FAA
Total N (%)	1.09	1.28	2.30	3.90
Total P (%)	0.10	0.11	0.43	0.31
Total K (%)	0.33	0.44	0.14	0.24
Total Ca (mg L^{-1})	340.0	380.0	215.0	330.0
Total Mg (mg L^{-1})	240.0	324.0	76.8	90.0
Total S (%)	1.40	1.80	0.21	0.49

mg L^{-1}), followed by herbal *Kunapajala* (240.0 mg L^{-1}), FAA (90.0 mg L^{-1}), and Panchagavya (76.8 mg L^{-1}). With respect to S content, Panchagavya accounted the least content (0.21%) preceded by FAA (0.49%), herbal *Kunapajala* (1.40%) and non-herbal *Kunapajala* (1.80%).

4.1.2.4 The micronutrient content of liquid organic manures

The table 7 portrays the micronutrient content of *Kunapajala*, FAA, and Panchagavya. *Kunapajala* recorded the highest content of micronutrients compared to FAA and Panchagavya except for total Cu. FAA registered the highest Zn content (1.93 mg L^{-1}), followed by non-herbal *Kunapajala* (0.61 mg L^{-1}), herbal *Kunapajala* (0.58 mg L^{-1}) and Panchagavya (0.49 mg L^{-1}). The highest Cu content was observed in Panchagavya (1.56 mg L^{-1}), followed by FAA (0.45 mg L^{-1}). Herbal and non-herbal *Kunapajala* recorded the least Cu content compared to others (0.21 and 0.25 mg L^{-1} respectively). The Fe content was found to be higher in non-herbal *Kunapajala* (12.30 mg L^{-1}), next herbal *Kunapajala* (7.55 mg L^{-1}), Panchagavya (7.23 mg L^{-1}), and FAA (5.14 mg L^{-1}). Non-herbal *Kunapajala* had the highest Mn content (1.04 mg L^{-1}), followed by herbal *Kunapajala* (0.87 mg L^{-1}), Panchagavya (0.23 mg L^{-1}) and FAA (0.19 mg L^{-1}).

Regarding the B content, non-herbal *Kunapajala* registered a maximum B content (4.86 mg L^{-1}), followed by herbal preparation (4.45 mg L^{-1}), FAA (3.40 mg L^{-1}) and Panchagavya (2.50 mg L^{-1}). With respect to sodium content, a beneficial element, Panchagavya recorded the lowest value for Na content (8ppm) superseded by FAA (0.13%), herbal *Kunapajala* (0.20%) and non-herbal *Kunapajala* (0.24%).

4.1.2.5 Biological and biochemical properties of liquid organic manures

Biological and biochemical properties of *Kunapajala*, FAA and Panchagavya are presented in table 8. Considering the bacterial count, non- herbal *Kunapajala* recorded the highest value of 8.43 log cfu ml^{-1} followed by Panchagavya (8.25 log cfu ml^{-1}), herbal *Kunapajala* (8.15 log cfu ml^{-1}), and FAA (7.83 log cfu ml^{-1}). FAA registered the highest fungal count (4.54 log cfu ml^{-1}),

Table 7. Micro and beneficial nutrient contents of organic liquid manures

	Herbal *Kunapajala*	Non-herbal *Kunapajala*	Panchagavya	FAA
Total Fe (mg L^{-1})	7.55	12.30	7.23	5.14
Total Mn (mg L^{-1})	0.87	1.04	0.23	0.19
Total Cu (mg L^{-1})	0.21	0.25	1.56	0.45
Total Zn (mg L^{-1})	0.58	0.61	0.49	1.93
Total Na %	0.20	0.24	0.0008	0.13
Total B (mg L^{-1})	4.45	4.86	2.50	3.40

Table 8. Biological and biochemical qualities of organic liquid manures

	Herbal *Kunapajala*	Non herbal *Kunapajala*	Pancha-gavya	FAA
Bacteria (log cfu ml $^{-1}$)	8.15	8.43	8.25	7.83
Fungi (log cfu ml $^{-1}$)	3.80	3.98	4.13	4.54
Actinomycetes (log cfu ml $^{-1}$)	0.00	0.00	0.00	0.00
Dehydrogenase activity (µg of TPF g^{-1} soil 24 h^{-1})	99.21	126.00	265.46	330.56
Ascorbic acid (mg 100 g^{-1})	19.23	21.63	16.82	33.65
Total Sugar %	2.66	2.01	3.01	10.25

followed by Panchagavya (4.13 log cfu ml^{-1}), non-herbal *Kunapajala* (3.98 log cfu ml^{-1}), and herbal *Kunapajala* (3.80 log cfu ml^{-1}). But no actinomycetes were found in these organic liquid manures.

Data indicated that the FAA recorded maximum dehydrogenase activity (330.56 μg of TPF g^{-1} soil 24 h^{-1}) and there after Panchagavya (265.46 μg of TPF g^{-1} soil 24 h^{-1}), non-herbal *Kunapajala* (126.00 μg of TPF g^{-1} soil 24 h^{-1}) and herbal *Kunapajala* (99.21 μg of TPF g^{-1} soil 24 h^{-1}). Regarding the ascorbic acid content of organic liquid manures, FAA registered the highest value (33.65 mg 100 g^{-1}) followed by non-herbal *Kunapajala* (21.63 mg 100 g^{-1}), herbal *Kunapajala* (19.23 mg 100 g^{-1}) and Panchagavya (16.82 mg 100 g^{-1}). It is evident from the table 8 that FAA had recorded the highest total sugar (10.25%) content. Panchagavya, non-herbal *Kunapajala* and herbal *Kunapajala* registered a total sugar content of 3.01%, 2.01% and 2.66% respectively.

PART II

4.2 LABORATORY INCUBATION STUDY

A laboratory incubation study was carried out to monitor the nutrient release pattern of herbal and non-herbal *Kunapajala*. The sampling was done at 0^{th}, 7^{th}, 15^{th}, 30^{th}, 45^{th} and 60^{th} day of incubation and the pH, EC, OC and available nutrients were estimated and are presented in tables 9-23.

4.2.1 pH

The variation in pH of the soil due to the treatments is represented in table 9. As evidenced from the table 9, there was no significant changes in pH throughout the incubation period due to the treatments.

4.2.2 EC

The table 10 portrays EC of soil at various intervals of incubation. It was observed that the electrical conductivity increased throughout the incubation period but no significant difference was noticed between treatments except on 0^{th} day. The highest mean value of electrical conductivity was recorded by the treatment with

Table 9. Changes in pH of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	5.57	5.59	5.76	5.85	5.90	5.94
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	5.58	5.75	5.81	5.85	5.93	5.97
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	5.65	5.75	5.85	5.86	5.94	6.02
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	5.69	5.70	5.81	5.88	5.90	6.02
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	5.69	5.77	5.84	5.91	5.94	6.00
SE (m)	0.066	0.069	0.054	0.047	0.064	0.041
CD (0.05)	NS	NS	NS	NS	NS	NS

Table 10. Changes in EC (dS m^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	0.137	0.140	0.174	0.179	0.180	0.217
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	0.156	0.163	0.182	0.187	0.195	0.297
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	0.177	0.165	0.193	0.194	0.208	0.246
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	0.204	0.206	0.218	0.220	0.245	0.290
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	0.187	0.191	0.206	0.207	0.217	0.314
SE (m)	0.009	0.015	0.023	0.016	0.023	0.031
CD (0.05)	0.023	NS	NS	NS	NS	NS

5% herbal *Kunapajala* on 0th day (0.204 dS m^{-1}), 7th day (0.206 dS m^{-1}), 15th day (0.218 dS m^{-1}), 30th day (0.220 dS m^{-1}), and 45th day (0.245 dS m^{-1}), followed by the treatment T_5. The soil + FYM (T_1) treatment registered the lowest mean value for electrical conductivity.

4.2.3 Organic Carbon

The mean values of OC of soil incubated for 60 days at various intervals are given in table 11. The data indicated that herbal and non-herbal *Kunapajala* at 2% and 5% concentrations significantly influenced the organic carbon content throughout the incubation period. Organic carbon content of soil increased up to 15th day of incubation and recorded the highest value for all the treatments and thereafter showed a declining trend. It was statistically observed from the data that the soil treated with 5% non-herbal *Kunapajala* had the highest organic carbon content throughout the incubation period. On 0th day and 15th day, the treatments T_5 &T_4 were found to be significantly on par. The lowest value was noticed by the soil + FYM (T_1) treatment. On 7th day of incubation T_5 significantly differed from T_4, which was on par with T_3. Same trend was observed on 45th day of incubation also. The organic carbon content of soil treated with 2 % herbal *Kunapajala* was on par with soil + FYM treatment on 0th and 7th day of incubation.

4.2.4 Available N

The available nitrogen content in soil of laboratory incubation study is presented in table 12. The data represented the mean value of available nitrogen and it indicated that there was significant difference among the treatments at all periods of incubation. The highest nitrogen content was observed in T_5 while the lowest value for T_1 throughout the incubation period. Each treatment was significantly different from one another on 0th, 7th, 30th, 45th and 60th day of incubation. On 0th day of incubation, T_5 had recorded the highest nitrogen content (173.1 kg ha^{-1}) follsowed by T_4 (161.9 kg ha^{-1}), which was on par with T_3 (158.1 kg ha^{-1}). The highest mean value of 204.7 kg ha^{-1} was recorded by T_5 on 15th day of incubation, which was on par with T_4 (197.0 kg ha^{-1}) and T_3 (193.1 kg ha^{-1}). The highest

Table 11. Changes in Organic Carbon (%) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	0.39	0.94	1.16	0.37	0.47	0.45
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	0.41	1.03	1.97	0.45	0.67	0.57
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	0.48	1.15	2.66	0.56	0.74	0.63
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	0.54	1.28	2.79	0.68	0.77	0.70
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	0.61	1.79	2.90	0.74	0.85	0.81
SE (m)	0.035	0.063	0.047	0.012	0.015	0.011
CD (0.05)	0.093	0.199	0.140	0.036	0.041	0.037

Table 12. Changes in available Nitrogen content (kg ha^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	122.9	136.5	175.6	165.2	177.8	132.4
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	143.2	141.3	185.6	189.9	234.6	187.4
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	158.1	156.1	193.1	210.1	252.5	199.8
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	161.9	166.9	197.0	202.2	259.6	215.4
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	173.1	177.7	204.7	229.7	293.4	275.5
SE (m)	2.27	1.19	4.17	2.86	2.23	2.67
CD (0.05)	6.85	3.61	12.57	8.60	6.71	8.05

nitrogen release was observed on 45th day of incubation by all the treatments and thereafter declined. Among the treatments 5% non- herbal *Kunapajala* (T_5) recorded the highest value (293.4 kg ha^{-1}) on 45th day and later declined to 275.5 kg ha^{-1} on 60th day of incubation.

4.2.5 Available P

Table 13 delineate the available phosphorus content in soil of laboratory incubation study. The perusal of the data indicated that available phosphorus content increased up to 30th day of incubation and then started declining and indicated a drastic reduction on 60th day of incubation. The treatment received 5% non- herbal *Kunapajala* maintained maximum P status throughout the incubation period. The maximum value of 62.4 kg ha^{-1} was observed by T_5 on 0th day of incubation and which was significantly different from other treatments T_4 (58.0 kg ha^{-1}), T_3 (52.3 kg ha^{-1}), T_2 (43.8 kg ha^{-1}) and T_1 (40.0 kg ha^{-1}). On 7th day, the maximum P content was recorded by T_5 (62.7 kg ha^{-1}), followed by T_4 (58.7 kg ha^{-1}), which was on par with T_3 (56.6 kg ha^{-1}). The lowest value of P content was noticed by T_1 (46.2 kg ha^{-1}). The treatment T_5 (5 kg soil + FYM + 5% non- herbal *Kunapajala*) had the highest values for available P content throughout the incubation period and found to be statistically different from all other treatments.

4.2.6 Available K

Significant difference was observed between treatments (Table 14). The K content increased up to 45th day of incubation and then declined. The treatment 5% herbal recorded the highest value for K at all stages of incubation preceded by 5% non- herbal *Kunapajala*. The maximum value of 379.8 kg ha^{-1} was recorded by T_4 at 45th day of incubation which was found to be on par with T_5 (368.2 kg ha^{-1}). The K content of 5% non- herbal *Kunapajala* was statistically on par with T_2 (2% herbal) and T_3 (2% non- herbal) all throughout the incubation period except 45th day and 60th day of incubation. The lowest value for available K content was observed by T_1 (soil + FYM) treatment.

Table 13. Changes in available Phosphorus content (kg ha^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	40.0	46.2	49.0	61.0	57.9	19.9
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	43.8	54.0	52.1	64.0	61.0	23.8
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	52.3	56.6	54.4	68.8	68.1	25.6
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	58.0	58.7	56.9	72.1	71.6	28.5
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	62.4	62.7	60.9	78.4	76.3	44.5
SE (m)	0.52	1.13	0.33	0.49	0.35	0.67
CD (0.05)	1.52	1.51	0.99	1.48	1.03	2.00

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

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	262.1	278.6	286.3	262.8	294.4	217.1
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	292.3	284.6	299.8	304.5	324.3	219.4
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	305.8	294.7	307.9	302.8	347.2	253.7
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	336.0	341.8	334.8	349.5	379.8	282.4
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	292.3	304.7	310.3	314.4	368.2	280.8
SE (m)	7.61	9.59	6.88	8.28	8.15	5.35
CD (0.05)	22.90	28.80	20.74	24.95	24.96	16.39

62

4.2.7 Exchangeable Ca

The variation in exchangeable Ca content is presented in table 15. In general, the Ca content increased upto 15^{th} day of incubation and then a decline was observed in Ca content. The highest Ca content was observed in T_5 all throughout the incubation period. The Ca content of T_5 (5 Kg soil + FYM + 5% non-herbal *Kunapajala*) was 204.0 mg kg^{-1} (0^{th} day), 212.3 mg kg^{-1} (7^{th} day), 261.7 mg kg^{-1} (15^{th} day), 197.0 mg kg^{-1} (30^{th} day), 240.7 mg kg^{-1} (45^{th} day) and 229.0 mg kg^{1}(60^{th} day) which was found to be on par with T_4 (on 0^{th}, 7^{th},30^{th},45^{th} and 60^{th} day of incubation), T_3 (on 7^{th},30^{th},and 60^{th} day of incubation) and T_2 (on 15^{th} and 45^{th} day of incubation). The lowest value for exchangeable Ca content was observed in treatment T_1 (Soil 5kg + FYM) throughout the experiment.

4.2.8 Exchangeable Mg

Under laboratory condition the exchangeable Mg content (Table 16) in soil increased up to 30^{th} day of incubation, then decreased and later increased at the end of the experiment. The treatment soil + FYM + 5% non-herbal *Kunapajala* recorded the highest Mg content and was found to be significantly different from all the other treatments at all intervals. The highest value was recorded by T_5 on 30^{th} day of incubation (73.78 mg kg^{-1}). T_5 was followed by T_4 (soil+ FYM + 5% Herbal *Kunapajala*) throughout the incubation period, which was on par with T_3 (Soil+ FYM+ 2% non-herbal *Kunapajala*) on 0^{th} and 15^{th} day of incubation.

4.2.9 Available S

A significant effect due to the imposement of treatments in available S content all throughout the incubation period was recorded. (Table 17). The S content increased up to 30^{th} day of incubation. The treatment T_5 (soil 5kg+ FYM+ 5% non- herbal *Kunapajala*) maintained the highest value for soil available S at all sampling stages. Soil + FYM treatment had the least available S content.

Table 15. Changes in exchangeable Calcium content (mg kg^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	147.0	177.5	186.3	160.1	175.9	186.5
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	172.5	187.7	240.2	165.8	226.1	192.4
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	179.0	194.8	221.4	184.5	199.8	217.1
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	196.8	201.3	219.2	194.4	222.5	217.8
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	204.0	212.3	261.7	197.0	240.7	229.0
SE (m)	5.83	7.08	9.09	7.19	10.46	9.68
CD (0.05)	17.57	21.36	27.38	21.66	31.51	29.19

Table 16. Changes in exchangeable Magnesium content (mg kg^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	17.64	14.05	29.78	55.13	33.90	28.80
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	29.26	22.88	44.85	55.63	39.10	45.60
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	36.80	32.58	47.54	56.10	40.60	56.63
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	39.13	42.30	48.87	66.06	56.70	66.00
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	46.31	47.55	56.44	73.78	65.70	74.20
SE (m)	2.03	1.07	1.43	1.45	1.92	1.49
CD (0.05)	6.11	3.24	4.31	4.36	5.79	4.49

Table 17. Changes in available Sulphur content (mg kg^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	8.20	10.90	11.20	15.40	1.90	8.10
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	10.00	13.40	15.20	26.00	4.50	12.90
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	13.00	15.40	20.00	35.40	8.00	20.80
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	16.10	17.90	25.90	44.40	12.40	27.50
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	19.10	19.60	36.30	57.50	19.00	33.70
SE (m)	0.41	0.22	0.46	0.89	0.34	0.89
CD (0.05)	1.24	0.66	1.39	2.68	1.03	2.65

4.2.10 Available B

Data on the available B content due to treatment effects during incubation period are presented in table 18. The available B content increased in all the treatments until 15th day except in T_4 and T_5 where it continued to increase up to 30th day. The treatment with 5% non- herbal *Kunapajala* had the highest B content at all levels of sampling and was found to have significant difference from all other treatments. The highest B content was recorded in T_5 (Soil+ FYM+ 5% non-herbal *Kunapajala*) at 30th day of incubation (0.56 mg kg^{-1}) while the lowest B content was noticed in T_1 (Soil +FYM) throughout the experiment.

4.2.11 Available Fe, Mn, Zn and Cu

Under laboratory conditions, the different treatments did not impart significant difference in the micronutrient contents such as Zn and Cu. But as evidenced from the table 19 and 20, it is clear that different treatments significantly influenced the iron and manganese contents. At 0th day of incubation there was no significant variation in Fe content. The Fe content increased upto 45th day of incubation and then decreased at the end of the experiment (Table 19). Treatment T_5 recorded the highest while T_1 recorded the lowest iron content at all intervals of sampling. At 7th, 15th and 45th day of incubation, T_5 was significantly superior to other treatments while at 30th and 60th day of incubation, T_5 showed on par values with T_4 and T_3.

It was observed from the data (Table 20) that Mn content increased upto 15th day of incubation and thereafter declined. The treatments significantly influenced the Mn content in soil. The highest mean value for Mn content was observed in T_5 throughout the experiment and lowest with T_1. Treatment T_5 was statistically superior than others except at 15th day of incubation. T_5, T_4 and T_3 exhibited on par values of 24.03 mg kg^{-1}, 23.48 mg kg^{-1}, and 23.18 mg kg^{-1} respectively on 15th day of incubation.

Table 18. Changes in available Boron content (mg kg^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	0.02	0.11	0.23	0.05	0.02	0.05
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	0.04	0.19	0.25	0.13	0.08	0.11
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	0.06	0.22	0.26	0.24	0.12	0.16
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	0.07	0.24	0.32	0.37	0.14	0.24
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	0.08	0.36	0.47	0.56	0.18	0.33
SE (m)	0.003	0.014	0.026	0.015	0.006	0.011
CD (0.05)	0.01	0.047	0.073	0.049	0.019	0.031

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

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	14.10	14.20	15.60	19.68	20.10	17.85
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	14.43	14.40	16.7	21.38	22.08	18.68
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	14.88	15.25	16.57	25.05	25.55	21.53
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	15.05	15.62	21.12	27.28	28.20	21.98
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	15.10	17.60	25.85	27.93	30.53	22.45
SE (m)	0.282	0.351	0.383	0.464	0.622	0.542
CD (0.05)	NS	1.058	1.145	1.395	1.879	1.632

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

Treatments	0th	7th	15th	30th	45th	60th
T_1: Soil 5kg + FYM	14.93	15.40	22.35	12.20	14.80	13.35
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	17.18	19.18	23.03	13.73	15.63	13.38
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	18.25	19.95	23.18	15.00	15.85	16.00
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	19.08	21.45	23.48	15.53	16.80	16.30
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	21.68	27.10	24.03	18.10	21.08	17.15
SE (m)	0.355	0.712	0.318	0.295	0.268	0.272
CD (0.05)	1.071	2.151	0.953	0.884	0.818	0.816

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

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	3.86	4.07	4.21	4.00	4.04	4.03
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	4.04	4.09	4.24	4.08	4.06	4.03
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	4.11	4.22	4.25	4.11	4.15	4.10
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	4.14	4.31	4.28	4.31	4.15	4.11
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	4.19	4.36	4.60	4.31	4.22	4.26
SE (m)	0.22	0.15	0.16	0.29	0.10	0.13
CD (0.05)	NS	NS	NS	NS	NS	NS

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

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1 : Soil 5kg + FYM	1.55	1.58	1.68	1.64	1.81	1.91
T_2 : Soil 5kg + FYM + 2% herbal *Kunapajala*	1.56	1.65	1.75	1.70	1.82	1.94
T_3 :Soil5kg + FYM + 2% non-herbal *Kunapajala*	1.61	1.65	1.82	1.74	1.84	1.96
T_4 : Soil5kg + FYM + 5% herbal *Kunapajala*	1.68	1.67	1.83	1.81	1.90	1.98
T_5 :Soil5kg + FYM + 5% non-herbal *Kunapajala*	1.70	1.83	1.85	2.38	1.94	1.99
SE (m)	0.080	0.077	0.106	0.377	0.071	0.102
CD (0.05)	NS	NS	NS	NS	NS	NS

No significant difference could be noticed among the treatments with regards to the available Zn content (Table 21). The values ranged from 3.86 mg kg^{-1} to 4.60 mg kg^{-1}.

Cu content of the incubation study is presented in the table 22. The available Cu content did not differ significantly among the treatments throughout the study period. In general, the Cu content increased upto 60th day of incubation. The values showed a narrow range in all the treatments from 1.55 mg kg^{-1} to 2.38 mg kg^{-1}. The highest value (2.38 mg kg^{-1}) was recorded for the treatment receiving 5% non-herbal *Kunapajala* at 30th day of incubation.

4.2.12 Available Na

The mean values of available Na content of incubation study are presented in table 23. An increase in Na content was observed until 45th day of incubation and then decreased at the end of the experiment. T_1 recorded the highest Na content at all levels of sampling except at 0th day of incubation. On 0th day the highest mean value was recorded by T_4 (Soil 5kg+ FYM+ 5% herbal *Kunapajala*) with 194.90 mg kg^{-1} which was found to be on par with T_5 (191.50 mg kg^{-1}), T_3 (188.20 mg kg^{-1}) and T_2 (181.40 mg kg^{-1}). Soil + FYM (T_1) treatment recorded the highest Na content (463.90 mg kg^{-1}) at 45th day of incubation and then T_2 (305.20 mg kg^{-1}) which was on par with T_3 (296.80 mg kg^{-1}) and T_4 (281.60 mg kg^{-1}).

In general, under laboratory conditions the treatment receiving 5% non-herbal *Kunapajala* (T_5) registered the highest nutrient contents and soil + FYM (T_1) without any *Kunapajala* treatment was found to be inferior at all intervals of sampling in the incubation study.

PART III

Field experiment

A field experiment was conducted to evaluate the efficacy of soil and foliar application of herbal and non-herbal *Kunapajala* on soil health and crop nutrition using bhindi as a test crop in the Model Organic Farm, under the Department of

Table 23. Changes in available Sodium content (mg kg^{-1}) of soil during incubation period

Treatments	0^{th}	7^{th}	15^{th}	30^{th}	45^{th}	60^{th}
T_1: Soil 5kg + FYM	174.70	220.60	263.60	290.90	463.90	222.80
T_2: Soil 5kg + FYM + 2% herbal *Kunapajala*	181.40	218.60	203.60	288.00	305.20	194.20
T_3: Soil 5kg + FYM + 2% non-herbal *Kunapajala*	188.20	212.50	196.70	229.20	296.80	183.20
T_4: Soil 5kg + FYM + 5% herbal *Kunapajala*	194.90	211.20	211.80	225.40	281.60	186.70
T_5: Soil 5kg + FYM + 5% non-herbal *Kunapajala*	191.50	193.10	209.50	221.60	265.70	177.30
SE (m)	4.51	3.85	8.05	2.74	9.07	5.59
CD (0.05)	13.59	11.59	24.25	8.26	27.37	16.82

Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during the period from November 2018- February 2019.

4.3.1 Biometric observations

4.3.1.1 Height of plants

The effects of treatments on height of bhindi plants at first and final harvest was found to be significant. Perusal of the data (Table 24) indicated that treatment receiving 50% N as FYM + 5% non-herbal *Kunapajala* as foliar application recorded the highest plant height at first harvest (74.93 cm) and final harvest (124.43 cm) which was on par with T_{12}, T_{11},T_{10}, and T_8 at first harvest and on par with T_{12}, T_{11}, T_{10}, T_8 and T_3 at final harvest. The lowest value was registered by T_5 at first harvest (45.27 cm) and the final harvest (87.07 cm) and was significantly inferior than all other treatments.

4.3.1.2 Number of branches

Data furnished in the table 25 represented the mean values of number of branches. It is evident from the data that there was significant difference in the number of branches among the treatments. The highest mean value (3.73) was observed by the treatment T_{13} (50% N as FYM+ 5% non-herbal *Kunapajala* as foliar application) which was found to be significantly different from all other treatments. T_{13} was followed by T_{12} (50% N as FYM+ 2% non-herbal *Kunapajala* as foliar application) and the lowest value (1.70) was noticed by the treatment T_5 (50% N as FYM+ Water).

4.3.1.3 Dry matter production

Scrutiny of the data (Table 25) indicated that the treatment application significantly influenced the dry matter production. Each treatment was significantly different from one another and the treatment that received 5% non- herbal *Kunapajala* as foliar application recorded the highest dry matter production (3845.51 kg ha^{-1}) succeeded by T_{12} (3682.24 kg ha^{-1}) T_{11} (3565.31 kg ha^{-1}), and

Table 24. Plant height (cm) affected by different treatments on bhindi

Treatments	First harvest (cm)	Final harvest (cm)
T_1	56.65	104.60
T_2	56.79	104.67
T_3	62.10	111.20
T_4	59.20	106.43
T_5	45.27	87.07
T_6	52.03	97.17
T_7	61.08	109.30
T_8	66.40	114.83
T_9	56.47	100.73
T_{10}	65.87	113.73
T_{11}	69.64	121.40
T_{12}	72.40	123.60
T_{13}	74.93	124.43
SE	3.170	4.766
CD (0.05)	9.255	13.993

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

Table 25. Number of branches, leaf area index and dry matter production as influenced by different treatments on bhindi

Treatments	Number of branches per plant	Leaf area index	Dry matter production (kg ha^{-1})
T_1	2.60	0.99	3066.44
T_2	2.80	0.39	2971.48
T_3	1.87	0.56	3092.09
T_4	2.43	0.59	2875.34
T_5	1.70	0.33	2525.21
T_6	2.80	0.54	2733.19
T_7	2.40	0.78	2771.02
T_8	2.47	0.87	3240.86
T_9	2.50	0.81	3326.97
T_{10}	2.60	0.84	3563.04
T_{11}	2.77	0.80	3565.31
T_{12}	3.17	1.03	3682.24
T_{13}	3.73	1.42	3845.51
SE	0.119	0.099	10.253
CD (0.05)	0.345	0.290	30.091

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

T_{10} (3563.04 kg ha^{-1}) and the lowest value of 2525.21 kg ha^{-1} was recorded by the treatment T_5 (50% N as FYM+ Water).

4.3.1.4 Leaf area index (LAI)

Leaf area index at first harvest (Table 25) was significantly influenced by the treatments and the best index (1.42) was reported with foliar application of 5% non- herbal *Kunapajala* along with 50% N as FYM (T_{13}) followed by foliar application of 2% non-herbal *Kunapajala* with 50 % N as FYM (1.03). T_{12} was statistically on par with T_{11} (0.80), T_{10} (0.84), T_9 (0.81), T_8 (0.87), T_7 (0.78), and T_1 (0.99). Treatment with water + 50% N as FYM (T_5) registered a least LAI (0.33) which was on par with organic Adhoc POP (0.39).

4.3.2 Physiological characters

Physiological characters such as chlorophyll a, chlorophyll b, and total chlorophyll contents were analysed and are depicted in the table 26. It is evident from the data that there were significant variations among the treatments. Chlorophyll a content was highest in T_1, KAU POP (0.433 mg g^{-1}) which was on par with T_{13} (0.426 mg g^{-1}), T_9 (0.396 mg g^{-1}), T_8 (0.400 mg g^{-1}) and T_{10} (0.390 mg g^{-1}), T_{11} (0.396 mg g^{-1}).

The highest chlorophyll b content (1.030 mg g^{-1}) was observed in T_{13} (50% N as FYM + 5% non-herbal *Kunapajala*) and was found to be statistically on par with T_8 (1.010 mg g^{-1}), T_9 (1.000 mg g^{-1}), and T_{11} (0.993 mg g^{-1}).

Treatment receiving foliar application of 5% non-herbal *Kunapajala* had higher total chlorophyll content (1.456 mg g^{-1}) which was on par with T_1 (1.416 mg g^{-1}), and T_8 (1.415 mg g^{-1}).

The lowest value of chlorophyll content (Chlorophyll a, Chlorophyll b and Total Chlorophyll) was recorded by T_5 (50% N as FYM+ Water) and was significantly inferior than all other treatments.

Table 26. Chlorophyll a, chlorophyll b and total chlorophyll content as effected by different treatments on bhindi

Treatments	Chlorophyll a ($mg\ g^{-1}$)	Chlorophyll b ($mg\ g^{-1}$)	Total chlorophyll content ($mg\ g^{-1}$ tissue)
T_1	0.433	0.976	1.416
T_2	0.393	0.973	1.388
T_3	0.376	0.893	1.282
T_4	0.386	0.990	1.364
T_5	0.320	0.880	1.252
T_6	0.380	0.936	1.334
T_7	0.393	0.973	1.363
T_8	0.400	1.010	1.415
T_9	0.396	1.000	1.396
T_{10}	0.390	0.990	1.381
T_{11}	0.396	0.993	1.389
T_{12}	0.380	0.980	1.359
T_{13}	0.426	1.030	1.456
SE	0.013	0.011	0.010
CD (0.05)	0.038	0.037	0.042

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

4.3.3 Yield characters

4.3.3.1 Days to first flowering

The table 27 depicted that days taken for first flowering varied significantly among the treatments. The treatments receiving 5% fish amino acid, 5% herbal *Kunapajala* as foliar application, and 2% non-herbal *Kunapajala* as soil application flowered earlier, and was found to be on par with T_{13}, T_{12}, T_{10}, T_9, T_7 and T_1. The flowering was delayed by 2-3 days in all other treatments. The plants which received 50% N as FYM + Water (T_5) were last to flower.

4.3.3.2 Days to 50% flowering

The mean values of days taken for 50% flowering are furnished in table 27. From the table 27, it was inferred that there was significant difference among treatments. Treatment receiving foliar application of 5% non -herbal *Kunapajala* recorded 50% flowering at the earliest (39.33 days) and was found to be on par with T_{12} (39.67 days) and T_9 (40.67 days) while T_5 took the highest number of days to 50% flowering (45.67).

4.3.3.3 Number of fruits

Results of the statistical analysis of the data (Table 28) on number of fruits revealed that the treatment effects were significantly different. The treatment with 5% non- herbal *Kunapajala* as foliar application had recorded the highest (25.50) number of fruits per plant and was found to be on par with T_{12} (2% non -herbal *Kunapajala* as foliar application-24.80). The minimum number of fruits per plant was recorded by T_2 (13.70).

4.3.3.4 Length of fruits

Data in table 28 indicated that the length of fruits varied significantly among treatments. T_{13} (50% N as FYM+ 5% non-herbal *Kunapajala* as foliar application)

Table 27. Effect of treatments on days to first flowering and days to 50% flowering of bhindi

Treatments	Days to first flowering	Days to 50% flowering
T_1	36.33	41.00
T_2	37.00	42.00
T_3	37.00	41.67
T_4	36.00	41.33
T_5	39.33	45.67
T_6	37.00	41.00
T_7	36.33	41.33
T_8	36.00	41.67
T_9	36.67	40.67
T_{10}	36.67	41.33
T_{11}	36.00	41.00
T_{12}	36.33	39.67
T_{13}	36.33	39.33
SE	0.286	0.495
CD (0.05)	0.833	1.448

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

Table 28. Effect of treatments on fruit characters of bhindi

Treatments	Number of fruits	Length of fruits (cm)	Girth of fruit (cm)	Average fruit weight (g)
T_1	16.70	15.07	6.55	18.10
T_2	13.70	13.98	6.48	14.50
T_3	17.50	14.57	6.60	15.90
T_4	17.30	13.55	6.42	16.80
T_5	14.20	11.48	5.38	10.20
T_6	18.60	13.42	6.43	18.10
T_7	18.90	14.41	6.58	19.20
T_8	18.70	14.56	6.54	19.20
T_9	19.10	14.92	6.71	19.60
T_{10}	19.30	15.01	6.74	19.50
T_{11}	19.60	14.81	6.72	20.80
T_{12}	24.80	14.30	6.77	20.70
T_{13}	25.50	15.24	7.22	22.30
SE	0.269	0.395	0.110	0.357
CD (0.05)	0.782	1.151	0.328	1.044

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

recorded maximum fruit length (15.24 cm) which was found to be statistically on par with other treatments except T_2, T_4, T_5 and T_6.

4.3.3.5. Girth of fruits

Girth of fruits is shown in table 28. Different treatments had significant influence on girth of fruits. T_{13} (50% N as FYM+ 5% non-herbal *Kunapajala* as foliar application) recorded maximum girth (7.22 cm) of fruits followed by T_{12} (6.77 cm) which was on par with all other treatments except T_4, T_5 and T_6.

4.3.3.6. Average fruit weight

Scrutiny of the data (Table 28) revealed that average fruit weight varied significantly with the treatments. Treatment T_{13} registered the highest fruit weight (22.30 g) which was statistically superior than all other treatments. T_{13} was succeeded by T_{11}, which received 50% N as FYM+ 5% herbal *Kunapajala* as foliar application (20.80 g) which was on par with T_{12} (20.70 g). The lowest value was recorded by T_5 (10.20 g) which was significantly lesser than all other treatments.

4.3.3.7 Total fruit yield t ha^{-1}

Perusal of the data in table 29 indicated that treatments significantly influenced the fruit yield of bhindi. The highest yield (20.78 t ha^{-1}) was recorded with the treatment that received 5% non-herbal *Kunapajala* as foliar application along with 50% N as FYM which was found to be on par with T_{12} (20.06 t ha^{-1}). The lowest yield of 14.27 t ha^{-1} was observed in T_5 which was found to be statistically on par with T_3 (Organic Adhoc POP + 3% Panchagavya) and T_4 (Organic Adhoc POP + 5% FAA) which recorded a yield of 14.74 t ha^{-1} and 14.95 t ha^{-1} respectively.

4.3.4 Quality parameters of fruit

4.3.4.1 Crude protein content (%)

Analysis of the data in the table 30 indicated that crude protein varied significantly. T_4 (Organic Adhoc POP + 5% FAA) recorded the highest value of

Table 29. Effect of treatments on yield of bhindi

Treatments	Yield (t ha^{-1})
T_1	19.14
T_2	16.22
T_3	14.74
T_4	14.95
T_5	14.27
T_6	16.07
T_7	15.98
T_8	16.44
T_9	16.88
T_{10}	17.93
T_{11}	18.39
T_{12}	20.06
T_{13}	20.78
SE	0.284
CD (0.05)	0.825

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

27.88% which was statistically on par with T_{13} (27.50 %), T_{10} (26.92 %) and T_{12} (26.81%). The treatments T_5 (13.37%) and T_1 (14.63%) had the lowest crude protein content.

4.3.4.2 Crude fibre content (%)

The crude fibre content of fruits as influenced by different treatments are presented in the table 30. Treatment T_5 (50% N as FYM + Water) registered the highest value for crude fibre content (17.40%) which was significantly different from other treatments. The lowest mean value was found in T_8 (4.91%) which was found to be statistically on par with T_{13} (5.37%), T_7 (5.43%) and T_{10} (5.73%).

4.3.4.3 Ascorbic acid content (mg 100 g $^{-1}$)

Imposition of treatments had significant influence in the ascorbic acid content (Table 30). T_{13} registered the highest mean value (22.83 mg 100 g $^{-1}$) for ascorbic acid content and was on par with T_{12} (22.54 mg 100 g $^{-1}$) and T_1 (22.04 mg 100 g $^{-1}$). Lowest mean value was recorded by T_5 (9.05 mg 100 g $^{-1}$).

4.3.5 Incidence of pest and diseases

The incidence of pest and diseases were monitored visually during the crop season. The incidence was not much severe. Yellowing of leaves was observed in a few plants excluding *Kunapajala* treated plants. Fruit and shoot borer attack were also observed in some plants and 5 per cent Nimbicidine was sprayed at fortnightly intervals to control vectors and other insects.

4.3.5 Soil analysis

The important physical, chemical and biological properties of the soil before and after the experiment.

4.3.5.1 Soil analysis before the experiment

The initial soil was sandy clay loam in texture with pH 5.25 and EC 0.179 dSm^{-1} (Table 31). Soil had medium organic carbon % (1.35%), low N content (169.5 kg ha^{-1}), high P (63.74 kg ha^{-1}) and medium K content (125.50 kg ha^{-1}).

Table 30. Effect of treatments on quality parameters of bhindi fruit

Treatments	Crude protein content %	Crude fibre content %	Ascorbic acid content mg 100 g^{-1}
T_1	14.63	12.37	22.04
T_2	17.10	6.33	12.20
T_3	20.44	10.47	17.70
T_4	27.88	13.13	10.72
T_5	13.37	17.40	9.05
T_6	23.83	12.17	14.23
T_7	23.89	5.43	12.13
T_8	22.54	4.91	16.37
T_9	25.80	8.37	17.84
T_{10}	26.92	5.73	18.65
T_{11}	26.13	8.20	20.61
T_{12}	26.81	6.40	22.54
T_{13}	27.50	5.37	22.83
SE	0.523	0.308	0.302
CD (0.05)	1.525	0.900	0.880

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

Regarding secondary nutrients Ca (327.50 mg kg^{-1}) and S (8.71 mg kg^{-1}) were in the sufficient range, while Mg was deficient (71.38 mg kg^{-1}). Soil contained sufficient quantities of micro nutrient such as Fe (18.87 mg kg^{-1}), Mn (18.88 mg kg^{-1}), Zn (5.44mg kg^{-1}), and Cu (2.04 mg kg^{-1}), but B was deficient (0.051 mg kg^{-1}). The dehydrogenase enzyme activity and microbial load were very low.

4.3.5.2 Chemical analysis of post-harvest soil

4.3.5.2.1 Soil pH

The perusal of the data (Table 32) indicated that soil pH increased after the experiment and value ranged from strongly acidic to slightly acidic. Initial pH of the soil was 5.25 and increased to a range of 5.76 - 6.29. The treatments had significant influence on soil pH. The highest pH of 6.29 was recorded with T_2 (Organic Adhoc POP) and which was on par with T_4 (Organic Adhoc POP + 5% FAA) registered a pH value of 6.28.

4.3.5.2.2 Soil EC

Analysis of the data (Table 32) revealed that electrical conductivity of the soil varied significantly with treatments. The initial soil EC was 0.179 dSm^{-1} and it was enhanced after the experiment, but within the safe limit. The highest electrical conductivity was noticed by the treatment T_{13} (1.51 dSm^{-1}) which was significantly superior to all other treatments. The lowest mean value was recorded by T_5 (0.98 dSm^{-1})

4.3.5.2.3 Organic Carbon

The effects of treatments in soil organic carbon is presented in the table 32. The results pointed out that treatment application significantly influenced the organic carbon content of the soil. T_{13} showed significantly highest value (1.50%) which was found to be on par with, T_{11} (1.44%), T_{10} (1.41%) and T_{12} (1.40%). Lowest value was noticed by treatment received 50% N as FYM + Water. High organic carbon percentage was resulted with the treatment application.

Table 31. Physical, chemical, biological and biochemical properties of soil before the experiment

Sl. No.	Parameters	Content
	A. Physical Properties	
1	Mechanical composition	
	Sand (%) Silt (%) Clay (%)	70.07 15.38 27.21
2	Texture	Sandy clay loam
	B. Chemical Properties	
3	pH (1:2.5)	5.25
4	EC (1:2.5) dSm^{-1}	0.179
5	Organic carbon (%)	1.35
7	Available N (kg ha^{-1})	169.50
8	Available P (kg ha^{-1})	63.74
9	Available K (kg ha^{-1})	125.50
10	Exchangeable Ca (mg kg^{-1})	327.50
11	Exchangeable Mg (mg kg^{-1})	71.38
12	Available S (mg kg^{-1})	8.71
13	Available B (mg kg^{-1})	0.051
14	Micronutrients (mg kg^{-1})	
	Fe Mn Zn Cu	18.87 18.88 5.44 2.04
	C. Biochemical Properties	
15	Dehydrogenase (µg of $TPFg^{-1}soil\ 24h^{-1}$)	7.85
	D. Biological Properties	
16	Microbial count (log cfu g^{-1})	
	Bacteria Fungi Actinomycetes	6.88 3.37 4.10

Table 32. Effect of treatments on physico-chemical properties of soil (post-harvest analysis)

Treatments	pH	EC (dS m^{-1})	Organic carbon (%)
T_1	6.08	1.13	1.13
T_2	6.29	1.25	1.15
T_3	5.97	1.33	1.33
T_4	6.28	1.24	1.26
T_5	5.99	0.98	0.95
T_6	5.97	1.25	1.23
T_7	5.78	1.18	1.17
T_8	5.95	1.23	1.19
T_9	5.76	1.40	1.37
T_{10}	6.14	1.41	1.41
T_{11}	5.87	1.44	1.44
T_{12}	6.02	1.41	1.40
T_{13}	6.03	1.51	1.50
SE	0.053	0.011	0.039
CD (0.05)	0.150	0.031	0.110

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

4.3.5.2.4 Available Nitrogen

Perusal of the data (Table 33) indicated that available nitrogen content of the soil varied significantly with the treatments. The initial value was 169.5 kg ha^{-1} (low nitrogen status) and was enhanced to medium status of nitrogen content after the experiment. Highest available nitrogen content was recorded in T_{13} (363.8 kg ha^{-1}) which was statistically on par with T_{12} (351.2 kg ha^{-1}) and T_{10} (351.2 kg ha^{-1}). The lowest content was recorded in T_5 (225.8 kg ha^{-1}) and T_2 (225.8 kg ha^{-1}).

4.3.5.2.5 Available Phosphorus

The available P content in soil (Table 33) were very high in different treatments. Available P content of initial soil was 63.74 kg ha^{-1}. The treatments had significant influence on the soil P content. T_{13} (100.7 kg ha^{-1}) and T_{12} (100.7 kg ha^{-1}) registered higher available P content which was on par with T_9 (98.9 kg ha^{-1}). The treatment T_5 had the least available P content of 73.7 kg ha^{-1}. The treatments T_8, T_9, T_{10}, and T_{11} exhibited on par values of 96.8 kg ha^{-1}, 98.9 kg ha^{-1}, 97.1 kg ha^{-1} and 96.1 kg ha^{-1} respectively.

4.3.5.2.6 Available Potassium

Imposition of treatments had significant influence on soil available potassium. Available K content of soil before the experiment was 125.5 kg ha^{-1}. It is evident from the table 33 that the mean values of available K ranged from 100.8 kg ha^{-1} to 209.1 kg ha^{-1} (low status to medium status of soil K content). T_{13} (50% N as FYM+ 5% non -herbal *Kunapajala* as foliar application) registered the highest mean (209.1 kg ha^{-1}) which was on par with T_1 (201.6 kg ha^{-1}) and T_{12} (182.9 kg ha^{-1}). The lowest mean value of 100.8 kg ha^{-1} was recorded by T_5 (50% N as FYM+ Water).

4.3.5.2.7 Exchangeable Calcium

It is inferred from the table 34 that exchangeable Ca content was significantly influenced by different treatments. The initial Ca content in soil was 327.5 mg kg^{-1}. Exchangeable Ca content was sufficient in the treatment by receiving

Table 33. Available NPK status in soil at different treatments of the crop (kg ha^{-1})

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	255.1	83.8	201.6
T_2	225.8	93.1	156.8
T_3	238.3	90.0	149.3
T_4	238.3	94.8	130.7
T_5	225.8	73.7	100.8
T_6	238.3	84.6	168.0
T_7	250.9	94.4	156.8
T_8	263.4	96.8	168.0
T_9	276.0	98.9	156.8
T_{10}	351.2	97.1	175.5
T_{11}	288.5	96.1	179.2
T_{12}	351.2	100.7	182.9
T_{13}	363.8	100.7	209.1
SE	9.76	1.05	9.25
CD (0.05)	28.48	3.06	27.00

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

foliar applications of 2% and 5% non-herbal *Kunapajala* and 5% herbal *Kunapajala*. The maximum exchangeable Ca content was recorded by T_{13} (340.0 mg kg^{-1}) which was superior to all other treatments followed by T_{11} (310.0 mg kg^{-1}) which was found to be on par with T_{12} (300.0 mg kg^{-1}). T_5 was significantly inferior to all other treatments and recorded the least value of 220.0 mg kg^{-1}.

4.3.5.2.8 Exchangeable Magnesium

The data pertaining to exchangeable Mg content of soil after the experiment is given in table 34. Foliar application of 5% non-herbal *Kunapajala* (T_{13}) resulted in the highest exchangeable Mg content (124.0 mg kg^{-1}) which was found to be on par with foliar application of 2% herbal *Kunapajala* (116.0 mg kg^{-1}) and foliar application of 2% non-herbal *Kunapajala* (114.0 mg kg^{-1}). The initial value was 71.38 mg kg^{-1} and after the experiment, the lowest value of 84.0 mg kg^{-1} was recorded for the treatment T_6 which was on par with T_5 (88.0 mg kg^{-1}) and T_3 (90.0 mg kg^{-1}).

4.3.5.2.9 Available Sulphur

The results revealed that the applied treatments had significant effect on the available sulphur content of the soil (Table 34). The mean values showed sufficient status of available S ranging from 12.2 mg kg^{-1} to 28.5 mg kg^{-1}. The highest value of 28.5 mg kg^{-1} was recorded by T_{13} (50% N as FYM +5% non-herbal *Kunapajala* as foliar application) followed by T_{12} (26.5 mg kg^{-1}). Lowest mean value of 12.2 mg kg^{-1} was registered by T_5 which was statistically on par with T_4 (13.3 mg kg^{-1}) and T_1 (13.0 mg kg^{-1}).

4.3.5.2.10 Micronutrients

The micronutrient contents of soil influenced by different treatments is presented in table 35. Perusal of the data indicated that treatment T_{13} receiving 5% non-herbal *Kunapajala* as foliar application recorded highest value for available Zn content (10.38 mg kg^{-1}) followed by T_{12} (8.17 mg kg^{-1}). The treatments T_{12}, T_{11}, T_3, T_{10}, T_2, T_9, T_8 and T_4 exhibited on par values of 8.17 mg kg^{-1},7.83 mg kg^{-1},7.60 mg

Table 34. Effect of treatments on secondary nutrients in soil (mg kg^{-1})

Treatments	Calcium (mg kg^{-1})	Magnesium (mg kg^{-1})	Sulphur (mg kg^{-1})
T_1	280.0	102.0	13.0
T_2	263.3	96.0	16.0
T_3	250.0	90.0	17.3
T_4	280.0	108.0	13.3
T_5	220.0	88.0	12.2
T_6	280.0	84.0	16.7
T_7	270.0	106.0	21.3
T_8	290.0	110.0	23.0
T_9	270.0	106.0	23.5
T_{10}	280.0	116.0	22.0
T_{11}	310.0	108.0	22.7
T_{12}	300.0	114.0	26.5
T_{13}	340.0	124.0	28.5
SE	5.37	3.81	0.55
CD (0.05)	15.67	11.12	1.62

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

kg^{-1},7.41 mg kg^{-1},7.37 mg kg^{-1},7.30 mg kg^{-1},7.23 mg kg^{-1} and 7.14 mg kg^{-1} respectively.

The Fe contents of soil significantly varied with the treatments. The highest value of 13.77 mg kg^{-1} was recorded by the treatment T_{13} (5% non- herbal *Kunapajala* as foliar application) which was on par with T_2 (13.67 mg kg^{-1}) and T_{12} (12.83 mg kg^{-1}).

The treatment application showed significant influences in Mn status. The treatment T_{13} resulted in higher value for Mn content (35.12 mg kg^{-1}) which was statistically on par with T_1 (34.40 mg kg^{-1}).

Foliar application of 5% non-herbal *Kunapajala* recorded significantly higher Cu content (3.41 mg kg^{-1}) followed by T_1 (2.60 mg kg^{-1}) which was found to be on par with T_{12} (2.43 mg kg^{-1}), T_{11} (2.17 mg kg^{-1}), T_{10} (2.17 mg kg^{-1}) and T_2 (2.11 mg kg^{-1}).

The variation among treatments in B content of soil was found to be significant under field study as evident from the table 35. The mean values of all the treatments were very low and only T_{12} and T_{13} had exhibited sufficient range of available B content in soil. The available B content recorded in T_{13} was significantly superior being 0.52 mg kg^{-1} but was on par with T_{12} (0.50 mg kg^{-1}).

The treatment T_5 (50% N as FYM + Water) recorded significantly lower values for all micronutrients (Zn-4.72 mg kg^{-1}, Fe-10.87 mg kg^{-1}, Mn- 22.71 mg kg^{-1}, Cu- 1.36 mg kg^{-1} and B- 0.06 mg kg^{-1}).

4.3.5.3 Biochemical Analysis

4.3.5.3.1 Dehydrogenase enzyme activity

Considering the dehydrogenase enzyme activity, data (Table 36) revealed that a pronounced increase of enzyme activity occurred after the experiment. The enzyme activity of initial soil was 7.85 μg of TPF g^{-1} soil 24 h^{-1} and the mean values after the experiment ranged from 37.49 to 62.00 μg of TPF g^{-1}soil 24 h^{-1}. T_{13} had the highest mean value of 62.00 μg of TPF g^{-1}soil 24 h^{-1} and was on par with T_{12}

Table 35. Effect of treatments on micronutrient contents of the soil

Treatments	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
T_1	11.90	34.40	6.54	2.60	0.15
T_2	13.67	32.32	7.37	2.11	0.21
T_3	12.73	27.06	7.60	1.41	0.20
T_4	12.70	26.21	7.14	1.61	0.22
T_5	10.87	22.71	4.72	1.36	0.06
T_6	11.43	24.46	6.37	1.43	0.25
T_7	11.70	26.58	6.79	1.46	0.27
T_8	11.70	28.39	7.23	1.57	0.34
T_9	12.47	30.08	7.30	1.79	0.37
T_{10}	12.40	31.00	7.41	2.17	0.42
T_{11}	12.97	31.09	7.83	2.17	0.45
T_{12}	12.83	31.57	8.17	2.43	0.50
T_{13}	13.77	35.12	10.38	3.41	0.52
SE	0.256	0.085	0.439	0.175	0.009
CD (0.05)	0.771	2.489	1.288	0.515	0.022

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5% herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

(56.24 μg of TPF g $^{-1}$soil 24 h^{-1}). Even though T_5 had lower enzyme activity (37.49 μg of TPF g $^{-1}$soil 24 h^{-1}), it was found to be on par with T_1 (42.61 μg of TPF g $^{-1}$ soil 24 h^{-1}), T_2 (39.22 μg of TPF g^{-1} soil 24 h^{-1}), T_3 (44.91 μg of TPF g $^{-1}$soil 24 h^{-1}), T_4 (45.43 μg of TPF g $^{-1}$soil 24 h^{-1}), T_6 (44.27 μg of TPF g $^{-1}$soil 24 h^{-1}), and T_7 (46.13 μg of TPF g $^{-1}$soil 24 h^{-1}).

4.3.5.4 Biological Analysis

The data on microbial population in soil are furnished in table 36. Scrutiny of the data indicated that there were significant variations in the microbial count among the treatments. The bacterial, fungal and actinomycetes count of initial soil was 6.88, 3.37 and 4.1 log cfu g^{-1} soil respectively.

Regarding bacterial count, the highest bacterial population was noticed in T_{13} (9.04 log cfu g^{-1} soil) which was on par with T_{12} (9.03 log cfu g^{-1}), T_{11} (8.98 log cfu g^{-1} soil), T_{10} (8.97 log cfu g^{-1} soil), and T_9 (8.98 log cfu g^{-1} soil). T_5 recorded the lowest value of 8.43 log cfu g^{-1} soil.

The highest population of fungi (4.52 log cfu g^{-1} soil) was recorded in T_{13} which was significantly superior to all other treatments. T_{13} was followed by T_{12} (4.46 log cfu g^{-1} soil) and T_{11} (4.43 log cfu g^{-1} soil) and the lowest value of 4.07 log cfu g^{-1} soil was recorded in T_5.

The treatment T_{13} (50% N as FYM+ 5% non-herbal *Kunapajala* as foliar application) resulted in the highest actinomycetes count (5.53 log cfu g^{-1} soil) which was statistically superior to all other treatments. The lowest count was noticed in T_5 (4.94 log cfu g^{-1} soil).

4.3.6 Plant nutrient uptake

It is evident from the data that treatments significantly influenced the plant nutrient uptake.

Table 36. Influence of treatments on biological and biochemical properties of post-harvest soil

Treatments	Bacteria (log cfu g soil^{-1})	Fungi (log cfu g soil^{-1})	Actinomycetes (log cfu g soil^{-1})	Dehydrogenase (µg of TPFg^{-1} soil 24 h^{-1})
T_1	8.95	4.43	5.17	42.61
T_2	8.98	4.24	5.19	39.22
T_3	8.93	4.36	5.20	44.91
T_4	8.93	4.29	5.22	45.43
T_5	8.43	4.07	4.94	37.49
T_6	8.81	4.17	5.17	44.27
T_7	8.85	4.25	5.19	46.13
T_8	8.92	4.35	5.23	48.05
T_9	8.98	4.37	5.31	48.62
T_{10}	8.97	4.38	5.36	50.54
T_{11}	8.98	4.43	5.43	51.25
T_{12}	9.03	4.46	5.49	56.24
T_{13}	9.04	4.52	5.53	62.00
SE	0.035	0.015	0.007	3.549
CD (0.05)	0.102	0.043	0.027	10.36

T_1: KAU POP (FYM 20 t ha^{-1} NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5 % herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2% non- herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar applicatio

4.3.6.1 Nitrogen uptake

Significant difference was observed in the case of plant nitrogen uptake among the treatments as evidenced from the table 37.The treatment T_{13} (5% non-herbal *Kunapajala* as foliar application) had highest nitrogen uptake (119.73 kg ha^{-1}) followed by T_{11} (5% herbal *Kunapajala* as foliar application) with a value of 99.24 kg ha^{-1} which was on par with T_{12} (92.27 kg ha^{-1}), and T_{10} (90.88 kg ha^{-1}). T_5 recorded the least value of 44.63 kg ha^{-1}.

4.3.6.2 Phosphorus uptake

Perusal of the data (Table 37) indicated that treatment with 5% non- herbal *Kunapajala* as foliar application registered the highest phosphorus uptake (28.22 kg ha^{-1}) which was superior to all other treatments and T_5 recorded the least P uptake (5.63 kg ha^{-1}). T_{12} and T_{11} exhibited on par values of 22.79 kg ha^{-1} and 21.33 kg ha^{-1} respectively.

4.3.6.3 Potassium uptake

The details of K uptake (Table 37) showed that there was significant difference among treatments and T_{13} had superiorly higher potassium uptake (131.15 kg ha^{-1}) followed by T_{11} (110.28 kg ha^{-1}) which was statistically on par with T_{12} (103.90 kg ha^{-1}), and T_{10} (103.52 kg ha^{-1}). Treatment T_5 was significantly inferior to all other treatments (50.45 kg ha^{-1}) with respect to K uptake.

4.3.6.4 Calcium uptake

As depicted in table 38, treatment T_{13} had the highest mean value (66.53 kg ha^{-1}) for Ca uptake which was on par with T_{12} (64.59 kg ha^{-1}), and T_{11} (59.19 kg ha^{-1}). The treatment T_5 recorded the lowest value (33.39 kg ha^{-1}).

4.3.6.5 Magnesium uptake

The Mg content in the plant varied significantly among the treatments as presented in the table 38. For the uptake of magnesium, the highest value of 61.56

Table 37. Plant uptake of major nutrients as affected by different treatments ($kg\ ha^{-1}$)

Treatments	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)
T_1	60.02	10.06	82.58
T_2	60.75	9.77	78.07
T_3	65.73	11.22	74.27
T_4	81.97	11.55	71.22
T_5	44.63	5.63	50.45
T_6	73.04	11.20	68.20
T_7	75.65	13.02	73.95
T_8	78.18	15.69	89.77
T_9	85.25	16.02	93.01
T_{10}	90.88	19.19	103.52
T_{11}	99.24	21.33	110.28
T_{12}	92.27	22.79	103.90
T_{13}	119.73	28.22	131.15
SE	4.250	0.646	4.741
CD (0.05)	12.409	1.880	13.832

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5 % herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2 % non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

Table 38. Plant uptake of secondary nutrients as affected by different treatments

Treatments	Ca (kg ha^{-1})	Mg (kg ha^{-1})	S (kg ha^{-1})
T_1	51.79	39.42	11.10
T_2	43.11	29.97	11.20
T_3	51.54	28.49	12.96
T_4	48.24	35.64	10.79
T_5	33.39	12.99	8.43
T_6	43.63	29.59	10.67
T_7	42.48	30.00	11.99
T_8	46.92	31.65	16.10
T_9	54.61	39.01	11.75
T_{10}	55.87	44.42	17.00
T_{11}	59.19	50.88	17.01
T_{12}	64.59	55.03	13.96
T_{13}	66.53	61.56	20.32
SE	2.88	2.32	1.17
CD(0.05)	8.405	6.775	3.416

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5 % herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2 % non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

kg ha^{-1} was observed in T_{13} and was on par with T_{12} (55.03 kg ha^{-1}). The lowest value of 12.99 kg ha^{-1} was recorded by the treatment, T_5 (50% N as FYM + Water).

4.3.6.6 Sulphur uptake

The S uptake in plant tissue is presented in the table 38. For S uptake, T_{13} (50% N as FYM + 5% non-herbal *Kunapajala* as foliar application) recorded the highest value (20.32 kg ha^{-1}) and was on par with T_{11} (17.01 kg ha^{-1}), and T_{10} (17.00 kg ha^{-1}). T_5 recorded the lowest value of 8.43 kg ha^{-1}.

4.3.6.7 Iron uptake

Significant differences in iron uptake between the treatments were depicted in the table 39. The highest value for Fe uptake was 2.266 kg ha^{-1} in T_{13} followed by T_1 (1.636 kg ha^{-1}) and T_{11} (1.506 kg ha^{-1}) which were on par with T_{10} (1.456 kg ha^{-1}), T_{12} (1.390 kg ha^{-1}), T_8 (1.360 kg ha^{-1}), and T_2 (1.350 kg ha^{-1}). Treatment T_5 recorded the lowest value (0.596 kg ha^{-1}).

4.3.6.8 Manganese uptake

The values from the data (Table 39) make it clear that Mn uptake by the plants recorded significant difference among treatments. For the uptake of Mn, T_{13} registered the highest value of 0.551 kg ha^{-1} and T_5 recorded the least value of 0.163 kg ha^{-1}. The treatments T_{12}, T_{11} and T_{10} exhibited on par values, of 0.333 kg ha^{-1},0.336 kg ha^{-1} and 0.336 kg ha^{-1} respectively.

4.3.6.9 Zinc uptake

The Zn uptake by plant varied among the treatments and values ranged from 0.186 kg ha^{-1} (T_5) to 0.406 kg ha^{-1} (T_{13}) as pointed out in the table 39. The highest value was recorded by T_{13} which was superior to all other treatments and followed by T_{10} (0.326 kg ha^{-1}), T_{11}(0.327 kg ha^{-1}) and T_{12} (0.330 kg ha^{-1}).

Table 39. Plant uptake of micro nutrients as affected by different treatments

Treatments	Iron (kg ha^{-1})	Manganese (kg ha^{-1})	Zinc (kg ha^{-1})	Copper (kg ha^{-1})	Boron (kg ha^{-1})
T_1	1.636	0.233	0.236	0.053	0.023
T_2	1.350	0.203	0.233	0.049	0.026
T_3	0.936	0.193	0.223	0.066	0.023
T_4	0.846	0.183	0.251	0.046	0.016
T_5	0.596	0.163	0.186	0.036	0.008
T_6	0.650	0.173	0.196	0.035	0.023
T_7	0.926	0.226	0.227	0.043	0.026
T_8	1.360	0.306	0.276	0.066	0.026
T_9	1.196	0.276	0.276	0.053	0.026
T_{10}	1.456	0.336	0.326	0.086	0.036
T_{11}	1.506	0.336	0.327	0.096	0.036
T_{12}	1.390	0.333	0.330	0.096	0.033
T_{13}	2.266	0.551	0.406	0.123	0.056
SE	0.106	0.017	0.017	0.005	0.002
CD(0.05)	0.305	0.044	0.050	0.016	0.007

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5 % herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2 % non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

4.3.6.10 Copper uptake

Data in the table 39 clearly indicated that there was significant difference between treatments with respect to Cu uptake. Maximum uptake of Cu was recorded by T_{13} with a value of 0.123 kg ha^{-1} followed by treatments T_{10} (0.086 kg ha^{-1}), T_{11} (0.096 kg ha^{-1}), and T_{12} (0.096 kg ha^{-1}). T_5 recorded the lowest value of 0.036 kg ha^{-1}.

4.3.6.11 Boron uptake

Scrutiny of the data in the table 39 revealed that boron uptake by the plant was significantly influenced by treatments. The maximum boron uptake was observed in T_{13} (0.056 kg ha^{-1}) while the lowest uptake was reported by the treatment T_5 (0.008 kg ha^{-1}).

4.3.7 Economics

Benefit-Cost Ratio

Economic analysis of bhindi influenced by different treatments is depicted in the table 40. The treatment received foliar application of 5% non-herbal *Kunapajala* along with 50% N as FYM recorded the highest B:C ratio (2.46) followed by T_{12} (2.39). B:C ratio was found to be the lowest for T_5 (0.89).

Table 40. Effect of different treatments on B:C ratio of bhindi

Treatments	B:C ratio
T_1	2.34
T_2	2.18
T_3	1.94
T_4	1.96
T_5	0.89
T_6	1.92
T_7	1.89
T_8	1.96
T_9	2.00
T_{10}	2.14
T_{11}	2.18
T_{12}	2.39
T_{13}	2.46

T_1: KAU POP (FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1})

T_2: Organic Adhoc POP

T_3: Organic Adhoc POP + 3% Panchagavya

T_4: Organic Adhoc POP + 5% Fish Amino Acids

T_5: 50% N as FYM + Water

T_6: 50% N as FYM + 2% herbal *Kunapajala* soil application

T_7: 50% N as FYM + 5 % herbal *Kunapajala* soil application

T_8: 50% N as FYM + 2 % non-herbal *Kunapajala* soil application

T_9: 50% N as FYM + 5% non-herbal *Kunapajala* soil application

T_{10}: 50% N as FYM + 2% herbal *Kunapajala* foliar application

T_{11}: 50% N as FYM + 5% herbal *Kunapajala* foliar application

T_{12}: 50% N as FYM + 2% non-herbal *Kunapajala* foliar application

T_{13}: 50% N as FYM + 5% non-herbal *Kunapajala* foliar application

Discussion

5. DISCUSSION

An experiment entitled "Characterization and evaluation of herbal and non-herbal *Kunapajala* on soil health and crop nutrition" was conducted during 2018-2019 at College of Agriculture, Vellayani. The experimental results regarding the characterization, laboratory incubation study and field study are discussed in this chapter in the light of available literature and theoretical knowledge.

PART I

5.1 Preparation and characterization of herbal and non-herbal *Kunapajala*

The traditional organic liquid manures such as herbal and non- herbal *Kunapajala*, Panchagavya and FAA were prepared and the physical, chemical, biochemical and biological properties of these organic liquid manures were analysed as per standard procedures.

5.1.1 Physical properties

The colour of herbal *Kunapajala*, non-herbal *Kunapajala,* Panchagavya and FAA were dark brown, yellowish brown, light brown and dark brown respectively (Plate 6). Venugopal (2004) reported that good quality of manure was indicated by its deep dark brown colour. Except FAA, other three organic liquid manures have fermented odour. The colour and odour of organic liquid manures might be due to the biological and biochemical changes during the fermentation period. The fermented odour of these organic liquid manure might be due to the presence of volatile fatty acid, methane, alcohol etc. produced during fermentation of carbohydrate, protein and lipids (Harison and Allan, 1980) present in the original ingredients.

a. Herbal *Kunapajala*

b. Non- Herbal *Kunapajala*

c. Panchagavya

d. Fish Amino Acid

Plate 6. Different types organic liquid manures used for the study

5.1.2 Chemical properties

5.1.2.1 pH & EC

The herbal and non- herbal *Kunapajala* recorded neutral pH (Table 5). The ingredients used for the preparation of *Kunapajala* had reported neutral pH. This might be the reason for neutral pH of the preparation. The fermentation of organic liquid manures also resulted in higher pH (Natarajan, 2008). Panchagavya and FAA were in acidic pH range. The production of weak organic acids during fermentation might have resulted in acidic pH (Pathak and Ram, 2013). The highest EC was recorded by Panchagavya, followed by FAA, non- herbal *Kunapajala* and herbal *Kunapajala*. Increase in EC may be due to an increase in soluble salts in the organic liquid manures.

5.1.2.2 Organic carbon

FAA recorded the highest organic carbon content (Table 5). This might be due to less degradation of carbon as it was prepared under anaerobic condition. The lowest organic carbon content in *Kunapajala* might be due to the exploitation of carbon as an energy source by the microbes present in it.

5.1.2.3 Macro and micronutrients

Among the four organic liquid manures, the highest values of nitrogen, phosphorus and potassium contents were recorded by FAA, Panchagavya and non-herbal *Kunapajala,* respectively (Table 6). Herbal and non- herbal *Kunapajala* recorded the least P content. Similar results were obtained by Ankad *et al.* (2017), and reported higher quantities of N, K, S, Ca, Mg, Zn, Fe, Mn, and Cu in *Kunapajala* followed by Panchagavya, humic acid and FYM. The highest P content was recorded by Panchagavya followed by *Kunapajala*, humic acid and FYM. *Kunapajala* derived from animal products contained appreciable quantities of primary nutrients. Masih et al. (2009) reported that the active principles used for the preparation of *Kunapajala* such as neem leaves, neem cake and cow dung were rich source of primary nutrients.

The Ca, Mg & S content of *Kunapajala* was greater than that of FAA & Panchagavya. Regarding the micronutrient contents, the highest Fe, Mn and B content were noticed in non- herbal *Kunapajala,* whereas the highest Cu & Zn content were observed by Panchagavya and FAA respectively. The beneficial element Na was the highest in non – herbal *Kunapajala*. The nutrient contents in liquid organic manures might have been contributed by its ingredients. The highest nutrient and quality parameters of non- herbal *Kunapajala* might have been obtained from the ingredients such as fish, milk, honey, ghee, and black gram. Honey acts as the carbohydrate source Likewise, milk is amino acid-rich compound and all these constituents are responsible for the quality of *Kunapajala*. The combined use of cow products and fish in the preparation of non- herbal *Kunapajala* might be the reason for its superiority among other three liquid organic manures. *Kunapajala* is a liquid organic manure rich in carbohydrates, proteins and alkaloids (Jani *et al*., 2017).

The major ingredients of non – herbal *Kunapajala* were cow dung, urine, milk, ghee, and fish. Singh (1996) reported that cow dung contains 82 % water and 18 % solid matter which constitutes 0.1 % minerals, 2.4 % ash ,14.6 % organic carbon , 0.4 % Ca and Mg, 0.05 % SO_4 ,1.5 % Silica ,0.5 % N ,0.2 % P and 0.5 % K. Cow urine contained 0.07% N, 0.06% P, 0.17% K, 135.23 ml L^{-1} Ca, 46.62 mg L^{-1} Mg, 308 mg L^{-1} S (Parvathy, 2017). Milk is rich in protein, fat, carbohydrates, amino acids, calcium, hydrogen, lactic acid and *Lactobacillus* bacterium (Mc Graw,1999). The nutrient contents in trash fish manure were analysed by Ramalingam *et al*. (2014) and reported the higher amount of nitrogen (6%), phosphorous (5%), potassium (4%) and trace amount of heavy metals like Ni, Cu, Zn, and Pb in trash fish manures and ensured that it was safe for agricultural fields.

Rajesh and Jayakumar (2013) reported that the beneficial property of Panchagavya was contributed by its ingredients such as milk, curd, cow urine and ghee present in it. The nutrient content of Panchagavya was reported to be 1.4 % N, 0.08% P, and 0.5% K (Ali *et al*., 2011). Gore and Sreenivasa (2011) analysed the nutrient content of Panchagavya, Beejamrutha and Jeevamrutha and reported that these are rich in plant growth promoting substances, beneficial microorganisms in addition to essential nutrients for plant growth. The organic liquid manures viz, Panchagavya, Jeevamrutha and Beejamrutha were rich in macronutrients and micronutrients. Maheshwari *et al.* (2007), Swaminathan *et al.* (2007), Sreenivasa *et al.* (2012), Raghavendra *et al.* (2014) and Anandan *et al.* (2016) reported similar results.

The quantity, quality of ingredients used and duration of fermentation influenced the nutrient content of organic liquid manures (Gore and Sreenivasa, 2011). Sreenivasa *et al.* (2010) opined that the nutrient status of liquid organic manures varied with the type and quantity of material used and environmental conditions.

The carbon and hydrogen linkage in the natural or synthetic organic fertilizers slows the release of nutrient ions, which resulted in sustained availability of nutrients, without toxicity and loss compared to inorganic fertilizers (Shaikh and Patil, 2013).

5.1.2.4 Biological and biochemical properties of liquid organic manures

Estimation of the microbial population in these organic liquid manures revealed that the highest bacterial count was observed in non- herbal *Kunapajala* whereas the highest fungal count was observed in FAA. No actinomycetes were found in all these liquid manures (Table 8). Radha and Rao (2014) reported that actinomycetes were absent in freshly prepared Panchagavya which corroborated with the present findings. Rameeza (2016) also observed the absence of actinomycetes in freshly prepared Panchagavya and Jeevamrutha. The presence of species of *Azotobacter, Pseudomonas, Azospirillum, Rhizobium,* and *Phosphate Solubilizing Bacteria* and a substantial amount of total organic carbon, GA and IAA in *Kunapajala* were detected by Nene (2018).

The microbial population in Panchagavya was enumerated by Amalraj *et al.* (2013) and reported the microbial count as, bacteria (22×10^9 cfu ml^{-1}), actinomycetes (60×10^4 cfu ml^{-1}), phosphate solubilizers (103×10^6 cfu ml^{-1}), fluorescent pseudomonas (151×10^5 cfu ml^{-1}), and nitrifiers (5.4×10^6 cfu ml^{-1}). Panchagavya was rich in beneficial microorganisms *viz.*, lactic acid and photosynthetic bacteria, PSB, actinomycetes, N fixers, yeast and fungi (Swaminathan *et al.* 2007). Microbial load in organic liquid formulation increased due to ageing (Rameeza 2016). Dhanalakshmi (2017) also reported the variation in microbial load due to ageing and enumerated the highest microbial load in 10 weeks old fish jaggery extract. Devakumar *et al.* (2014) recorded higher colony forming units of bacteria, fungi, actinomycets, N-fixers and P-solubilizers on beejamrutha and Jeevamrutha.

The variation in ingredients and method of preparation of organic liquid formulation might be the reason for changes in count and species of microbes present in it. Ali *et al.* (2011) confirmed that the difference in the microbial population in Sanjibani was due to the difference in cow dung used. The microbial population was the highest in the solution prepared from native breed than that from jersey cow.

Parvathy (2017) enumerated the microbial population in on-farm liquid manure such as vermiwash, cow urine, Panchagavya, FAA and Jeevamrutha. The N fixers, K fixers and P solubilising bacteria present in these liquid manures might have enhanced the nutrient content. The microbial richness in organic liquid manures such as Panchagavya, *Kunapajala*, Vermiwash, Compost tea, Jeevamrutha and FAA were also reported by Ingham (2005), Zambare *et al.* (2008), Sreenivasa *et al.* (2009), Gore and Sreenivasa (2011), Sarkar *et al.*(2013) and Anandan *et al.* (2016). Mineralization of nutrients occurs due to the microbial activity. Hence faster decomposition of organic manures and nutrient availability was enhanced by the microbial population of these liquid organic manures, which sustain the soil fertility and plant growth.

The dehydrogenase enzymatic activity was less in *Kunapajala* compared to FAA and Panchagavya. FAA recorded the highest ascorbic acid content and total sugar percentage (Table 8).

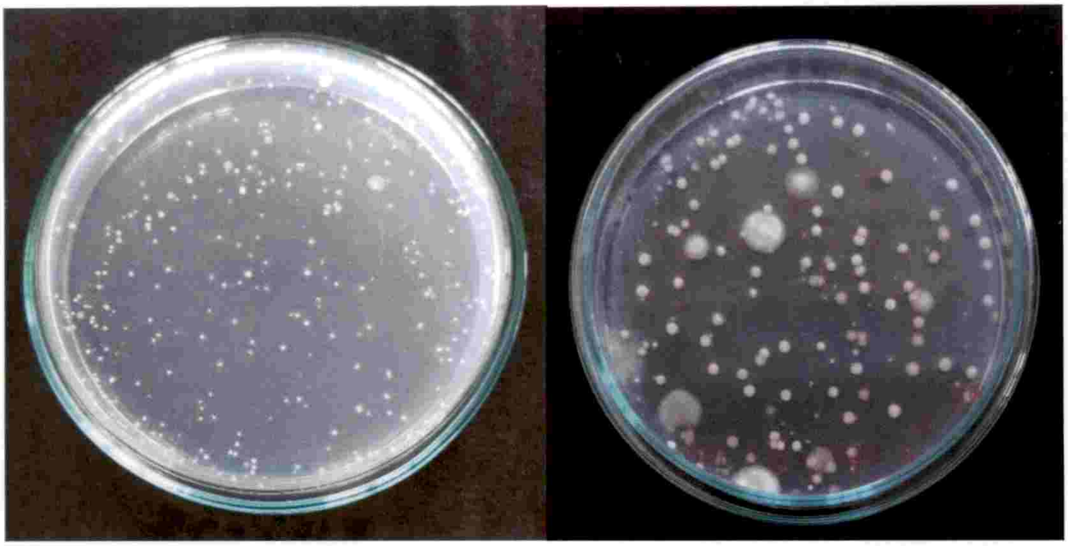


Plate 7. Bacterial and fungal population in herbal *Kunapajala*

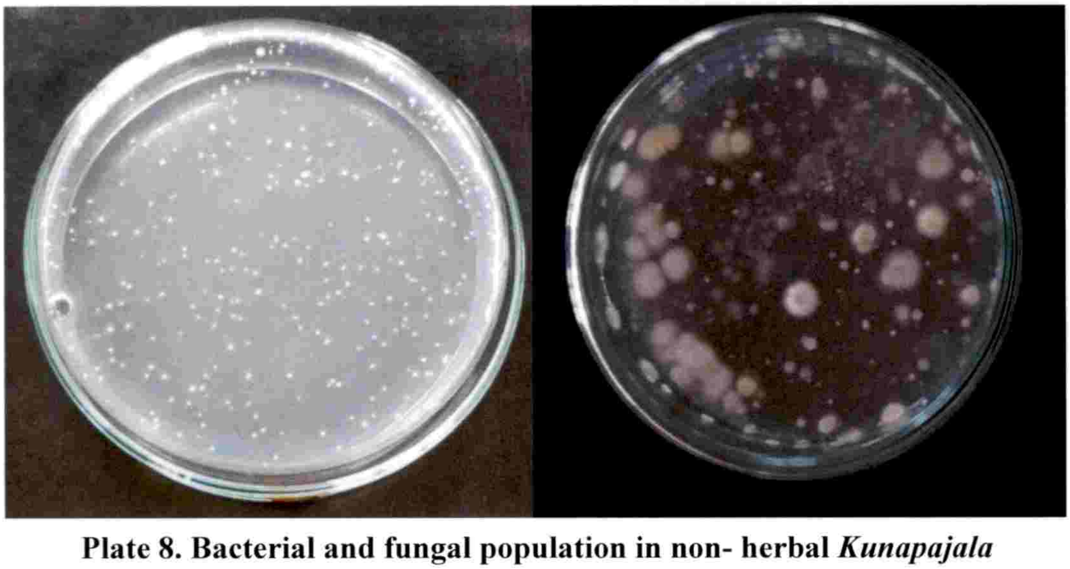


Plate 8. Bacterial and fungal population in non- herbal *Kunapajala*

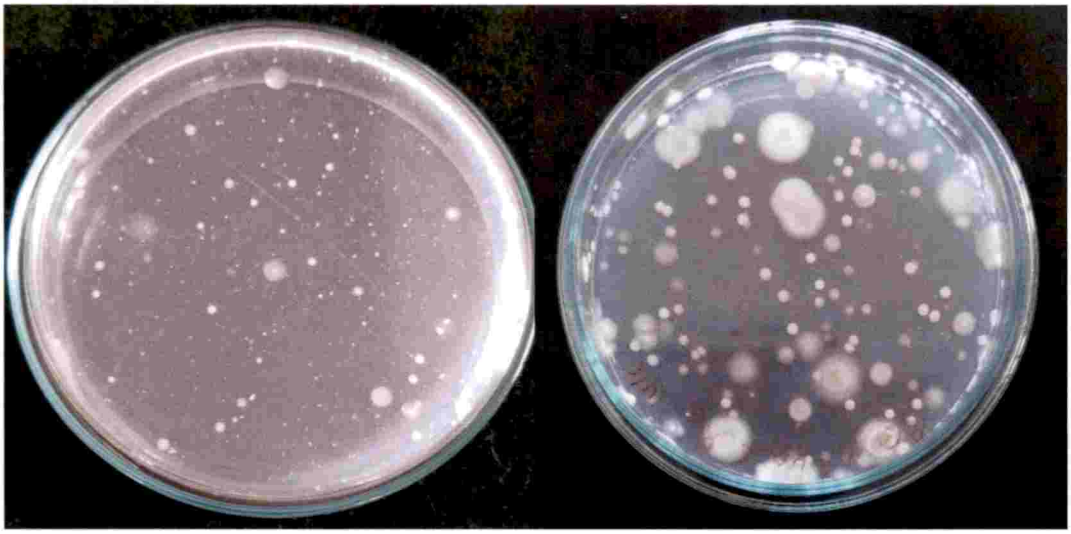


Plate 9. Bacterial and fungal population in Fish Amino Acid

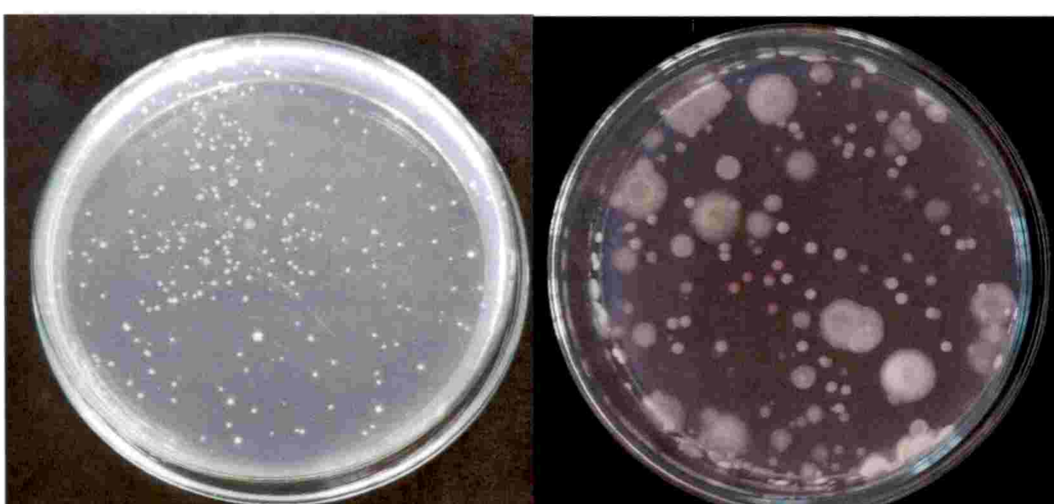


Plate 10. Bacterial and fungal population in Panchagavya

Parvathy (2017) observed the highest enzyme activities viz., acid and alkaline phosphatase activities and urease activities in FAA. The highest value for IAA and GA was also recorded by the FAA while highest cytokinin content in Panchagavya.Vincent *et al.* (2014) also observed the microorganisms such as ammonifiers, nitrifiers and phosphate solubilizers in fermented fish waste.

Natarajan (2002) reported the presence of growth promoting substances like indole acetic acid, proteins, carbohydrates, fats, amino acids, vitamins, enzymes which help in improving soil fertility, plant growth, and metabolic activity in Panchagavya. Similar findings were reported by Xu (2001), Papen (2002), Selvaraj *et al.* (2007), Ravikumar *et al.* (2011), Ali *et al.* (2011) and Ukale *et al.* (2016). The different organic compound in varying proportions due to bacterial metabolomes resulted in the high efficacy of organic manures (Ukale *et al.*, 2016).

Vermiwash bound the mineral particles in the form of colloids of humus and clay, which facilitated stable aggregates of soil particles for desired porosity and sustained plant growth (Haynes, 1986). According to Tripathi and Bharadwaj (2004), vermiwash was rich in several enzymes, growth hormones and vitamins. According to Gopal *et al.* (2010), higher content of total sugar, reducing sugar, proteins, free amino acids, and plant growth hormones, are responsible for the effectiveness of vermiwash as a growth promoter. This might have been the reason for the high quality and enzyme activities of *Kunapajala* also.

The chemical, biological and biochemical properties of these organic liquid manures may vary in accordance with the quality of ingredients used such as cow dung, cow urine and milk which differed with the breeds of cow and feed given to them. The quality of these manures depend upon the reactions occurring during the fermentation process.

Part II

5.2 LABORATORY INCUBATION STUDY

Laboratory incubation study was carried out to monitor the nutrient release pattern from soil treated with the herbal and non- herbal *Kunapajala* for a period of two months. The study comprised of 5 treatments and 4 replications. The treatments consisted of soil + FYM (T_1), 2 % and 5 % herbal and non- herbal *Kunapajala* applied along with soil + FYM (T_2-T_5) and all the treatments were maintained at sixty percentage moisture capacity. The changes in pH, EC, OC, N, P, K, Ca, Mg, S, Fe, Mn, Zn, B, Cu, and Na were assessed by periodical sampling and analysis. The results are discussed below.

5.2.1 Changes in pH, EC and Organic carbon

An increasing trend in the pH of incubated soil in all treatments was evidenced from Fig 4. Treatments T_3 and T_4 recorded the highest pH on the 60^{th} day of incubation followed by T_5. The treatment with *Kunapajala* recorded high pH when compared to treatment without *Kunapajala*. The added organic matter with neutral pH helps to increase the pH thus making the nutrients become available. The characterization study revealed that both of them were neutral in pH (Table 5) and indicated the favourable environment for nutrient availability. According to Brady (1990), the optimum availability of all the nutrients required for plant growth is at neutral pH. The degradation of organic matter in soil on the advancement of incubation period may control the H^+ ion concentration and provide a beneficial condition for plant growth.

The electrical conductivity (EC) of soil increased throughout the incubation period (Fig 5). Increase in electrical conductivity may be due to the addition of *Kunapajala* to the soil which may lead to the production of weak organic acids resulted in an increase in soluble salt concentration. Electrical conductivity measures the total soluble nutrients and also useful in monitoring the organic matter mineralization (Smith and Doran, 1996; De Neve *et al*, 2000). Thompson *et al.* (1989) reported that organic amendments with ionic concentration gives high EC value due to mineralization of nutrients. This might be the reason for the increase in EC of soil treated with *Kunapajala*. These findings are in accordance with the research findings of Sreeja (2015) and Parvathy (2017).

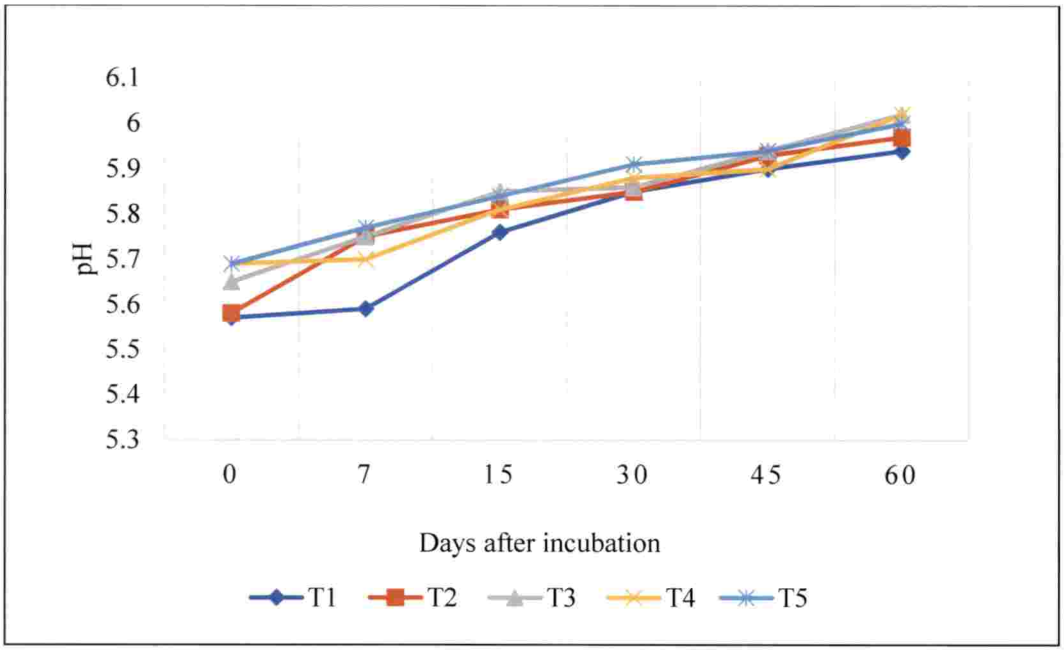


Fig 4. Effect of treatment on pH of soil during incubation period

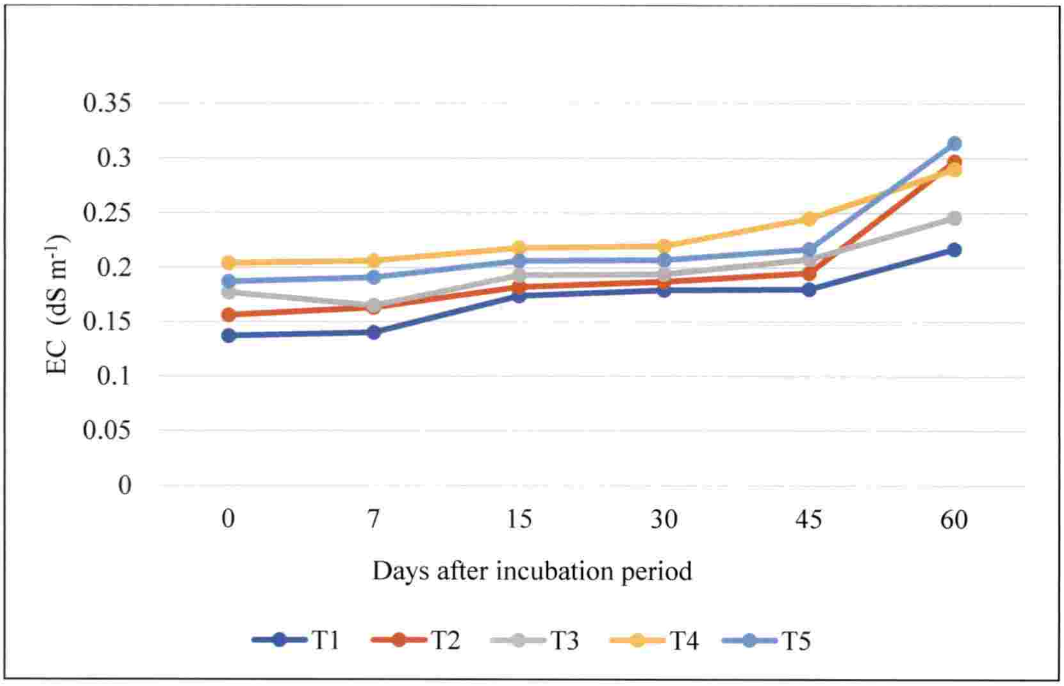


Fig 5. Effect of treatment on EC (dS m^{-1}) of soil during incubation period

Organic carbon content varied significantly with the treatments and which increased up to the 15th day of incubation and decreases at 30th day (Fig 6). The highest organic carbon content was recorded by 5% non-herbal *Kunapajala* treated soil and the lowest was observed in soil + FYM treatment. This may be due to the presence of high organic carbon content in non- herbal *Kunapajala*. The addition of tobacco waste also significantly enhanced organic carbon content during incubation (Gulser *et al*., 2010). Organic residues and organic fertilizers additions increased the soil organic C level, soil microbial biomass, and microbial activities as reported by Goyal *et al*. (1999), Manivannan *et al*.(2009). The mineralization of organic matter due to the microbial activity might be the reason for the increase in organic carbon content in soil.

5.2.2 Changes in primary and secondary nutrients

Available nitrogen content during the incubation period increased upto 45th day of incubation and then declined (Fig 7). An increase in available N up to 45th days of incubation for soil treated with vermicompost enriched with the bone meal was reported by Sheeba (2004). The highest available nitrogen content was observed in treatment T_5 which contained higher nitrogen content than herbal *Kunapajala* (Table 6). The mineralization of organic matter through high microbial activity might be the reason for the enhanced release of nutrients. There exists a close relationship between soil N and soil organic carbon, and cumulative mineralization and total soil N. Even though the mineralisation occurred rapidly, the amount of mineralized N per week was reduced in the later weeks of incubation. Variation in net mineralization among soil samples may be due to the variation in soil organic matter content and state of decomposition (Charoulis *et al*., 2005). The addition of earthworm casts and conventional compost to the soil enhanced the nitrate nitrogen in the initial 30th day of incubation (Chaoui *et al*., 2003). Active mineralisation of organic manure and N fixation by nitrogen-fixing bacteria present in organic liquid manures may enhance the available nitrogen content during the incubation period. (Parvathy, 2017).

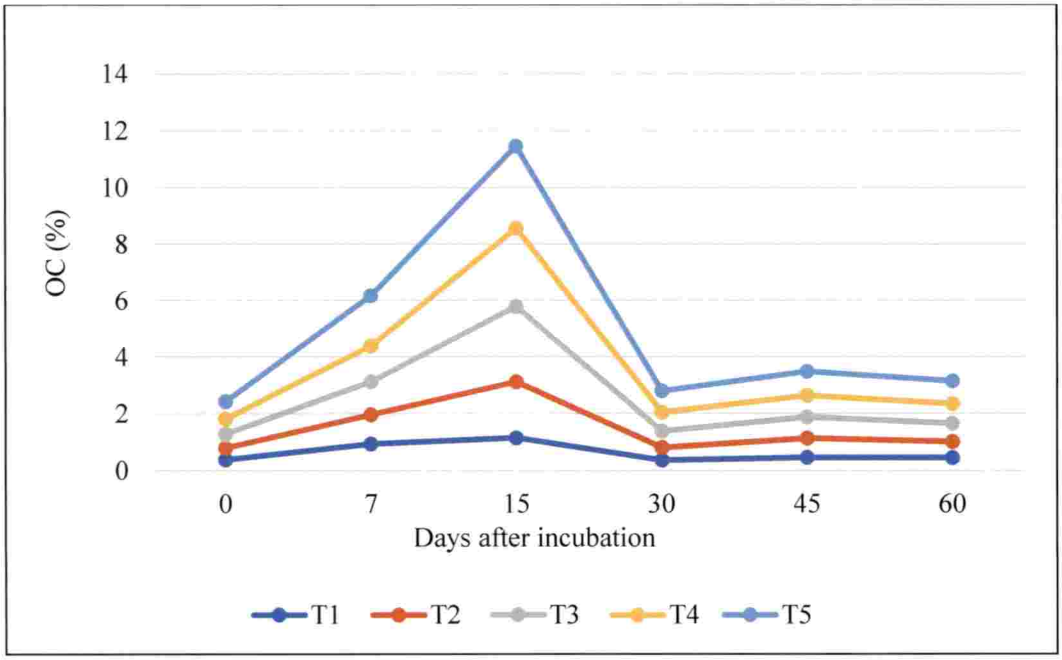


Fig 6. Effect of treatment on Organic Carbon (%) of soil during incubation period

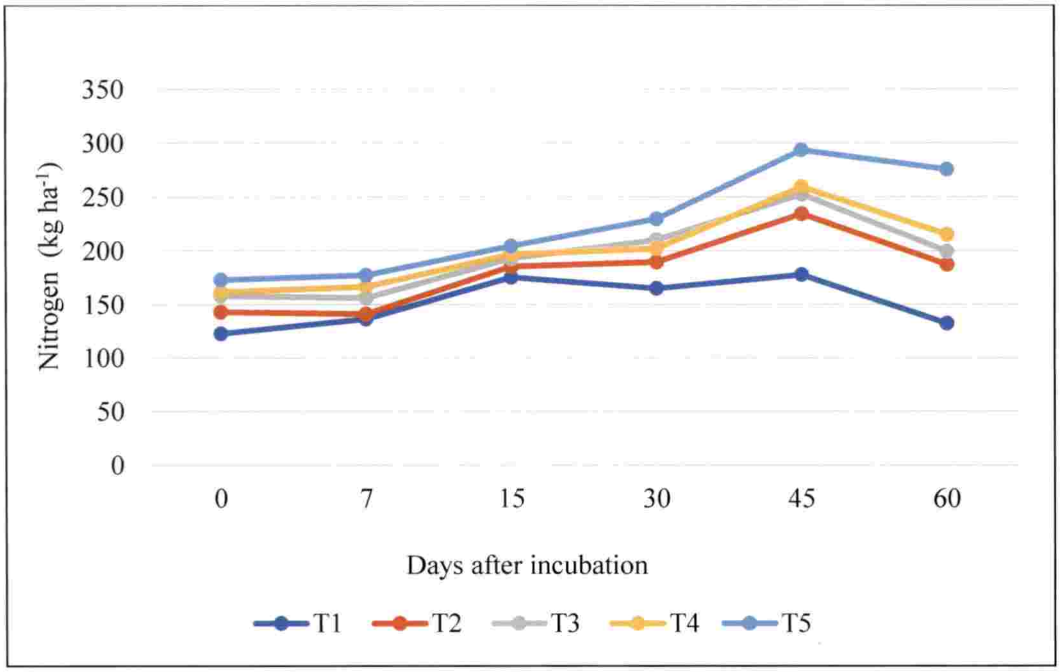


Fig 7. Effect of treatment on available Nitrogen (kg ha^{-1}) of soil during incubation period

Available phosphorus content increased up to 30th day of incubation and then started declining and indicated a drastic reduction on the 60th day of incubation (Fig 8). A similar trend was observed by Parvathy (2017) and reported that general P release from soil treated with 10% FAA was found to be the highest. The treatment received 5% non- herbal *Kunapajala* recorded the highest P release throughout the incubation period. The greater mineralization of organic matter and increased enzyme activity with the help of microorganisms might be the reason for the highest P release. Bijulal (1997) reported that significant addition of phosphorus through organic matter improved the solubility of P due to microbial activity. The same may be applicable in the case of *Kunapajala* also. There exists a positive effect of organic matter and soil humus on P availability (Vyas and Mothiramani 1971). The biochar or compost can effectively fix Al and Fe instead of P, thus making P available by keeping the inorganic phosphorus in a bio - available labile phosphorus pool for a longer period (Ch'ng *et al.*, 2014). The mineralization of organic phosphorus can also be enhanced by the addition of inorganic soluble phosphate compounds (Enwezor,1966). Sreeja (2015) reported that the use of composting inoculum and PGPR Mix I released the phosphorus from rock phosphate and made available during the composting period. The decline in phosphorus availability on advancement of incubation period may be due to the fact that the high amount of P released to the soil by organic manures might have been fixed.

The data (Table 14) indicated that the available Potassium content varied significantly with the treatments (Fig 9). The available K_2O increased up to 45th day of incubation and then declined. Treatment T_4 (Soil + FYM + 5% herbal *Kunapajala*) recorded the highest potassium content throughout the incubation period. The highest value for available potassium content at the 45th day of incubation was on par with soil + FYM + 5% non- herbal *Kunapajala*. It might be due to the highest potassium content in herbal and non- herbal *Kunapajala* as indicated in the characterisation study. According to Tan (1982), the interaction with organic matter and clay accelerated the mineralisation which enhanced the release of potassium during incubation. The lowest potassium content was recorded by soil + FYM without any *Kunapajala* treatment. The

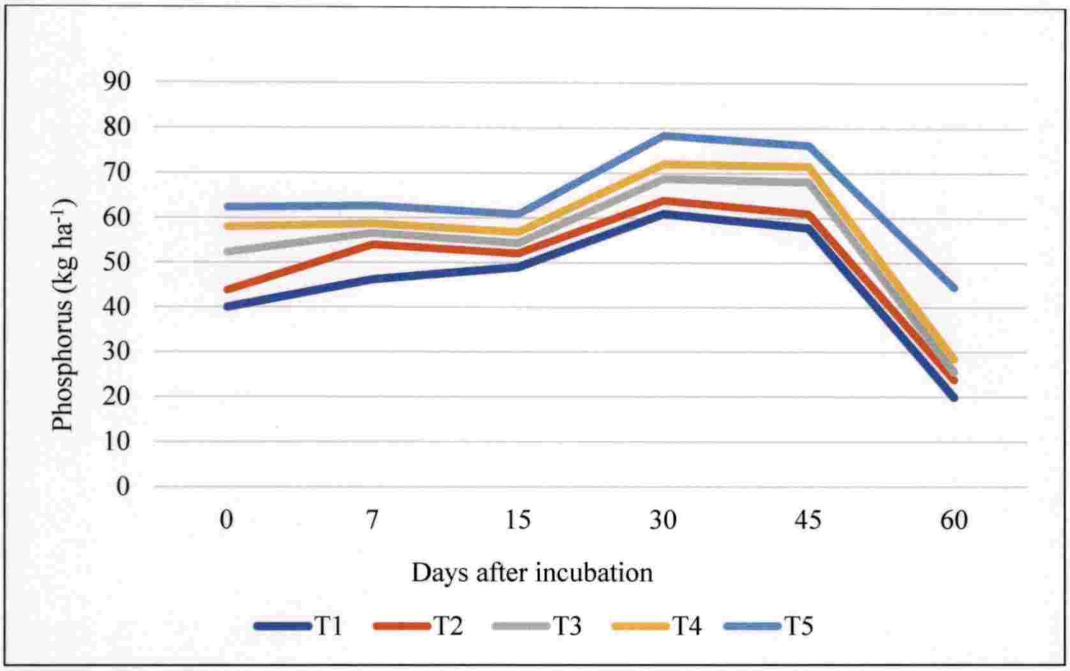


Fig 8. Effect of treatment on available Phosphorous (kg ha^{-1}) of soil during incubation period

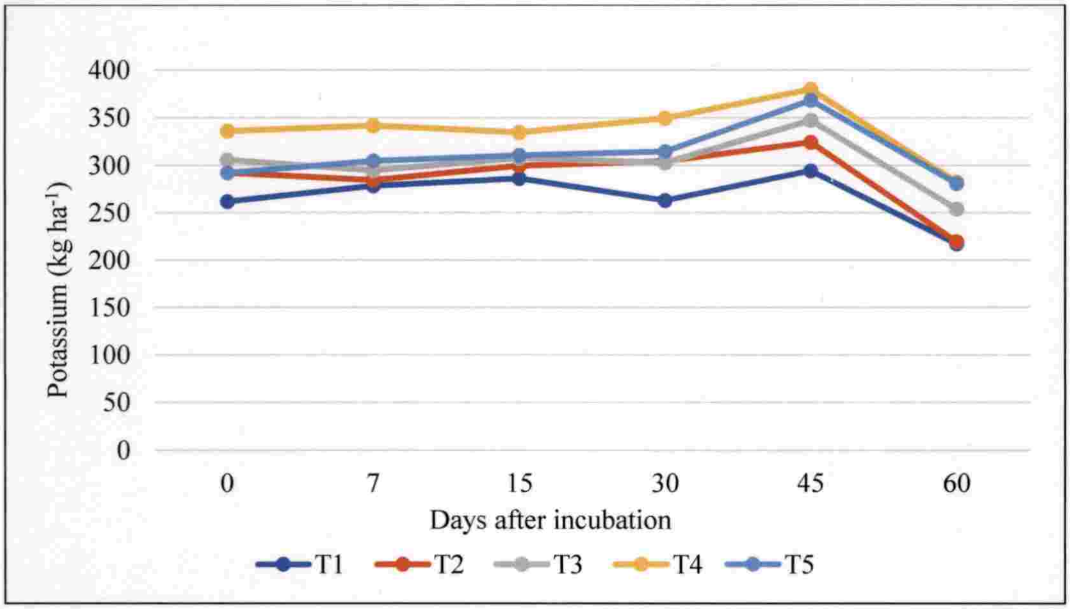


Fig 9. Effect of treatment on available Potassium (kg ha^{-1}) of soil during incubation period

addition of potassium through *Kunapajala* might be the reason for the highest K release. Samuel and Ebenezer (2014) conducted an incubation study and reported that organo mineral fertilizer increased the soil forms of N, P and K to sufficient levels that can boost the plant growth. The highest cation exchange capacity of organic manures enabling them to retain K ions effectively. Also, the available potassium content increased due to the dissolution of insoluble K minerals by weak organic acids produced from the added organic manures (Hue and Silva, 2000).

Fig 10 depicted the variation in exchangeable Ca content. The study indicated that the Ca release was increased upto 15th day of incubation and then declined. Treatment T_5 recorded the highest Ca content throughout the incubation period. This may be due to the highest Ca content in non- herbal *Kunapajala* as evident from characterization study (Table 6). Parvathy (2017) reported the variation in exchangeable Ca content due to the addition of on-farm liquid manures. An initial increase and later a declining trend was also noticed.

Similarly, the exchangeable Mg content (Fig 11) and available sulphur (Fig 12) content varied significantly with the treatments and these contents increased upto 30th day of incubation and then declined. Soil incubated with 5% non- herbal *Kunapajala* along with FYM showed a better release of magnesium and sulphur. The reason may be that the non- herbal *Kunapajala* which contained higher Mg and S content than other liquid manures become readily available during incubation. Olsen *et al.* (1954) reported that the application of manures enhanced the exchangeable Ca and Mg particularly at higher rates of their application.

5.2.3 Changes in micronutrients

In the case of available boron, the highest B content was observed in treatment T_5 (Fig 13). This might be due to the highest B content in non- herbal *Kunapajala* than other liquid organic manures.

The micronutrients such as Fe (Fig 14) and Mn (Fig 15) varied in accordance with the treatments. The Fe content increased up to 45th day of incubation while Mn content increased up to 15th day of incubation. The treatment

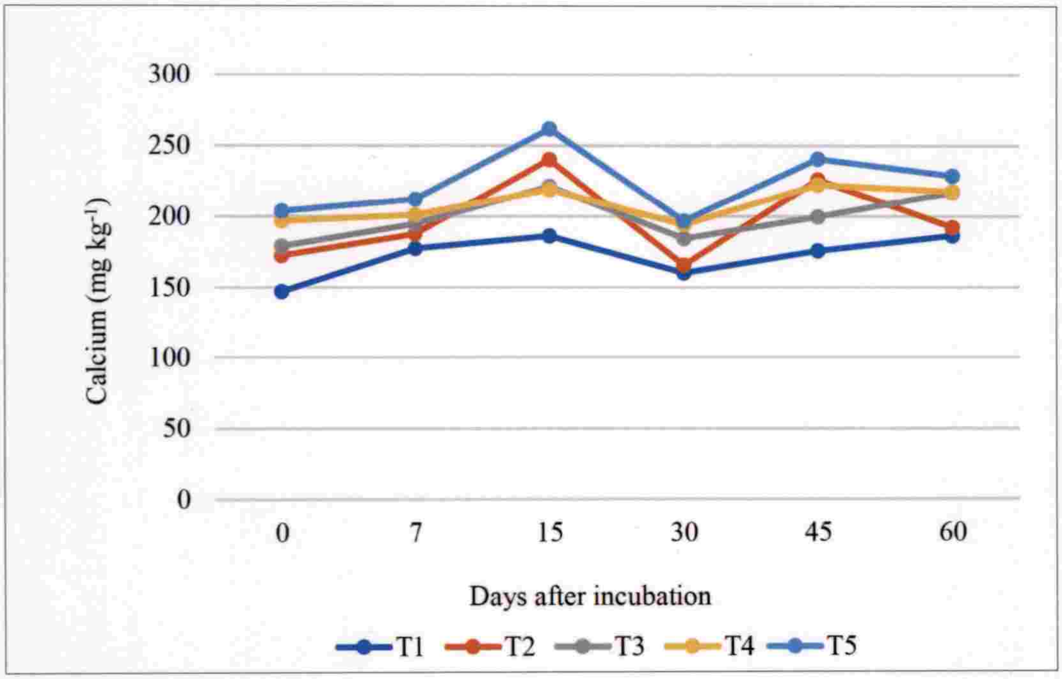


Fig 10. Effect of treatment on exchangeable Calcium (mg kg^{-1}) of soil during incubation period

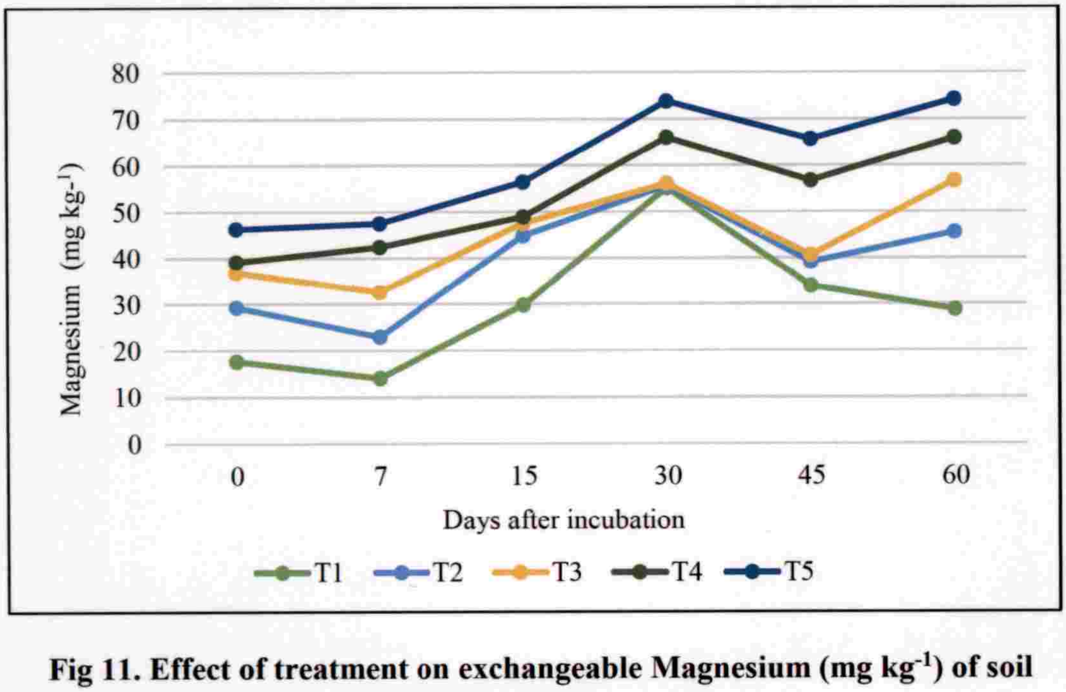


Fig 11. Effect of treatment on exchangeable Magnesium (mg kg^{-1}) of soil during incubation period

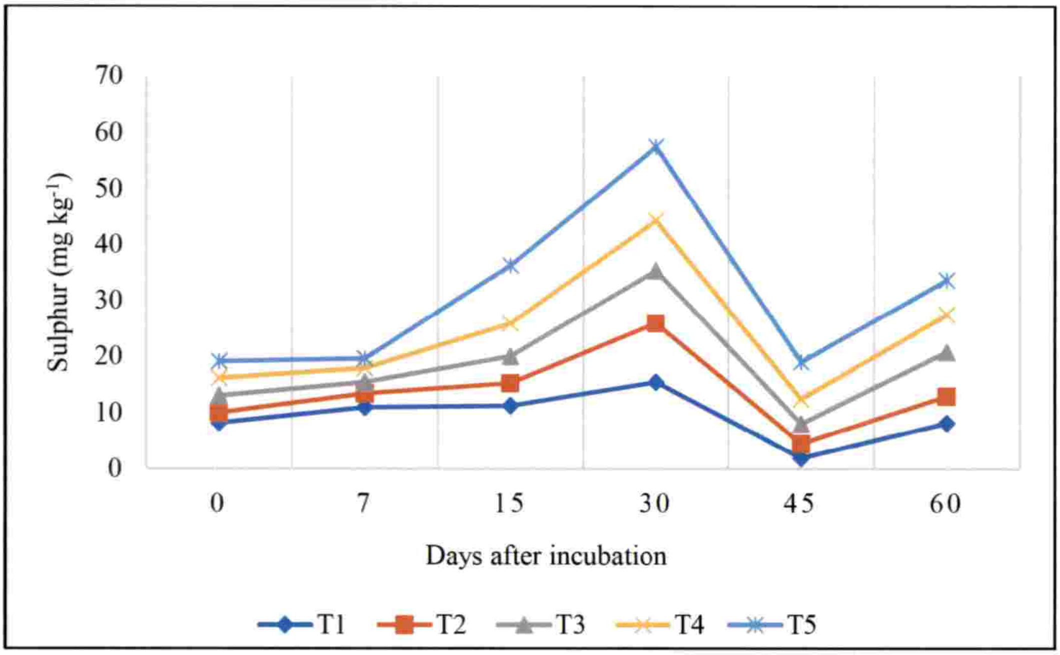


Fig 12. Effect of treatment on available Sulphur (mg kg^{-1}) of soil during incubation period

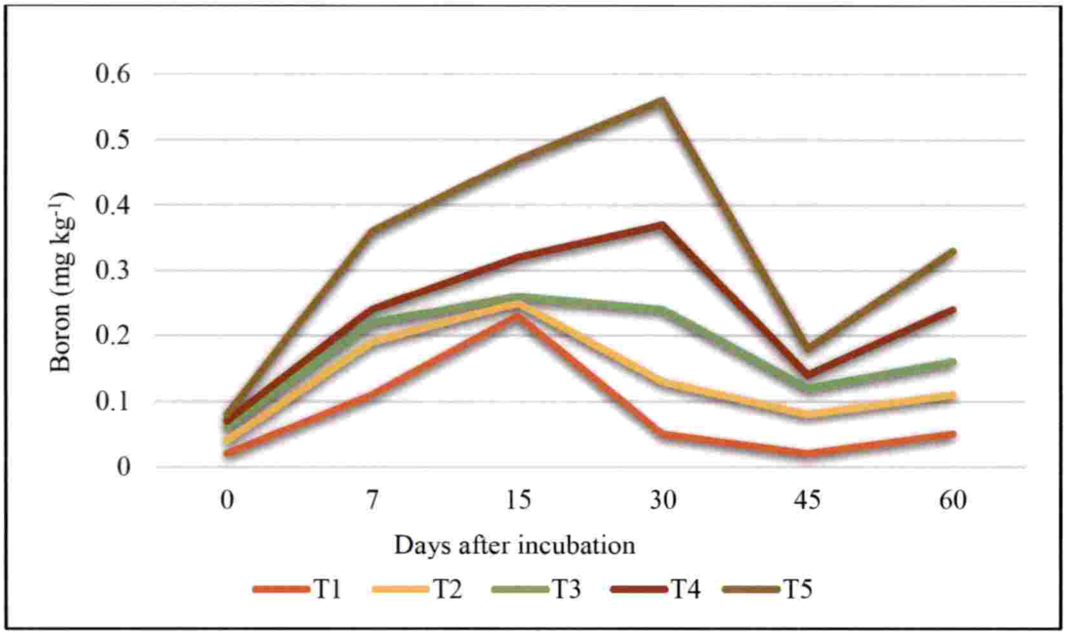


Fig 13. Effect of treatment on available Boron (mg kg^{-1}) of soil during incubation period

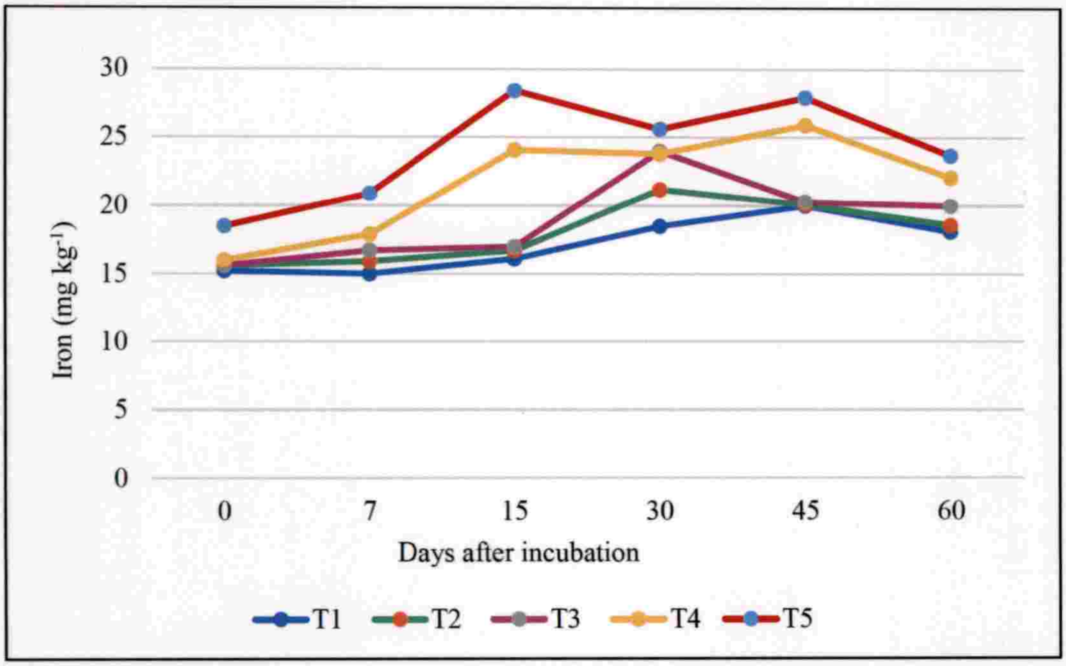


Fig 14. Effect of treatment on available Iron (mg kg^{-1}) of soil during incubation period

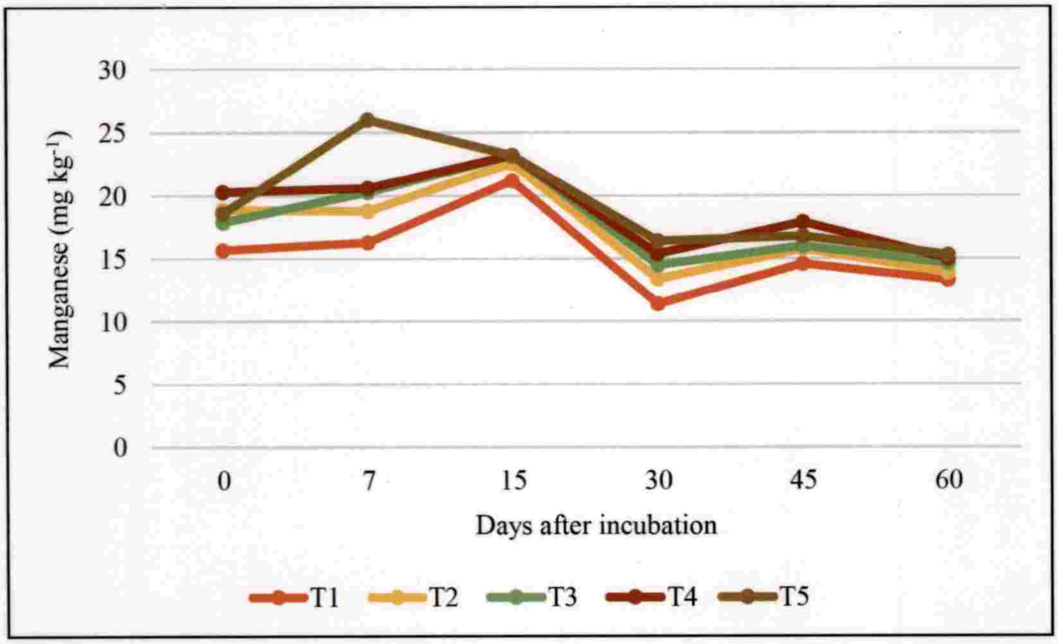


Fig 15. Effect of treatment on available Manganese (mg kg^{-1}) of soil during incubation period

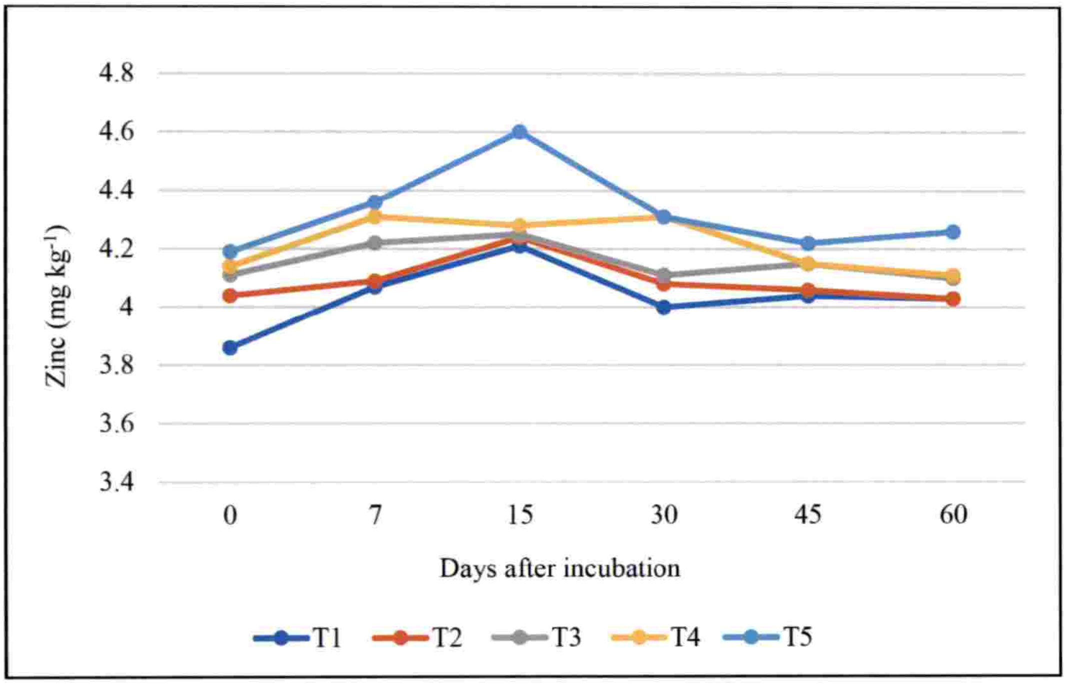


Fig 16. Effect of treatment on available Zinc (mg kg^{-1}) of soil during incubation period

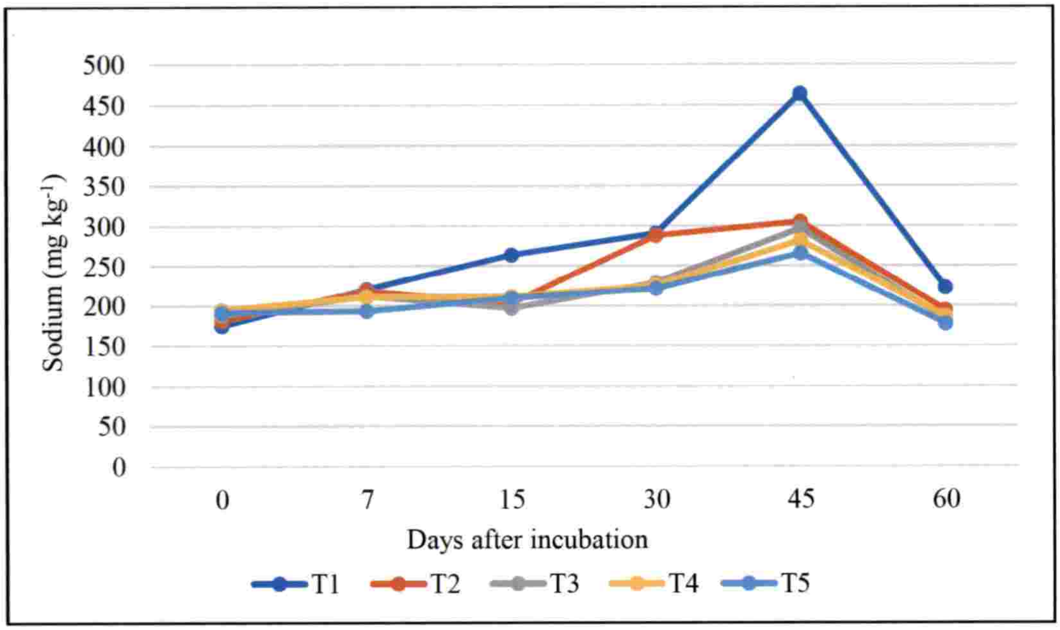


Fig 17. Effect of treatment on available Sodium (mg kg^{-1}) during incubation period

with 5% non- herbal *Kunapajala* recorded the highest Fe and Mn content throughout the incubation period. Addition of nutrient-rich non- herbal *Kunapajala* might be the reason for the maximum solubility of these micronutrients during incubation. Parvathy (2017) reported that the soil treated with 10% Jeevamrutha recorded the highest available Fe and Zn content, while the highest Mn and Cu content was observed in soil treated with 10% cow urine. These findings also suggested that addition of organic liquid manures accelerated the micronutrient release from the soil. Rostami and Ahangar (2013) noticed that with the addition of cow manure, the exchangeable Fe and Mn were enhanced. The decreased solubility of micronutrients on the advancement of the incubation period may be due to the specific adsorption and bonding of nutrients.

The laboratory incubation study indicated that 5% of non-herbal *Kunapajala* recorded higher primary, secondary and micronutrients release than the other treatments.

PART III

5.3. Field experiment

The soil and foliar efficacy of these organic liquid manures were evaluated by conducting a field experiment using bhindi variety, Varsha Uphar, as a test crop.

5.3.1 Effect of organic liquid manures on biometric characters of bhindi.

Biometric characters such as the height of plants, number of branches per plant, dry matter production and LAI were significantly influenced by different treatments. Foliar application of 5% non- herbal *Kunapajala* along with 50% N as FYM recorded the highest plant height at both first and final harvest of the crop and was on par with treatments, T_{12}, T_{11}, T_{10}, T_8 and T_3 (Fig 18). The treatment, T_{13} significantly differed from all other treatments with respect to number of branches, dry matter production and LAI. The lowest value was recorded by the treatment, T_5.

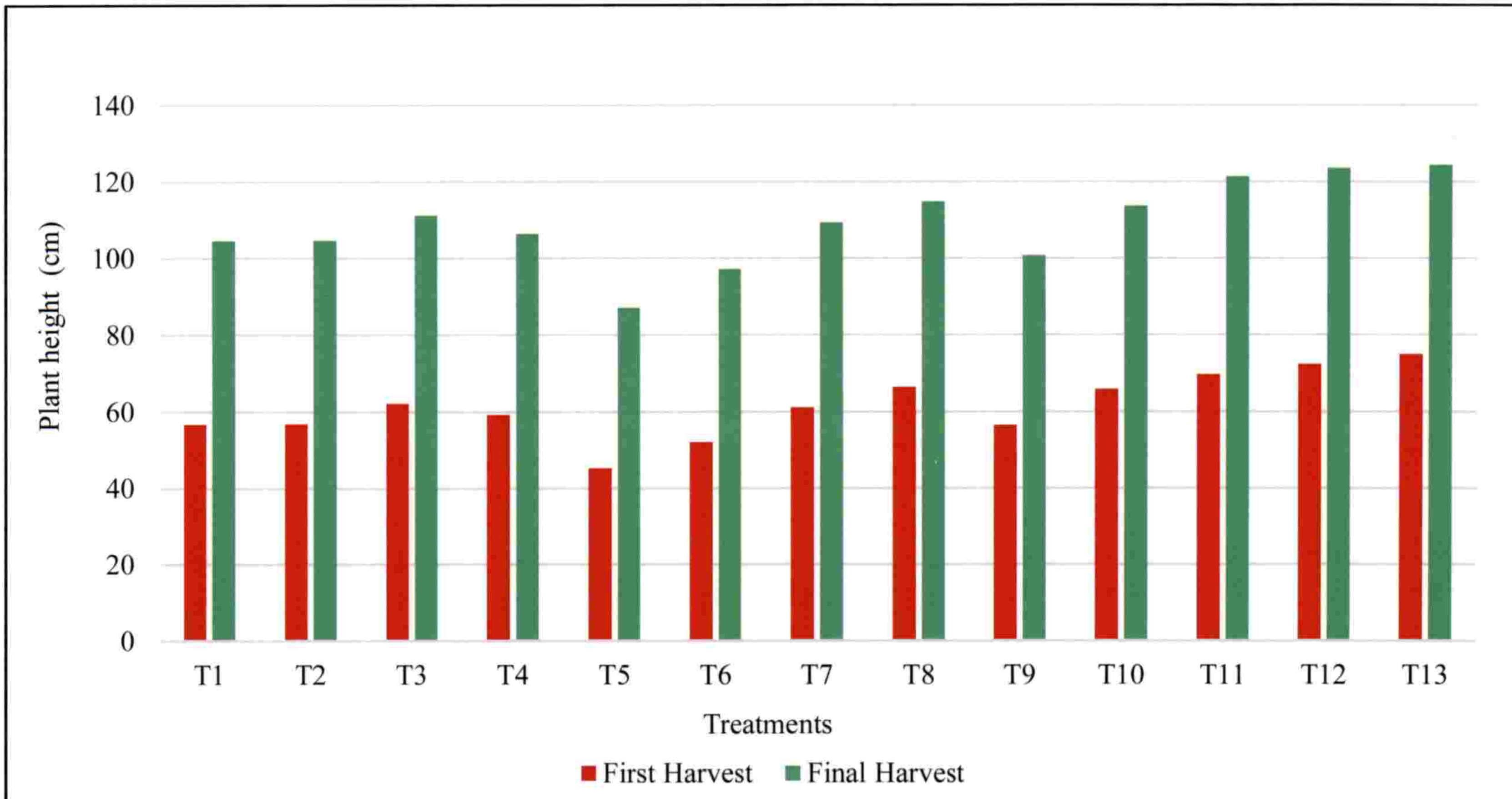


Fig 18. Effect of different treatments on plant height (cm) at different growth stages of bhindi

The application of organic liquid manures significantly enhanced the plant growth parameters due to the better and rapid availability of essential plant nutrients. It was evident from the incubation study that *Kunapajala* application recorded higher nutrient release than soil without *Kunapajala*. *Kunapajala* application enhanced the growth attributes and these observations are in confirmity with the report of Brajeshwar, (2002), Mishra (2007), Deshmukh *et al.* (2012a), Ali *et al.* (2012), Sarkar *et al.* (2013) and Ankad *et al.* (2017). *Kunapajala* possesses the plant growth regulatory activity, which increases the foliage, enhance profuse flowering, fruiting, and overall growth in plants (Rajasekharan and Nair, 2017).

From the study, it was noticed that the increase in plant height might be due to increased uptake of nutrients as observed from table 37. Leaf area index is a function of leaf size and number of leaves which indicated the photosynthetic efficiency and thus the production of crops. Higher level of nitrogen availability through foliage might be the reason for the highest plant growth attributes. The increased nitrogen supply enhanced the protein content and also allowed the plant leaves to grow larger and increased the photosynthesis (Russel, 1973). *Kunapajala*, a natural organic fertilizer provides all the primary nutrients required for the plant growth (Savitha *et al.*, 2012). The organic nitrogen readily converted to ammoniacal nitrogen and nitrate nitrogen through bacterial action and they become available for a longer period (Neff *et al.*,2003). The sustained availability of higher levels of nitrogen from *Kunapajala* had resulted in higher plant height and leaf area. Brajeshwar (2002) reported that the application of *Kunapajala* increased the plant height and foliage due to the presence of nutrient-rich ingredients which was similar to the present findings. Fish and bone meal contain ample quantities of nitrogen, phosphorus and potassium. These nutrients enhanced the root and shoot growth, water absorption of plants and protein synthesis thus better growth, yield and yield attributes of plants. Savitha *et al.* (2012) opined that the combination of ingredients for the preparation of *Kunapajala* can be changed according to the need of the plant part to be used. For good yield of fruits and flowers, decomposed excreta and flesh of animals can be mixed with *Kunapajala* (Jugnu, 2004). The better growth resulted by the foliar application of non- herbal *Kunapajala* may be due to the rapid availability of essential nutrients to the plants. The plant can absorb nutrients about 20 times faster through the leaves than if they are applied through the soil (Agro Chadza,2011). Deshmukh *et al.* (2012b) observed the maximum number of leaves, leaf area index and total biomass in tomato plants by the application of *Kunapajala* for five times at an interval of 10 days as compared to conventional and organic farming. Improved performance of non-herbal *Kunapajala* might be due to the faster decomposition of organic manures, hence nutrients become rapidly available, specifically nitrogen, which help in protein synthesis and ultimately resulted in more dry matter production (Subbiah and Asija, 1956). Babalad (2005), Dhananjaya (2007) and Shijini (2010) reported the same. The complex molecules in ingredients of *Kunapajala* become readily available to the plants through boiling and subsequent fermentation process (Nene, 2018). According to Sakr (1985), the dry weight of plants increased after the organic manure addition due to the production of humus substances and which improved the physical, chemical properties of the soil and enhanced the growth of plants.

The application of Panchagavya at 3% recorded the highest morphological parameters of bhindi when compared to control (Rajesh and Jayakumar, 2013). Similarly, it was reported that foliar application of 3% Panchagavya along with 75% N as enriched vermicompost enhanced the plant height and LAI (Parvathy, 2017). The efficacy of Panchagavya application on growth attributes of crops were reported by Muthuvel (2002), Natarajan (2008), Vemaraju (2014), Satish *et al.* (2006), and Ananda and Sharanappa (2017).

Dhanalakshmi (2017) observed the highest plant growth with the application of 2 weeks old fish jaggery extract at 10%. The presence of hormones and plant growth regulators in these liquid organic manures might be the reason for better plant growth. Somasundaram and Sankaran (2004) opined the similar findings.

5.3.2 Effect of organic liquid manures on physiological characters of bhindi

The chlorophyll a, chlorophyll b, and total chlorophyll content of bhindi leaves varied significantly with the treatments (Fig 19). The highest chlorophyll a content was observed in treatment T_1 (KAU POP) and was on par with *Kunapajala* treatments. The highest chlorophyll b content and total chlorophyll content was recorded by the foliar application of 5 % non-herbal *Kunapajala* along with 50% N as FYM. Deshmukh *et al.* (2012b) observed the same and reported that photosynthetic capacity in the leaves was higher than that of vermicompost and N.P.K treatment. Foliar application of liquid organic manures showed accumulation of nutrient in leaf tissues, which leads to greater translocation and accumulation of carbohydrates and chlorophyll (Gathala *et al.*, 2007). This might be the reason for the increased chlorophyll content in non- herbal *Kunapajala* applied bhindi plants. Non- herbal *Kunapajala* is superior with respect to nutrient content than herbal as indicated in characterization study. Parvathy (2017) also observed an increase in chlorophyll content by the application of 10% Jeevamrutha along with 75% N as EVC. The effect of cow's urine, one of the ingredients in *Kunapajala* on chlorophyll content was studied by Shivamurthy and Patel (2006) and Jandaik *et al.* (2015).

5.3.3 Effect of organic liquid manures on yield characters

Yield and yield characters (Tables 27-29) significantly varied with the treatments. Regarding days to first flowering, the plants treated with 5% herbal and non- herbal *Kunapajala* applied as foliar and 5% fish amino acid flowered earlier. Foliar application of 5% non- herbal *Kunapajala* recorded 50% flowering at the earliest. Similar results were also reported by Deshmukh *et al.* (2012a). *Kunapajala* treated plants showed reduced days for flower initiation, 50% flowering and fruit initiation which was significant for the quantitative enhancement in the yield. The same trend was observed by the foliar application of fish amino acid and Panchagavya in cucumber by Krishnan (2014) and Vemaraju (2014) in oriental pickling melon.

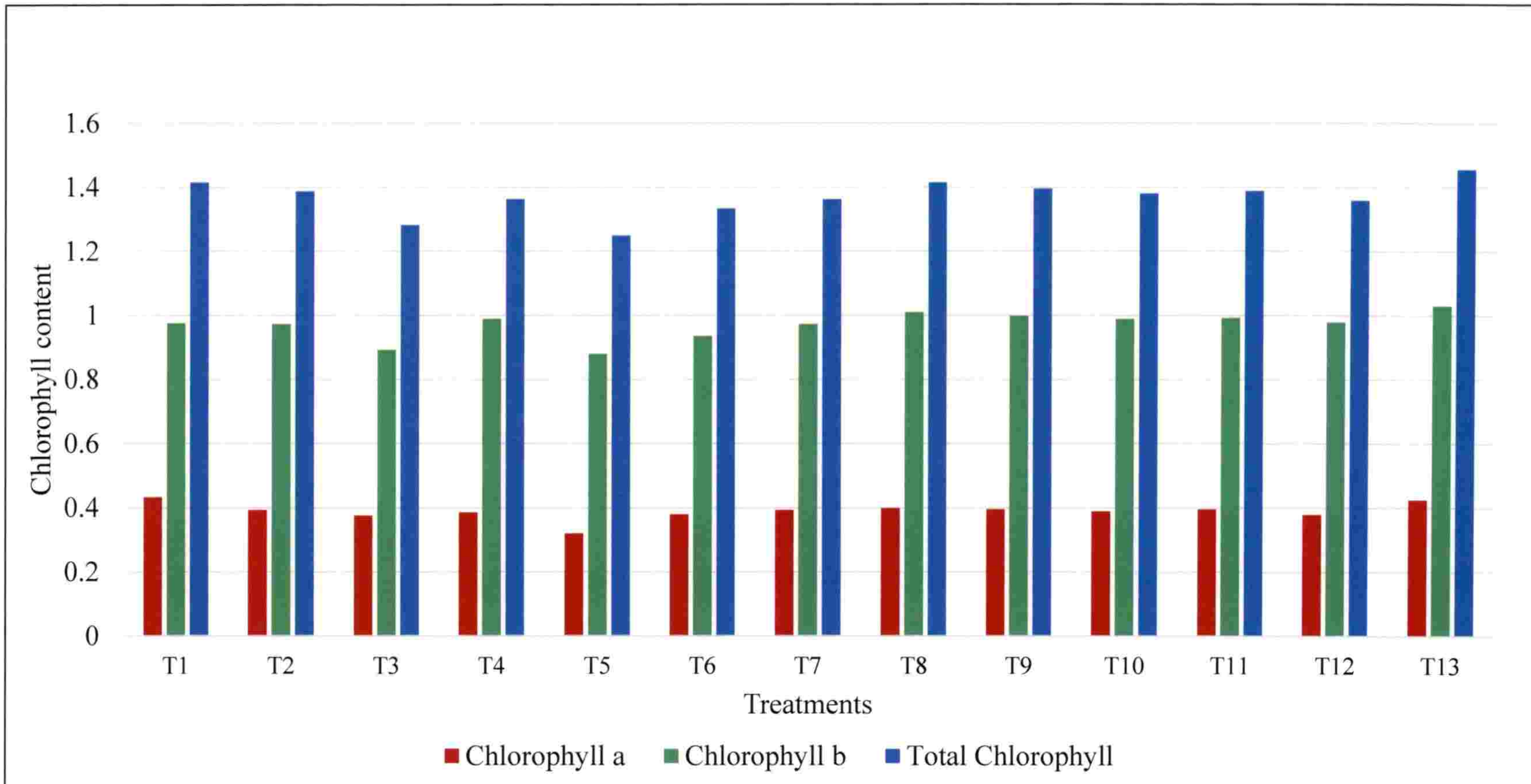


Fig 19. Chlorophyll a, chlorophyll b and total chlorophyll content (mg g^{-1}) as effected by different treatments on bhindi

Foliar application of 5% non- herbal *Kunapajala* recorded the highest mean value for number of fruits, length and girth of fruits, average fruit weight and yield. Foliar application of 5% non- herbal *Kunapajala* recorded the highest number of fruits per plant which was on par with T_{12}. The treatment T_{13} (50% N as FYM +5 % non- herbal *Kunapajala* as foliar application) registered the highest fruit length and was on par with all other treatments except T_2, T_4, T_5 and T_6. Maximum fruit girth and average fruit weight were significantly higher for the treatment, T_{13} than other treatments (Fig 20). Similar results were reported by Deshmukh *et al.* (2012a) that *Kunapajala* application increased the length, diameter, and fresh weight of fruits in tomato. This might be due to the presence of hormones, enzymes and growth regulators in *Kunapajala*.

The highest yield (Fig 21) was observed by the treatment T_{13} (50% N as FYM +5 % non- herbal *Kunapajala* as foliar application) and was on par with T_{12} (50% N as FYM + 2 % non- herbal *Kunapajala* as foliar application). Growth promoters, enzymatic activity and supply of nutrients through the foliage on the addition of liquid manures may increase the duration of crops (Vemaraju,2014). These hormones present in these liquid manures might have improved the physiological activities and leading to better fruit production in bhindi. Similar results were reported by Rameeza (2016) in the case of foliar application of 100 % Jeevamrutha in cucumber. Foliar application of 3% Panchagavya along with 75% N as EVC recorded the highest fruit number and average fruit weight (Parvathy, 2017). According to Prabhu *et al.* (2008), the marketable yield per plant was correlated with the plant height, number of branches and fruit characters. Foliar application of 5% non- herbal *Kunapajala* was superior than other treatments with respect to growth characters and this indicated the efficacy of foliar application of non-herbal *Kunapajala*. Ramesh and Vasanthi (2008) recorded more number of branches, higher yield and fruits with lesser seeds in brinjal fruits by the application of *Kunapajala* when compared with plants grown with synthetic fertilizers.

The fermentation of liquid manure breaks down the complex forms into simpler forms, making it rapidly available to plants than the traditionally applied

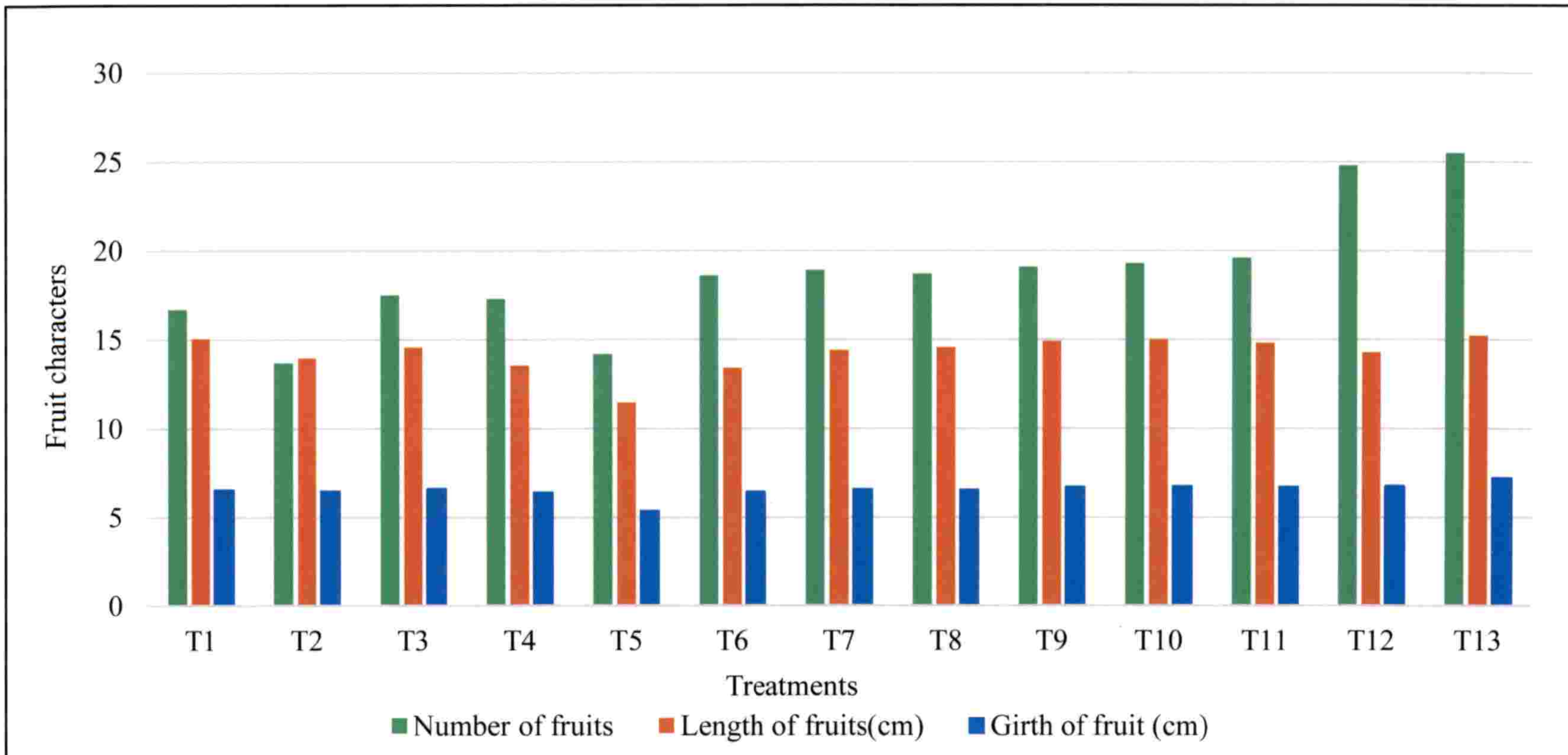


Fig 20. Effect of treatments on fruit characters of bhindi

Plate 11. Effect of treatments on fruit length of bhindi

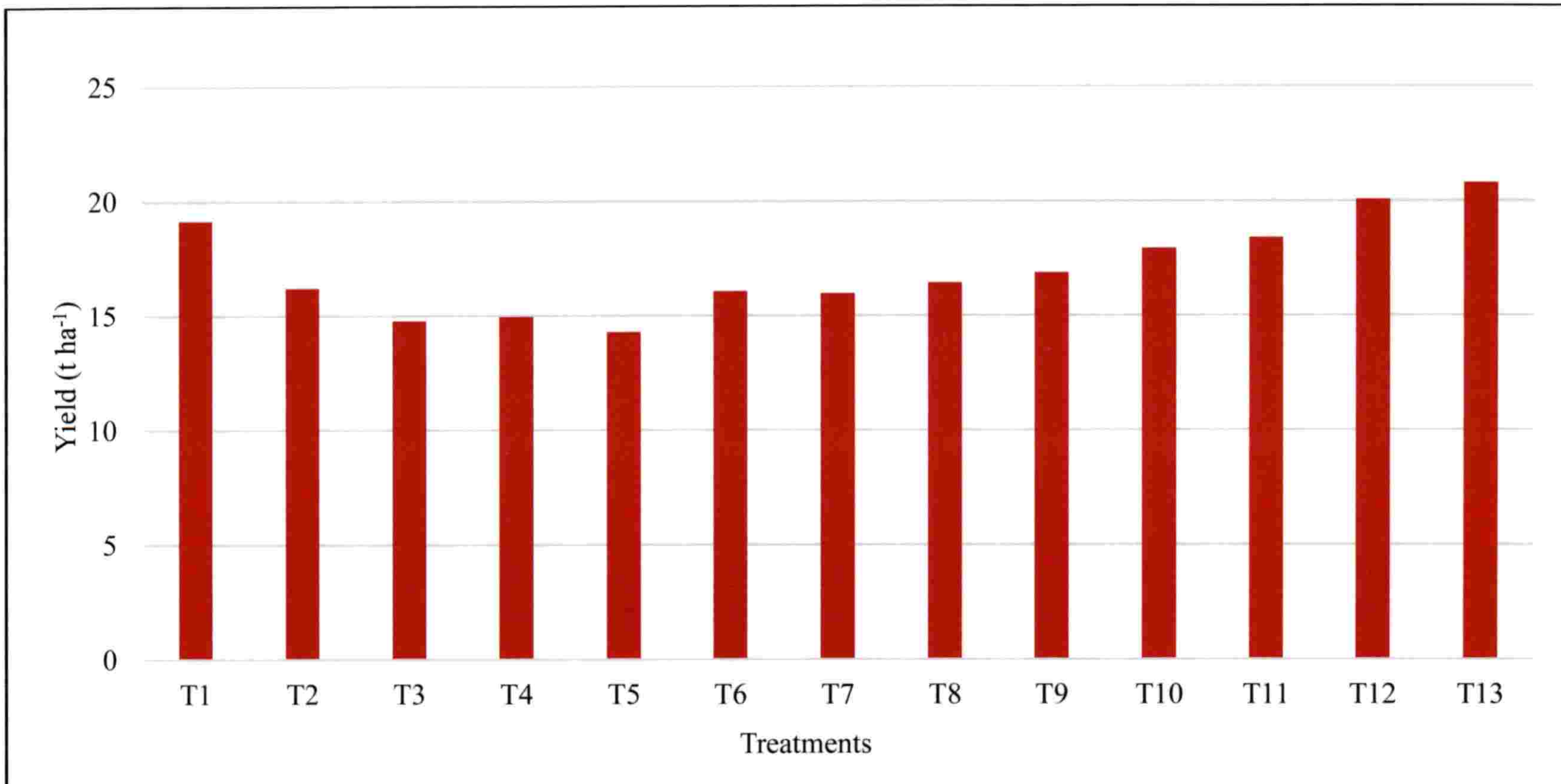


Fig 21. Effect of treatments on Yield (t ha^{-1}) of bhindi

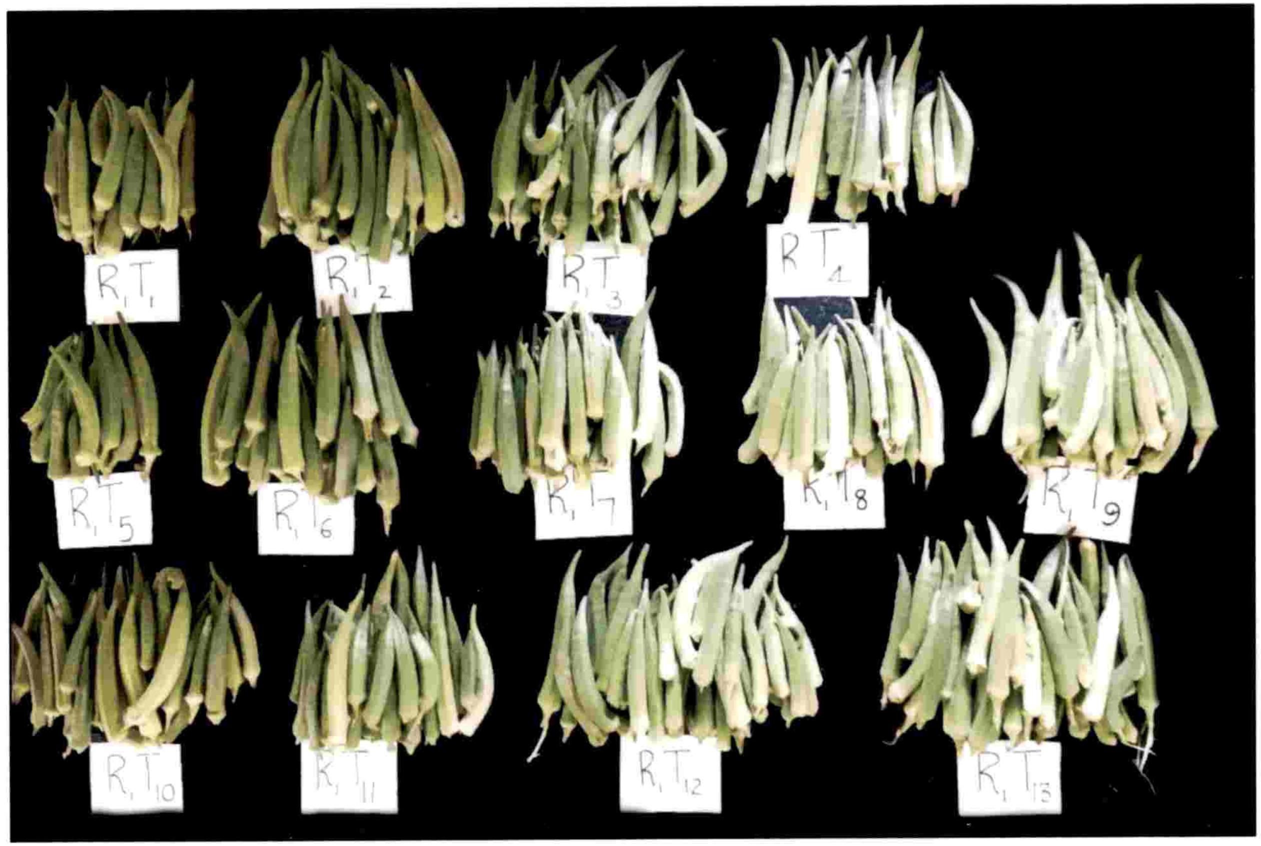


Plate 12. Effect of treatments on yield of bhindi

organic matter (Prabha et al.,2008). The nutrients are readily available to the plants from the liquid organic manure. This might be the reason for better yield attributes of bhindi. Similar results were obtained also by the application of Panchagavya and fish amino acid (Muthuvel, 2002; Vemaraju, 2014; Krishnan, 2014; Parvathy, 2017 and Dhanalakshmi, 2017).

The application of liquid manures enhanced the soil biological activity and foliar application provided nutrients readily to the plants. This confirmed the findings of Devakumar *et al.* (2008). *Kunapajala* is a rich source of beneficial micro organims and these might be the reason for better yield and yield attributes of bhindi. The beneficial micro-organisms presented in the *Kunapajala* may produce growth hormones like IAA and GA and resulted in improvement in plant growth. Rhizosphere activity was enhanced by the foliar application of organic liquid manures (Subha *et al.*, 2014). Nene (2018) opined that being a liquid *Kunapajala* can quickly reach the rhizosphere. The production, translocation and assimilation of photosynthates from source to sink might have increased by the better nutrient availability and uptake during the vegetative and fruiting phase and resulted in better yield attributes.

According to Dar *et al.* (2007) increased fruit yield in plants might be due to improved vegetative growth, better availability of nutrients, greater synthesis of carbohydrates and their proper translocation from source to sink. The yield and yield attributes of crops are influenced by the nutritional status of the soil. The increased plant growth might be due to the improvement in physical, chemical and biological properties of soil on addition of *Kunapajala*. The incubation study indicated better nutrient release from non- herbal *Kunapajala*. This might be the reason for the highest growth, yield and yield attributes recorded by the treatment T_{13} (5 % non- herbal *Kunapajala* along with 50 % N as FYM) in the field experiment.

Sreenivasa *et al.* (2009) observed that the beneficial microorganisms such as free-living N_2 fixers, P solubilizers and bacteria in beejamrutha. Palekar (2006) and Devakumar *et al.* (2008) reported that application of Jeevamrutha promotes higher microbial population in the soil. These beneficial micro-organisms resulted in the production of plant growth hormones thus enhancing growth and yield in plants. Similar observations were noticed by Sreenivasa *et al.* (2009). The improvement in yield and yield attributes of different crops by the application of Jeevamrutha and Beejamrutha were also reported by Chandrakala (2008); Sreenivasa *et al.* (2010); Ravikumar *et al.* (2011); Channagoudra (2012) and Murali and Neelanarayanan (2011).

5.3.4 Effect of organic liquid manures on quality parameters of bhindi

The quality parameters of the fruit showed significant variation due to the treatments. Data revealed that 5% FAA recorded the highest value for crude protein which was statistically on par with T_{13}, T_{10} and T_{12} (Table 30). This might be due to the highest nitrogen content in FAA as indicated by characterization study. N may translocate effectively to the fruits. The foliar application of non- herbal *Kunapajala* might have increased the nitrogen availability to the plants and the highest crude protein content in T_{13}, T_{12} and T_{10} compared with other treatments. The high N content that directly influenced the protein content in fruit was enhanced by the foliar application of 3% Panchagavya (Parvathy, 2017). The N fixers and other microbes presented in these organic liquid manures made N more available to the plants, which resulted in more protein content.

The lowest fibre content, was found as a desirable quality of fruit that was observed in T_{13}. Treatment T_5 (50% N as FYM + water) registered the highest value for crude fibre content. The crude fibre content decreased due to the increase in N uptake which might have resulted in increase in succulence. Parvathy (2017) observed that the lowest crude fibre content by the foliar application of 10% cow urine along with 75 % N as EVC. The highest value of crude fibre indicated little food value. The crude fibre content in fruits might be reduced by the activity of growth hormones. Increased N uptake in plants resulted in decreased crude fibre content. This was confirmed by Tiwanan *et al.* (1975) in Napier bajra hybrid fodder.

The fibre content was reduced due to N application. The highest level of N application through organic manures enhanced the ascorbic acid content and reduced the crude fibre content (Raj, 1999).

The treatment T_{13} registered the highest mean value for ascorbic acid content which was on par with T_{12} and T_1. *Kunapajala* application on tomato plants increased the lycopene, proline and ascorbic acid content (Deshmukh *et al.*, 2012b). The application of organic mixture contains Panchagavya, humic acid and micro herbal fertilizer enhanced the protein and ascorbic acid content in seeds of the soybean (Vijayakumari *et al.*, 2012). Integrated application of organic manures, biofertilizers, and chemical fertilizers revealed high content of ascorbic acid. Similar findings were reported by Chandrakala (2008) with the combined application of beejamrutha + jeevamrutha+ Panchagavya. The growth hormones present in the organic liquid manures resulted in the high quality of products. These results are in corroboration with the findings of Vennila and Jayanthi (2008) and Parvathy (2017). The application of liquid manures such as Jeevamrutha at 1500 L ha^{-1} enhanced the crop quality content in field bean (Siddappa, 2015).

The quality parameters of fruits were enhanced by the application of organic liquid manures specifically, foliar application. This might be due to the rapid availability and uptake of nutrients by the plants. Being fermented, the nutrients in these manures were in the available form.

5.3.5 Incidence of pest and diseases

The pest and disease attack were not much severe. Yellow vein mosaic was observed in a few plants. Insecticidal and anti-microbial activity of the ingredients used for the preparation of *Kunapajala* may have provided resistance to pest and diseases. Shailaja *et al.* (2014) reported that the insecticidal property of cow dung and cow's urine was responsible for the rare incidence. Microbes which are capable of P solubilization, synthesizing pathogenesis related proteins. Sidereophore, antibiotic and auxins were isolated from organic liquid manures by

Babu (2011). According to Sarkar *et al.* (2013), the lower incidence of pest and disease may be due to the production of enzymes by added organic manures.

The ingredients used such as leaves, milk and honey have anti- microbial and anti-inflammatory activities as reported by Mohandas and Narayanan, 2017 and Sreeletha and Geetha 2011. The plant growth hormones produced may have stimulated the growth of beneficial micro-organisms which inturn offered resistance to the plants. Vemaraju (2014) opined that, beneficial micro organisms in these manures might be responsible for the production of secondary metabolites and helped to prevent the attack of pest and diseases. Solaiappan (2002), Sangeetha and Thevanathan (2010b), and Krishnan (2014) reported similar findings.

5.3.6 Effect of organic liquid manures on post-harvest soil

5.3.6.1 Chemical properties

The results revealed that pH of the soil varied significantly with the treatments (Table 32). pH increased after the experiment and values ranged from strongly acidic to slightly acidic. This might be due to the application of organic manures to the soil. The highest pH value was recorded by the treatment received Organic Adhoc POP. Application of lime also decreased the soil acidity and activity of Fe and Al. The active degradation of organic matter increased the bases and suppressed the activity of H^+ ions and Fe and Al oxides (Dahiya *et al.*, 2003). Lal *et al.* (2000), Vemaraju (2014), Krishnan (2014) and Rameeza (2016) reported an increase in pH after addition of organic manures to the soil.

The electrical conductivity of the soil was increased after the experiment in all treatments. Highest electrical conductivity was observed by the treatment T_{13} (foliar application of 5% non- herbal *Kunapajala* along with 50% N as FYM). An increase in EC was the indication of increased content of total soluble salts. Addition of organic manure with beneficial microorganisms facilitated the mineralization of nutrients and faster release of bases. This finding was in corroboration with the results of Thompson *et al.* (1989).

Regarding organic carbon content, the highest value was recorded with the treatment T_{13} (foliar application of 5% non- herbal *Kunapajala* + 50% N as FYM) and was found to be on par with T_{11}, T_{10} and T_{12}. The addition of FYM and liquid manures might have resulted in the increased organic carbon content. Application of liquid dairy manure improved the organic carbon status of soil in plough layer (Maillard *et al.*,2015). The addition of organic manures enhanced the root biomass production and thus the carbon content in soil (Halvorson *et al.*, 1999). Ravishankar *et al.* (2008) reported the improvement in soil organic carbon with the addition of FYM, vermicompost, neem cake and biofertilizers. It was obvious that, the addition of carbonaceous materials improved the soil organic carbon content (Vemaraju, 2014).

Fig 22 shows the variation in available nitrogen due to different treatments. The available nitrogen of the soil enhanced to medium status after the experiment. The highest available N content was recorded by treatment T_{13} which was statistically on par with T_{12} and T_{10}. The increase in the availability of nitrogen may be due to the presence of microbes and enzymes in the non- herbal *Kunapajala* which might have enhanced the mineralization of organic matter resulting in the release of more available nitrogen. As evident from the laboratory incubation study, the N release from the 5% non- herbal *Kunapajala* was higher than that of herbal *Kunapajala*. The *Kunapajala* is rich in N- fixers (Nene, 2018) which might have responsible for increased N availability. The increased available soil nitrogen by the addition of organic liquid manures were reported Vemaraju (2014), Krishnan (2014), Rameeza (2016) and Parvathy (2017). According to Kara *et al.* (2007) application of organic manure facilitated the biological and enzymatic activities and resulted in mineralization of nitrogen into available forms *viz.*, NH^{4+} N and NO_3^- N.

Available phosphorus content was found to be the highest for treatments T_{13} and T_{12} which was on par with T_9 (Fig 23). The increased availability of phosphorus may be due to the presence of *Phosphorus Solubilizing Bacteria* and its improved activity which resulted in the rapid release of phosphate ions from the soil (Ninan

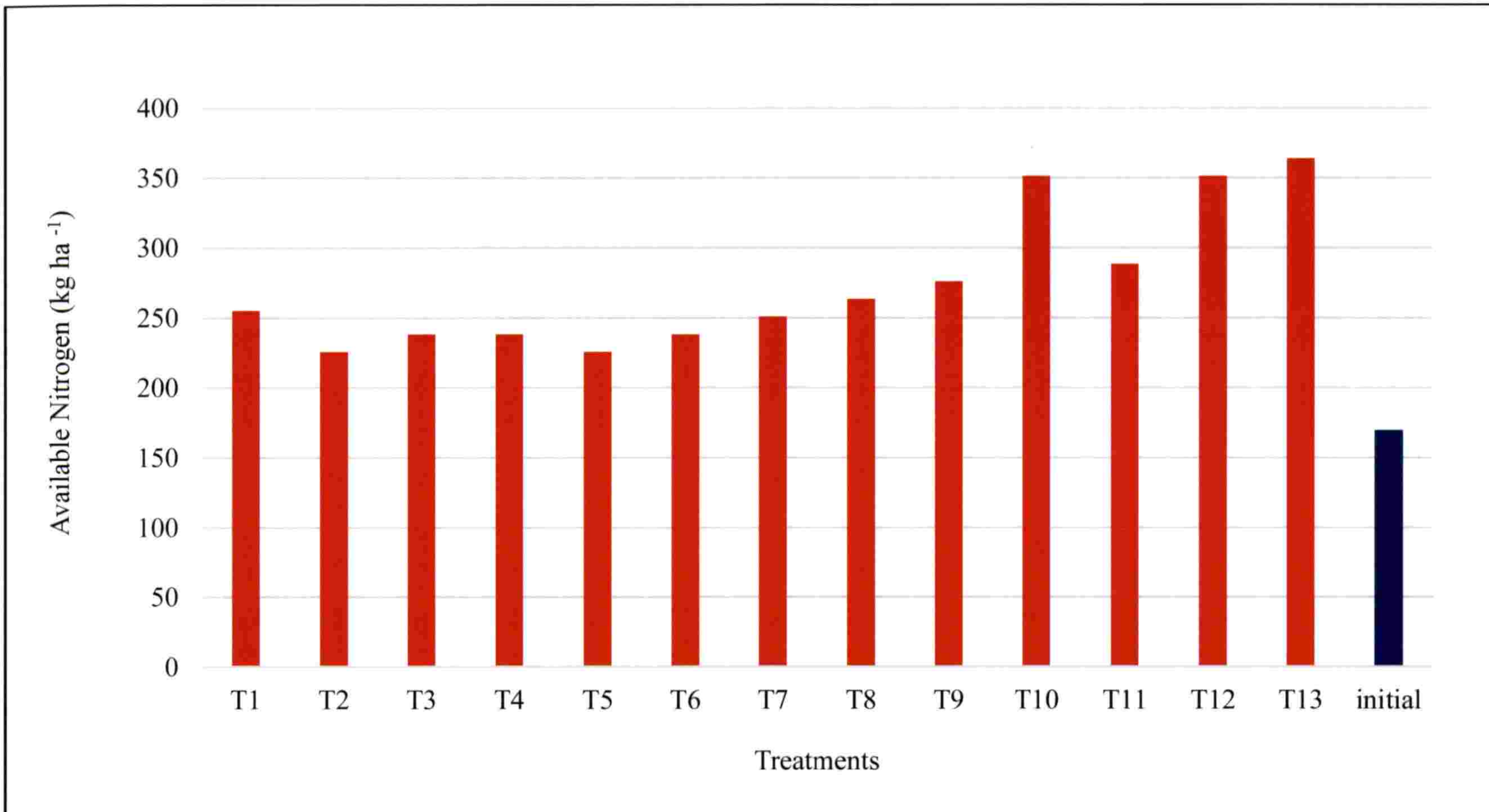


Fig 22. Effect of treatments on soil available Nitrogen content, kg ha^{-1}

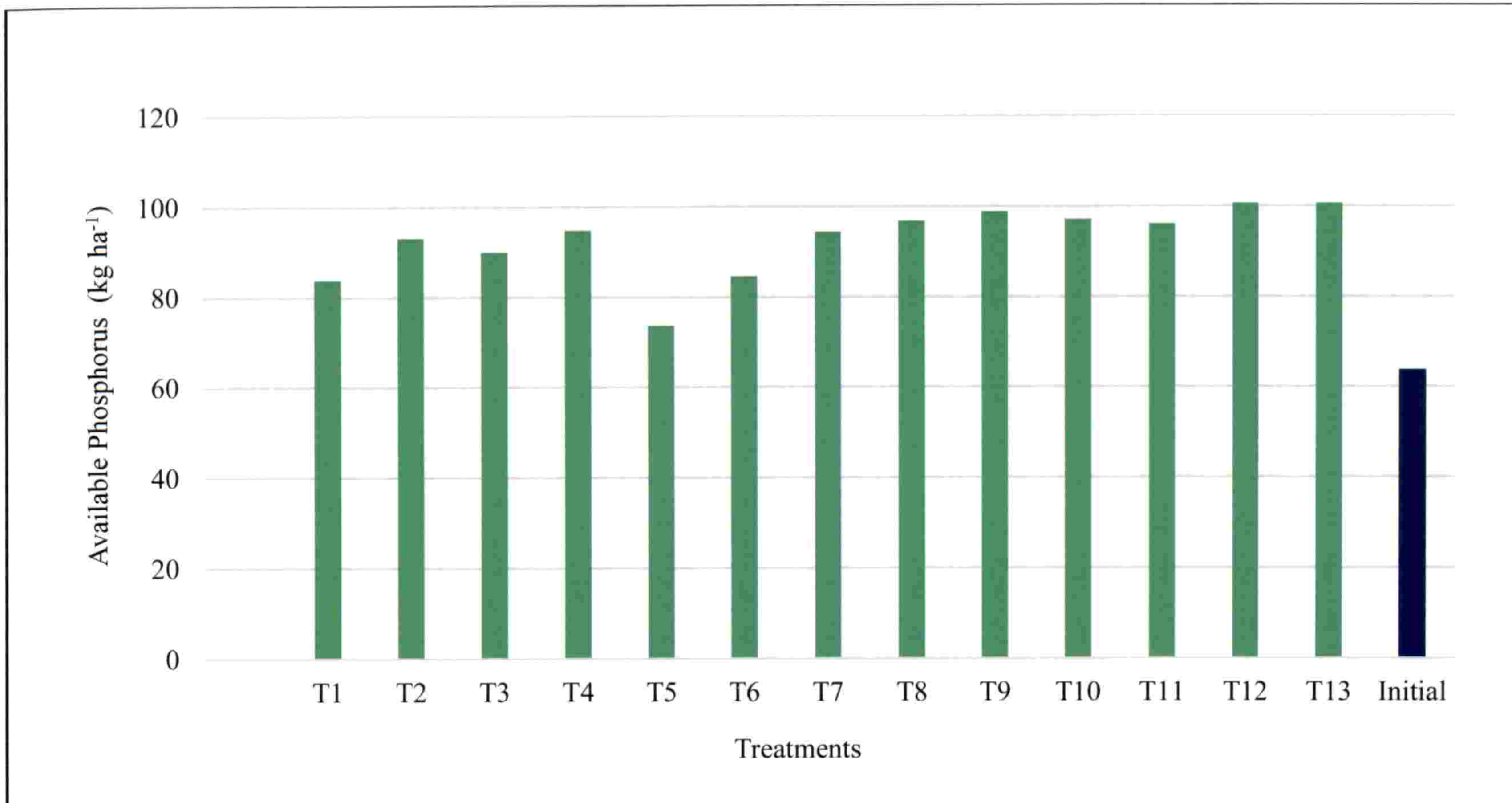


Fig 23. Effect of treatments on available Phosphorus content of soil, kg ha^{-1}

et al., 2013 and Nene, 2018). From the incubation study, it was clear that the release of P from non- herbal *Kunapajala* was higher than that of other treatments. Native soil P might have released during the decomposition of organic matter. The highest uptake of nutrients through foliage may have enhanced the rhizosphere activities and its exudates resulted in faster decomposition of organic matter in the soil. Sushma *et al.* (2007) reported that the significant increase in available P content might be due to the complexation of cations like Cu, Mg and Al by organic colloids and which reduced the fixation of P.

Fig 24 delineated the significant increase in available potassium content after the experiment. The available K content might be increased due to the release of potassium ions. Chitra and Janaki (1999) reported that the increase in available potassium in soil is due to the release of non- exchangeable K to the water-soluble forms through the action of weak organic acids produced from the decomposition of added organic matter.

Veeresha *et al.* (2014) reported that the highest availability of NPK in the soil as a consequence of fast decomposition of added organic matter through the activity of beneficial microorganisms. Similar results were reported by Vemaraju (2014), Sailaja *et al.* (2014), Sreeja (2015), Rameeza (2016), Parvathy (2017) and Ram (2017).

The treatment with foliar application of non- herbal *Kunapajala* recorded the highest available NPK content in the soil, due to the reduced plant uptake from soil. The plants gained the required nutrients through foliar application.

In the case of secondary nutrients, the highest exchangeable Ca content was observed in treatment T_{13} and was significantly superior than other treatments. Mg content was highest for treatment T_{13} and was found to be on par with T_{12}. The S content varied significantly with the treatment and the highest for T_{13} (Fig 25).

The highest secondary nutrient contents in the soil received treatment T_{13} might be due to the high content of Ca, Mg, and S in non- herbal *Kunapajala* as indicated by the characterisation study. The laboratory incubation study also

171

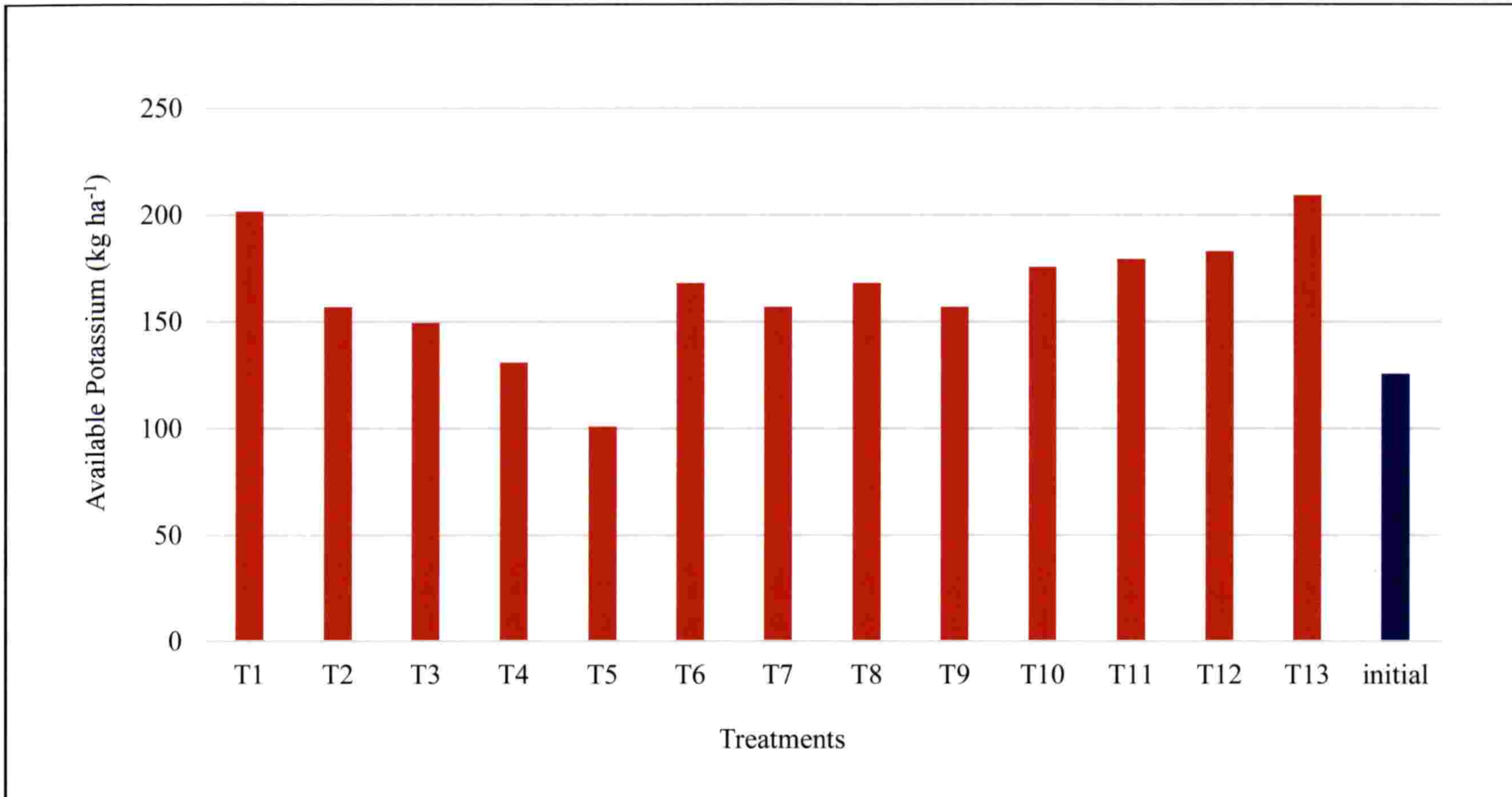


Fig 24. Effect of treatments on available Potassium content of soil, kg ha^{-1}

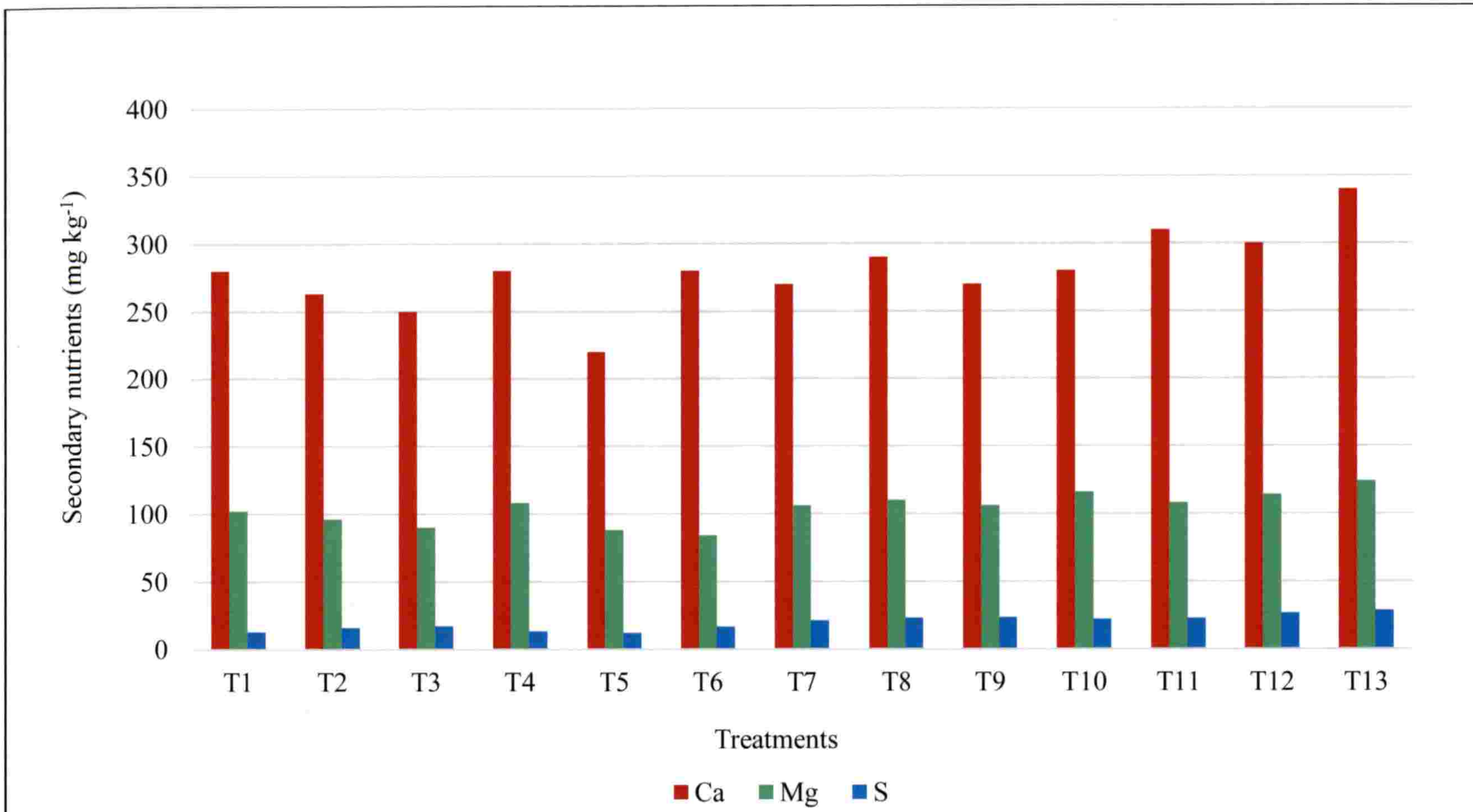


Fig 25. Effect of treatments on secondary nutrients of soil, mg kg^{-1}

revealed the highest nutrient release pattern of 5% non- herbal *Kunapajala*. The sufficient range of exchangeable Ca in the soil for the treatments T_{12} and T_{13} might be due to the less plant uptake from the soil.

The micro- nutrients such as Fe, Cu, Mn, Zn and B varied significantly with the treatments. Higher concentrations of micronutrients in soil after the field experiment was registered by the treatment, T_{13} (5% non-herbal *Kunapajala* as foliar spray along with 50% N as FYM). Thenmozhi and Paulraj (2009) reported the increase in the availability of native nutrients to the crops through the addition of organic manure. The availability of micronutrients enhanced due to its less susceptibility to absorption, fixation or precipitation reaction in soil. The addition of organic matter facilitated the microbial action, pH of the soil and also the formation of stable complexes with the organic colloids. This might be the reason for the highest availability of micronutrients and their availability increased the growth, yield and yield attributes of crops.The experiment conducted by Naidu *et al.* (2009), Balraj *et al.* (2014) Sreeja (2015), and Parvathy (2017) confirmed these findings.

The beneficial microorganisms present in the organic liquid manure enhanced the microbial activity in the soil and hence increased the availability of nutrients. Nutrition through foliage facilitated better nutrient absorption than soil application and rapid translocation of nutrients from source to sink and high nutrient content might be responsible for the superiority of the treatment T_{13} than other treatments with respect to nutrient availability, growth and yield of bhindi.

5.3.6.2 Biochemical and biological analysis

The dehydrogenase enzyme activity of soil was found affected by different treatments (Fig 26). Dehydrogenase activity serves as an indicator of the microbiological redox systems. Parvathy, (2017) reported that increased microbial activity increased the content of enzyme activities. The enzyme activity depends on numerous external factors such as climate, amendments, soil properties and crop cultivation. The treatment comprising of 5% non- herbal *Kunapajala* as foliar

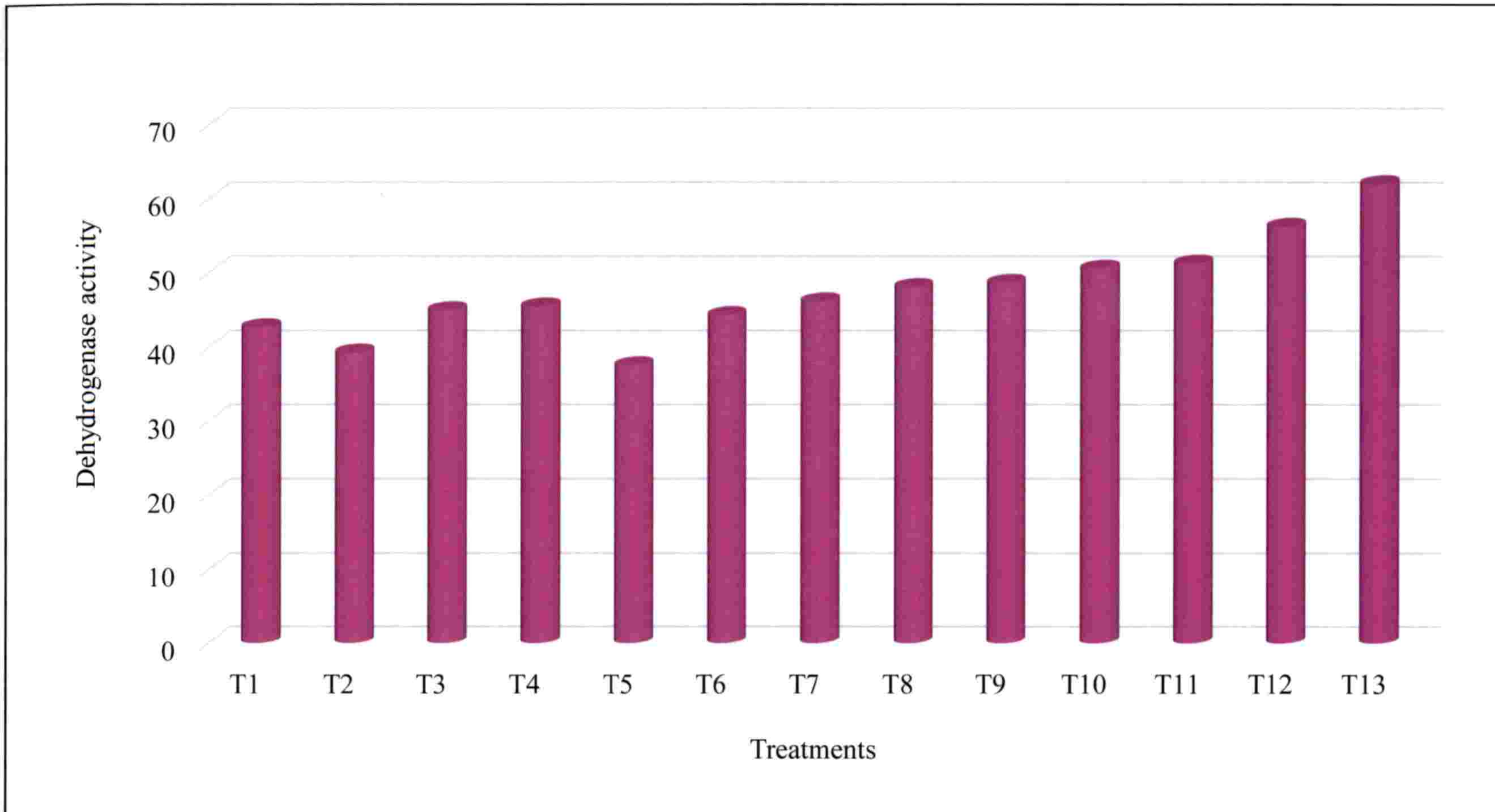


Fig 26. Effect of treatments on dehydrogenase activity of soil, μg TPF g^{-1} soil 24 h^{-1}

application along with 50% N as FYM recorded the highest enzyme activity and was on par with T_{12}.

According to Beyer *et al.* (1992), the study of microbial biomass and enzyme activity was essential to obtain a more complete and precise definition of soil fertility. The enzymes play an important role in organic matter decomposition. The dehydrogenase enzyme activity enhanced after the experiment indicating the increased microbial activity in the soil through organic manure addition.

Regarding microbial load, highest bacterial count was recorded by treatment T_{13} and was found to be on par with T_{12}, T_{11}, T_{10}, and T_9. The treatment T_{13} was significantly superior to other treatments with respect to fungal and actinomycetes. The highest microbial count in soil was due to the addition of microbial rich organic manures. The foliar application of non- herbal *Kunapajala* recorded the highest microbial load. This is in accordance with the findings of Subha *et al.* (2014), who reported that the foliar application of Panchagavya improved the rhizosphere microbial activity. The increased microbial activity might be due to the increased availability of nutrients through foliage and this stimulated proliferous root system and enhanced the production of root exudates and thereby the rhizosphere activity. This leads to better absorption of water and nutrients from lower layers resulting in higher uptake and yield (Thenmozhi and Paulraj, 2009). Gaind and Nain (2010) studied the synergism among soil organic material and microorganisms and reported that organic matter addition stimulated the biological activity of soil. Lower availability of organic matter and unfavourable conditions due to various kinds of losses of applied nutrients in the soil also may be responsible for the lowest microbial count in soil applied treatments.Similar observations were reported by Veeresha *et al* (2014). The increase in soil bacteria, fungi and actinomycetes after the application of liquid organic manures were also reported by Vemaraju (2014), Krishnan (2014), Siddappa (2015), Rameeza (2016), Dhanalekshmi (2017) and Parvathy (2017). The organic manure addition enhanced the microbial count by providing carbon as a source of energy for microbes and also provide protection to enzyme fraction due to increase in humus content (Martens *et al.*, 1992). The rapid

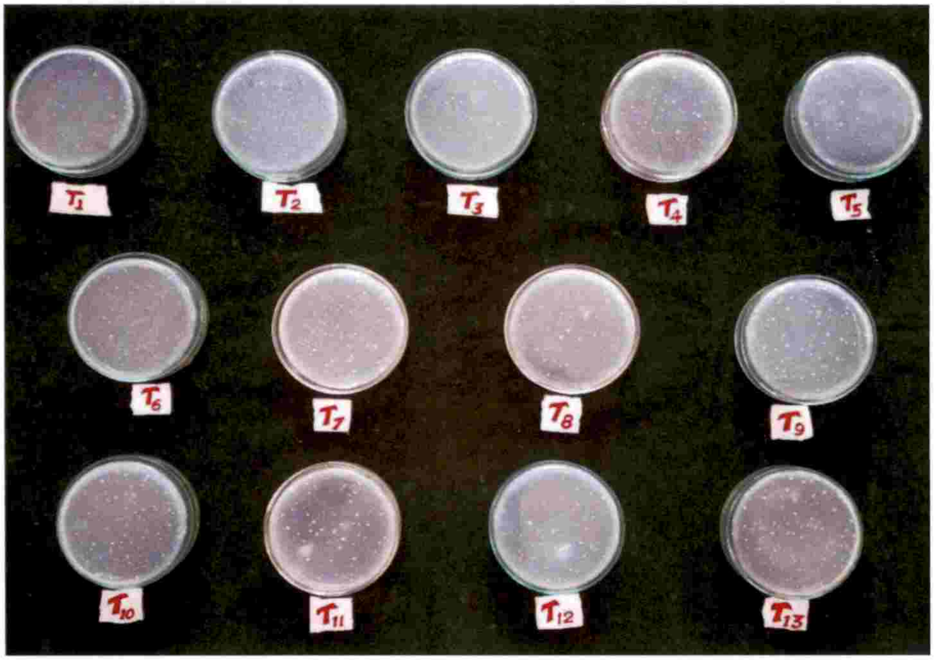


Plate 13. Influence of treatments on soil bacterial population

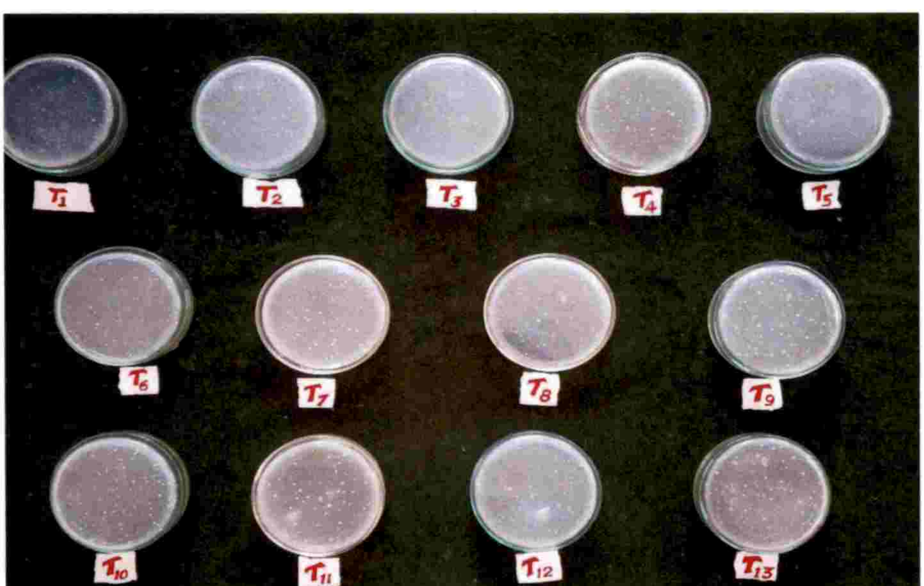


Plate 14. Influence of treatments on soil actinomycetes population

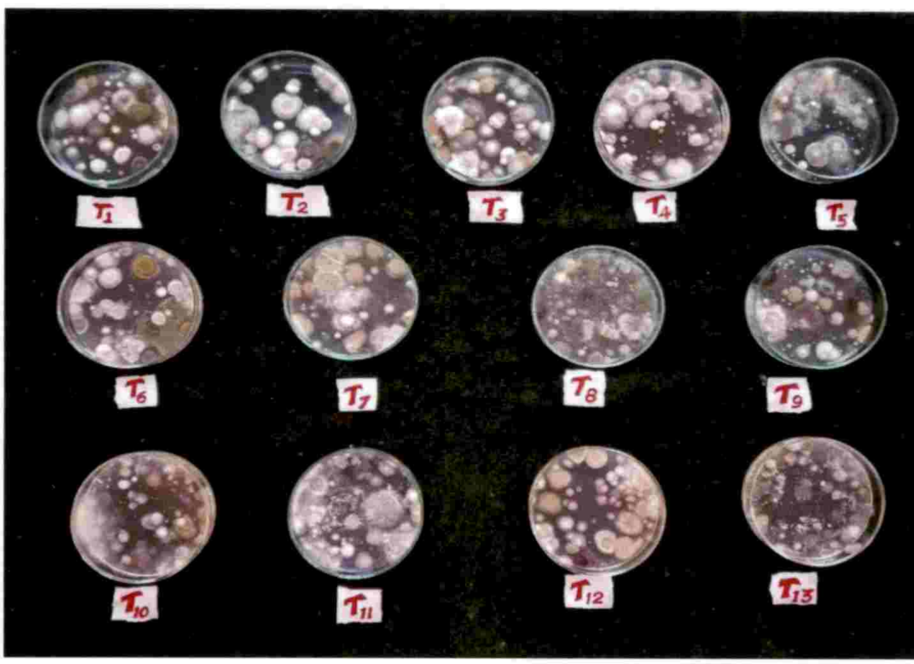


Plate 15. Influence of treatments on soil fungal population

multiplication of microbes can also be correlated with the increase in pH due to organic matter addition (Vemaraju,2014).

The increased microbial activity on addition of microbial rich organic liquid manures could improve the nutrient availability of crops (Gore and Sreenivasa, 2011). The increased microbial load might be responsible for the enhanced dehydrogenase enzyme activity, as this assay is an estimate of viable microbial activity. This was similar to the reports of Dahiya *et al.* (2003), Shwetha (2008) and Tejada *et al.* (2009).

5.3.7 Effect of organic liquid manures on nutrient uptake

The different treatments significantly influenced the uptake of nutrients (Table 37-39). Regarding primary nutrients, 5% non- herbal *Kunapajala* applied as foliar application along with 50% N as FYM registered the highest significant uptake of N, P and K in plants (Fig 27). The increased uptake of plant nutrients might be due to the solubilisation effect of plant nutrients by the addition of organic manures which resulted in better fruit weight and fruit yield of the crops (Sendurkumaran *et al.*, 1998).

The increased N uptake may be due to the microbial activity, which leads to the rapid availability of vast portion of non- oxidizable N in organic manures and also through biological nitrogen fixation. The highest P uptake in plants may be due to the enzyme activities and occurance of P mineralization. Similarly, Niranjana (1998) reported that, the increased P content through mineralization and addition may be due to the production of weak organic acids during decomposition. The K uptake was also enhanced on the addition of 5% non- herbal *Kunapajala* as foliar application along with 50% N as FYM (T_{13}).

Results revealed that foliar spray of 5% non- herbal *Kunapajala* recorded the highest NPK content. Boomathi *et al.* (2005) observed increased availability of nutrients due to microbial and enzymatic activity and biological efficiency of crop plants creating greater source and sink in the plant system. The highest nutrient content in non- herbal *Kunapajala* resulted in better physiological characters,

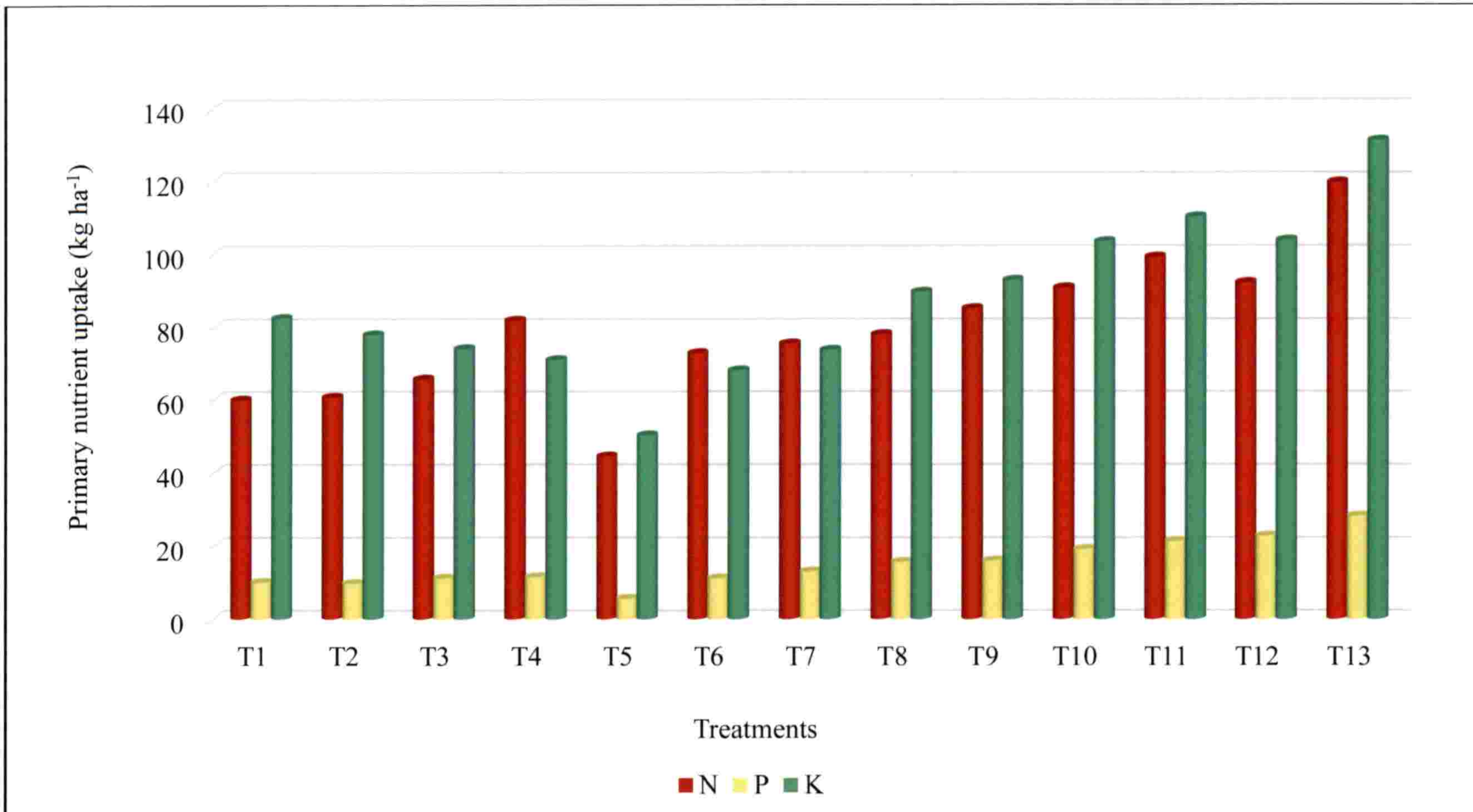


Fig 27. Effect of treatments on plant uptake of primary nutrients, kg ha^{-1}

increased the photosynthetic efficacy, leading to increased uptake of nutrients (Chandrakala, 2008).

According to Prabha *et al.* (2008) *Kunapajala* being in liquid form, was readily available for the roots. The breakdown of *Kunapajala* into simpler forms by composting and presence for long period in the soil enhancing microbial action in the soil allowing it to absorb and retain water and nutrients more efficiently. The maximum growth and yield were resulted by the foliar application of liquid formulations which enhanced the nutrient uptake and might have led to the effective conversion of vegetative phase to the reproductive phase. This was confirmed by Karthikeyan (2010) Abhilash (2011) and Parvathy (2017). The nutrient uptake in plants can be facilitated by quality organic liquid manures. As reported by Devakumar *et al.* (2008), the beneficial effect of organic manures might be due to the presence of microbes and enzymes which facilitated the uptake of applied as well as native nutrients which inturn resulted in growth and yield of crops.

Calcium and Magnesium uptake was the highest for T_{13} which was on par with T_{12}. The highest sulphur content in these treatments were on par with T_{12}, T_{11} and T_{10} (Fig 28). This might be due to the presence of high Ca, S, and Mg content in non- herbal *Kunapajala* as evident from characterization study.

Foliar application of 5% fish amino acid along with 75% N as EVC reported the highest uptake of secondary nutrients by bhindi plants (Parvathy, 2017). In the present investigation the uptake of nutrients, growth and yield of crops with FAA and Panchagavya application were not much effective compared to *Kunapajala*. This might be due to the mode of application of these manures. Foliar application can perform well than that of soil application.

Foliar application of 5% non-herbal *Kunapajala* along with 50% N as FYM resulted in the highest uptake by the crops with respect to micro-nutrients also. Maximum Fe, Cu, Mn, Zn and B contents were registered by treatment T_{13}. The highest B content was found to be on par with T_{12}. This might be due to the highest micronutrient content in the non- herbal *Kunapajala*. Non- herbal *Kunapajala* may

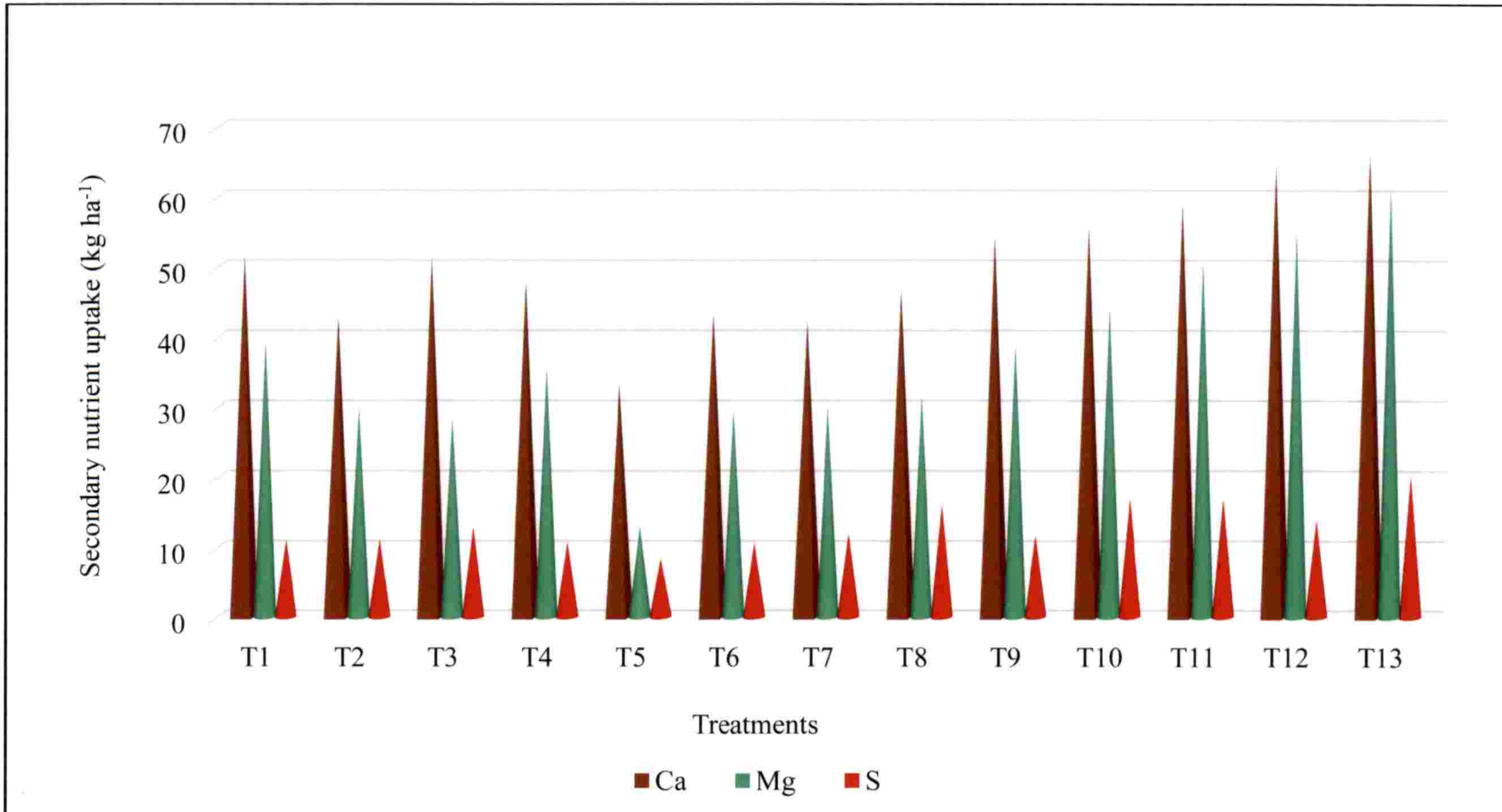


Fig 28. Effect of treatments on plant uptake of secondary nutrients, kg ha^{-1}

182

be rich in plant growth hormones and regulators. Plant growth hormones were responsible for the production of the highest biomass and better recovery of nutrients. According to Deb and Sakal (2002), the increased nutrient availability to the plants through organic matter addition was due to its ability to hold nutrients in stable combinations. Organic matter chelated the micronutrients cations and were readily available to the plants. Assimilation and mineralization by microorganisms resulted in the rapid availability of micronutreints.

The increased supply of nutrients through the foliar application of liquid manures effected the ramification of roots and thereby increased the nutrient uptake of plants (Choudhary *et al.*,2014). The beneficial micro-organisms present in these manures produced bioactive molecules and they involved in stomata regulation which facilitated the uptake of nutrient. The higher nutrient content in plant parts responsible for the overall yield and growth of crops. Similar findings were reported by Shwetha *et al.* (2009), Rao *et al.*(2015) and Choudhary *et al.*2017.

Siddappa (2015) opined that higher nutrient content in plants by the application of Jeevamrutha @ 1500 L ha^{-1} might be due to the build up of soil microflora in the soil. The growth and yield characters were significantly influenced by the uptake of nutrients. The favourable effect of organic manures in plant nutrient uptake may be due to is ability in providing nutrients in sufficient quantities, and the uptake of the nutrients at the early growth stage may be resulted in increased plant metabolic activity and thus vigorous growth and yield (Anburani and Manivannan 2002).

5.3.8 Economics of cultivation

The economics of cultivation of bhindi is depicted in the table 40. The B: C ratio was the highest (2.46) for treatment T_{13} (50% N as FYM + 5% non- herbal *Kunapajala* as foliar application) followed by T_{12} (2.39). The lowest B: C ratio was observed in treatment T_5 (50% N as FYM + Water). All the treatments were profitable except T_5. The increased yield resulted in the highest B: C ratio and the cost of preparation of *Kunapajala* was very low. Since the diluted form was used

183

the quantity requirement was also less for realising maximum yield. Hence, proper storage without deterioration in quality will help to reduce the labour charge for preparation. The highest B : C ratio attained by the application of organic manures were reported by Krishnan (2014) in cucumber, Vemaraju (2014) in oriental pickling melon, Sreeja (2015) in yard long bean, Rameeza (2016) in salad cucumber, and Parvathy (2017) in bhindi.

Conclusion

The study "Characterisation and evaluation of herbal and non- herbal *Kunapajala* on soil health and crop nutrition" revealed the efficacy of herbal and non-herbal *Kunapajala*. The physical, chemical, biochemical and biological characterization indicated that both herbal and non-herbal *Kunapajala* contained all the primary, secondary and micronutrients. Among the two types of *Kunapajala*, non-herbal *Kunapajala* was found to be superior over the herbal one. The laboratory incubation study revealed that soil + FYM treated with 5 % non-herbal *Kunapajala* recorded the highest nutrient release within 60 days

Application of 50% N as FYM + 5% non-herbal *Kunapajala* as foliar application (T_{13}) was the best treatment in the field experiment which resulted in the highest growth, yield and yield attributes of bhindi and yield was on par with the treatment T_{12} (50% N as FYM+ 2% non-herbal *Kunapajala* as foliar application). From the study, it was clear that FYM as nutrient source can be reduced to half, if 2% or 5% non-herbal *Kunapajala* as foliar spray (at 10 days interval) was applied along with 50% N as FYM. Application of non-herbal *Kunpajala* as foliar spray along with 50% N as FYM is essential to get higher crop yield in organic farming and also inorganics can be substituted with foliar spray of *Kunapajala* along with quality organic manures. The two treatments (T_{12} &T_{13}) were found to be superior to KAU POP for bhindi with respect to yield and yield attributes and quality of produce. Present study confirmed that *Kunapajala* is a promising and eco-friendly plant stimulant for sustainable crop production and safe agro ecosystem.

FUTURE LINE OF WORK

- The best treatment from the present investigation can be tested in different Agro Ecological Zones of Kerala using different test crops to derive package of practices recommendation for sustainable and economic organic farming in Kerala.
- Standardisation of dose of application of organic liquid manures for various crops at different stages of growth will be assessed.
- Shelf life of organic liquid manures and their effect on quality parameters of organic products will be assessed.
- Identification of microorganisms in organic liquid manures and detailed microbial and enzymatic studies need to be done to explain the nutrient mineralization pattern of organic liquid manures.

Summary

6. SUMMARY

An investigation entitled "Characterization and evaluation of herbal and non-herbal *Kunapajala* on soil health and crop nutrition" was undertaken with the objectives to prepare and characterize organic liquid manures, monitor the nutrient release pattern under laboratory condition and to evaluate the efficacy of soil and foliar applications of these traditional manures on soil health and crop nutrition using bhindi as a test crop. The study was carried out at the Model Organic Farm under the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during November 2018 to February 2019. The study comprised of three parts and the summary of salient findings is presented below.

6.1 Preparation and characterization of organic liquid manures

The organic liquid manures such as herbal and non-herbal *Kunapajala*, Panchagavya, FAA were prepared for the experimental purpose.

- The colour and odour of herbal *Kunapajala* were dark brown and fermented odour respectively. Colour of non- herbal *Kunapajala* was yellowish brown with fermented odour. Panchagavya was light brown in colour with fermented odour. The colour and odour of the FAA were dark brown and odourless.
- The pH of herbal and non-herbal *Kunapajala* was in the neutral range (7.00 and 7.70, respectively) while Panchagavya and FAA were in acidic range (5.50 and 4.40 respectively)
- Panchagavya registered the highest EC (7.30 dS m^{-1}) followed by FAA (3.60 dS m^{-1}), herbal *Kunapajala* (2.25 dS m^{-1}) and non- herbal *Kunapajala* (2.41 dS m^{-1}).
- FAA recorded the highest organic carbon content of 35.67% followed by herbal *Kunapajala* (2.00%), non-herbal *Kunapajala* (2.30%) and Panchagavya (1.20%).
- The highest nitrogen content was recorded by FAA (3.90%)

- Panchagavya registered the highest phosphorus content (0.43%).
- The potassium content was highest for non- herbal *Kunapajala* (0.44%) followed by herbal *Kunapajala* (0.33%), FAA (0.24%) and Panchagavya (0.14%).
- The highest Ca, Mg and S content was noticed in non-herbal *Kunapajala* followed by herbal *Kunapajala*, FAA and Panchagavya.
- The highest Fe (12.3 mg L^{-1}), Mn (1.04 mg L^{-1}), and B (4.86 mg L^{-1}), contents were observed in non- herbal *Kunapajala* whereas the highest Cu (1.56 mg L^{-1}) & Zn (1.93 mg L^{-1}) contents were recorded by Panchagavya and FAA respectively.
- The highest population of bacteria was observed in non- herbal *Kunapajala* and the fungal population was higher for FAA compared to other organic liquid manures. No actinomycetes were found in any of these organic liquid manures.
- The biochemical characters such as dehydrogenase enzyme activity, ascorbic acid content and total sugar percentage were found to be the highest in FAA.

6.2 Laboratory Incubation Study

The soil was collected from Model Organic Farm under the Department of Soil Science and Agricultural Chemistry, for conducting the laboratory incubation study. Herbal and non- herbal *Kunapajala* were added separately as per the treatments to maintain sixty percentage moisture capacity. The incubation study was conducted for two months to monitor nutrient release pattern from herbal and non- herbal *Kunapajala*.

- An increasing trend was noticed for pH and EC of soil throughout the incubation period.
- The organic carbon content of soil increased upto 15th day of incubation and the soil + FYM treated with 5 % non- herbal *Kunapajala* recorded the highest organic carbon content.

189

- The available nitrogen, phosphorus and potassium contents of soil varied significantly with the treatments. Available nitrogen and potassium increased upto 45th day of incubation. Nitrogen and phosphorus released from soil + FYM treated with 5% non- herbal *Kunapajala* recorded the highest value while potassium released from soil + FYM treated with 5% herbal *Kunapajala* recorded the highest value.
- The results of secondary nutrients release pattern indicated that exchangeable Ca and Mg content increased upto 15th day and 30th day of incubation respectively. Higher release of Ca and Mg were noticed in soil + FYM treated with 5% non- herbal *Kunapajala* compared to other treatments.
- There was a gradual increase in available S and available B content upto 30th day of incubation. The treatment T_5 (Soil + FYM + 5% non- herbal *Kunapajala*) recorded the highest value for soil available S and B at all sampling intervals.
- In the case of micronutrients, the different treatments did not impart a significant difference in the micronutrient contents such as Zn and Cu. The maximum Fe release was obtained at the 45th day of incubation and that of Mn was obtained at the 15th day of incubation.
- In general soil + FYM treated with 5% non- herbal *Kunapajala* resulted in the maximum release of almost all the nutrients throughout the incubation period.

6.3 Field Experiment

A field experiment was laid out in RBD with 13 treatments and three replications for evaluating comparative efficacy of soil and foliar applications of herbal and non- herbal *Kunapajala*. KAU POP, Organic Adhoc POP, 3% Panchagavya, 5 % FAA applied along with organic Adhoc POP, water spray and soil and foliar application of 2% and 5% herbal and non- herbal *Kunapajala* applied along with 50% N as FYM.

Salient findings of the field experiment are summarised below

- Treatment with foliar application of 5% non- herbal *Kunapajala* (T_{13}) recorded the highest bhindi plant height at first harvest (74.93 cm) and final harvest (124.43 cm). At first harvest T_{13} was found to be on par with T_{12}, T_{11},T_{10} and T_8. T_{13} was on par with T_{12}, T_{11}, T_{10},T_8, and T_3 at final harvest of the crop.
- Number of branches per plant (3.73), leaf area index (1.42) and dry matter production (3845.51 kg ha^{-1}) of bhindi were significantly higher for the treatment T_{13} than any other treatmentS. Treament that received water application along with 50% N as FYM recorded the lowest value.
- Physiological characters of bhindi viz., chlorophyll a content was the highest in T_1 and was found to on par with T_8, T_9 and T_{11}. The chlorophyll b and total chlorophyll content were found to be the highest for the treatment T_{13}. T_{13} was on par with T_8, T_9 and T_{11} for chlorophyll b and T_{13} was on par with T_8 for total chlorophyll content.
- In the case of yield contributing characters, T_4 and T_{11} flowered earlier and was found to be on par with T_1,T_7,T_9,T_{10},T_{12} and T_{13}. T_{13} recorded number of days to 50% flowering at the earliest and was found to be on par with T_{12} nad T_9.
- Foliar application of non- herbal *Kunapajala* along with 50% N as FYM recorded the highest fruit characters such as number of fruits, length of fruits, girth of fruits and average fruit weight.
- The highest fruit yield was registered by treatment T_{13} and was on par with T_{12}.
- Quality parameters viz, protein content, fibre content and ascorbic acid content varied significantly with the treatments. T_4 recorded the highest crude protein content and was found to be on par with T_{13}, T_{10} and T_{12}.
- The lowest crude fibre content content was recorded by treatment T_{13}
- The highest ascorbic acid content was recorded by T_{13} and was on par with T_{12} and T_1.
- Pest and disease incidence were very rare

- Post harvest analysis of soil revealed that the chemical , biological and biochemical properties of soil varied significantly with the treatments.
- The highest pH was recorded by the treatment Organic Adhoc POP (T_2)
- Highest EC value was recorded by treatment T_{13} (1.51 dSm^{-1})
- Treatment T_{13} recorded highest organic carbon (1.50%) content and was found to be on par with T_{10},T_{11}, and T_{12}.
- T_{13} (50% N as FYM +5 % non- herbal *Kunapajala* as foliar application) recorded the highest mean value of available nitrogen (363.8 kg ha^{-1}) and was found to be on par with T_{10} and T_{12}.
- Highest mean value of available P was recorded by the treatment T_{13} and T_{12} and was on par with T_9 whereas the highest available K content was recorded by T_{13} and was found to be on par with T_{12}.
- In the case of exchangeable Ca and available S the treatment T_{13} recorded significantly higher value than other treatments. Exchangeable Mg content was highest for T_{13} and was on par with T_{12}.
- Regarding micronutrient contents, treatment that recived foliar application of 5% non-herbal *Kunapajala* along with 50% N as FYM registered significantly highest significant value for micronutrients such as Fe (3.77 mg kg^{-1}), Mn (35.12 mg kg^{-1}), Zn (10.38 mg kg^{-1}), Cu (3.41 mg kg^{-1}) and B (0.52 mg kg^{-1}).
- Total bacterial count was found to be highest in T_{13} (9.04 log cfu g $soil^{-1}$) and was found to be on par with T_{12},T_{11},T_{10} and T_9.
- Fungi and actinomycetes count were significantly highest for treatment T_{13}
- The highest dehydrogenase activity was recorded by treatment T_{13} (62.00 µg of $TPFg^{-1}$ soil 24 h^{-1}) and was on par with treatment T_{12}.
- Regarding the uptake of primary nutrients,the highest NPK uptake was reorded by treatment T_{13}.
- Similarly, treatment T_{13} recorded highest Ca, Mg and S uptake. T_{13} was on par with T_{12} and T_{11} in Ca uptake, T_{12} in Mg uptake and with T_{10} and T_9 in S uptake.

192

- Plant uptake of micronutrients varied significantly with the treatments and the treatment T_{13} recorded significantly the highest value.
- The treatment T_{13} secured a B:C ratio of 2.46 followed by treatment T_{12} (2.39).

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194

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210

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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

Appendix II

Weather parameters during field experiment

	Week	Avg. rf (mm)	Max temp (^0C)	Min temp (^0C)	Evaporation (mm)	Max RH (%)	Min RH (%)
1	Nov 5-11	8.5	31.1	24.3	2.1	93.6	78.7
2	12-18	7.3	31.7	23.8	2.5	92.1	73.3
3	19-25	7.4	31.6	24.1	2.8	93.0	74.0
4	26-2	0	31.9	23.7	2.9	93.3	72.4
5	Dec 3-9	2.5	31.9	23.7	2.5	92.9	73.9
6	10-16	3.7	32.2	23.8	3.1	94.3	73.9
7	17-23	0.3	32	22.9	3.3	92.4	71.9
8	24-31	0.9	31.9	23.5	3.3	92.7	71.7
9	Jan 1-7	0	31.97	19.6	3.6	92	66.6
10	8-14	0	31.57	20.7	3.83	92	68.5
11	15-21	0	32.2	20.85	3.64	90.86	68.14
12	22-31	0.4	32.15	21.93	3.77	92.9	66.97
13	Feb 1-9	0	32.79	23.47	3.8	89.55	66.25

CHARACTERIZATION AND EVALUATION OF HERBAL AND NON-HERBAL *KUNAPAJALA* ON SOIL HEALTH AND CROP NUTRITION.

by

KAVYA S R

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ABSTRACT

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ABSTRACT

The study entitled "Characterization and evaluation of herbal and non-herbal *Kunapajala* on soil health and crop nutrition" was conducted in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during 2017-2019.

Kunapajala is a traditional organic liquid manure mentioned in *Vrikshayurveda* and popular among farmers. Few works have been carried out on application of *Kunapajala,* and characterization has not been studied till date. So, present investigation was undertaken with the objectives to prepare and characterize the herbal and non-herbal *Kunapajala*, monitor the nutrient release pattern under laboratory conditions and evaluate the efficacy of soil and foliar applications of herbal and non-herbal *Kunapajala* on soil health and crop nutrition using bhindi as a test crop.

The study comprised of three parts. The first part herbal and non- herbal *Kunapajala*, were prepared as prescribed by *Vrikshayurveda.* Herbal *Kunapajala* was prepared by mixing plant leaves (non-milky and non-grazing), cow dung, cow's urine, sprouted black gram and jaggery in 80 L of water while non- herbal *Kunapajala* was prepared from fish, bone meal, rice husk, coconut oil cake, sprouted black gram, cow dung, cow's urine, honey, ghee, jaggery, milk and 85 L of water.

Physical properties such as colour and odour of the organic liquid manures were recorded. Herbal and non- herbal *Kunapajala* were neutral in pH (7.00 and 7.70 respectively) whereas Panchagavya and FAA were in the acidic range as 5.50 and 4.40 respectively. Regarding EC Panchagavya has highest EC (7.30 dSm^{-1}) followed by FAA (3.60 dSm^{-1}). The highest value for organic carbon content was registered by FAA (35.67%). Non-herbal *Kunapajala* recorded the highest values for K (0.44%), Ca (380 mg L^{-1}), Mg (324 mg L^{-1}), and S (1.8%). Its N and P contents were less than that of Panchagavya and FAA. *Kunapajala* recorded the highest content of micronutrients compared to FAA and Panchagavya except for total Cu. Non- herbal *Kunapajala* was found to be rich in Fe (12.3 mg L^{-1}), Mn (1.04 mg

L^{-1}), B (4.86 mg L^{-1}). FAA recorded the highest Zn (1.93 mg L^{-1}), content whereas Cu content was the highest in Panchagavya (1.56 mg L^{-1}). Regarding biochemical characteristics, FAA recorded the highest dehydrogenase activity (330.56 µg of TPF g^{-1} soil 24 h^{-1}), total sugar content (10.25%) and ascorbic acid content (33.65 mg 100ml^{-1}). The maximum population of bacteria was observed in non- herbal *Kunapajala* while fungal population in FAA, but the population of actinomycetes found to be nil in these liquid manures.

The second part of the experiment was conducted to monitor the nutrient release pattern under laboratory conditions for a period of two months. The study was carried out in CRD with 5 treatments and 4 replications. The treatments included were soil + FYM (T_1), soil + FYM + 2% herbal *Kunapajala* (T_2), soil + FYM + 2% non- herbal *Kunapajala* (T_3), soil + FYM + 5% herbal *Kunapajala* (T_4) and soil + FYM + 5% non-herbal *Kunapajala* (T_5). All the treatments were maintained at 60% moisture capacity. There was no significant change in pH while an increase in EC was observed throughout the incubation period. The major and minor nutrients released were significantly influenced by the treatments except for Zn and Cu. Treatment that received 5% non-herbal *Kunapajala* had the highest content of organic carbon, N, P, Ca, Mg, S, B, Fe and Mn while K content was the highest for 5% herbal *Kunapajala*. Treatment T_1 (soil + FYM) recorded the lowest values for nutrient release throughout the incubation period.

The third part of the study was a field experiment to evaluate the efficacy of soil and foliar applications of herbal and non-herbal *Kunapajala* by using bhindi as a test crop. The study was carried out in a randomized block design with 13 treatments replicated thrice. The treatments comprised of KAU POP (T_1), Organic Adhoc POP (T_2), Organic Adhoc POP + 3% Panchagavya (T_3), Organic Adhoc POP + 5% Fish Amino Acids (T_4), 50% N as FYM + Water (T_5), 50% N as FYM + 2% herbal *Kunapajala* soil application (T_6), 50% N as FYM + 5 % herbal *Kunapajala* soil application (T_7), 50% N as FYM + 2 % non- herbal *Kunapajala* soil application (T_8), 50% N as FYM + 5% non-herbal *Kunapajala* soil application (T_9), 50% N as FYM + 2% herbal *Kunapajala* foliar application (T_{10}), 50% N as FYM + 5% herbal *Kunapajala* foliar application (T_{11}), 50% N as

FYM + 2% non-herbal *Kunapajala* foliar application (T_{12}), 50% N as FYM + 5% non- herbal *Kunapajala* foliar application (T_{13}).

Foliar application of 5% non-herbal *Kunapajala* recorded the highest growth and yield attributes such as plant height (124.4 cm), number of branches (3.73), leaf area index (1.42) , dry matter production (3845.51 kg ha^{-1}), chlorophyll contents, number of fruits per plant (25.5), length of fruits (15.24 cm), girth of fruits (7.22 cm), average fruit weight (20.8 g) and yield (20.78 t ha^{-1}) .

The post-harvest analysis of soil revealed that the pH, EC, organic carbon content and nutrients varied significantly among the treatments. The highest N (363.88 kg ha^{-1}), P (100.70 kg ha^{-1}) and K (209.10 kg ha^{-1}) contents were observed in T_{13} (50% N as FYM+ 5% non-herbal *Kunapajala* foliar application) which was on par with T_{12} (50% N as FYM+ 2% non-herbal *Kunapajala* as foliar application). Treatment T_{13} recorded highest mean values for all macronutrients, micronutrients and enzymatic activity. The total microbial population *viz*., bacteria, fungi and actinomycetes were significantly influenced by the treatments and treatment comprising of 5% non-herbal *Kunapajala* as foliar application along with 50% N as FYM recorded the highest microbial count. Regarding the plant uptake of nutrients, T_{13} registered the highest plant uptake of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B. The highest B:C ratio of 2.46 was recorded by the treatment T_{13}.

From the study, it can be concluded that both herbal and non-herbal *Kunapajala* contained all the primary, secondary and micronutrients. Among the two types of *Kunapajala,* non-herbal *Kunapajala* was found to be superior over the herbal one. The incubation study revealed that the highest nutrient release was noticed in the treatment T_5 (soil + FYM + 5% non- herbal *Kunapajala*). In the field experiment, application of 50% N as FYM + 5% non-herbal *Kunapajala* as foliar application (T_{13}) was the best treatment which resulted in the highest growth, yield and yield attributes of bhindi but yield was on par with the treatment T_{12} (50% N as FYM+ 2% non-herbal *Kunapajala* as foliar application). From the study, it was observed that FYM as nutrient source can be reduced to half, if 2% or 5% non-herbal *Kunapajala* as foliar spray (at 10 days interval) was applied along with 50%

N as FYM. Present study confirmed that *Kunapajala* is a promising and eco-friendly plant stimulant for sustainable crop production and safe agro ecosystem.