BIOMINERAL ENRICHED COMPOSTS (BOKASHI) – A TOOL FOR ENHANCING NUTRIENT AVAILABILITY AND ENZYME ACTIVITY IN RHIZOSPHERE

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2023

DECLARATION

I, hereby declare that this thesis entitled **"BIOMINERAL ENRICHED COMPOSTS (BOKASHI) – A TOOL FOR ENHANCING NUTRIENT AVAILABILITY AND ENZYME ACTIVITY IN RHIZOSPHERE"** 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.

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Date: 5.08.2023

CERTIFICATE

Certify that this thesis entitled **"BIOMINERAL ENRICHED COMPOSTS (BOKASHI) – A TOOL FOR ENHANCING NUTRIENT AVAILABILITY AND ENZYME ACTIVITY IN RHIZOSPHERE"** is a record of research work done independently by **Ms. Shilpa S** (2020-11-027) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

%	-	percent
@	-	at the rate of
µg	-	microgram
°C	-	Degree Celsius
B	-	Boron
B:C	-	Benefit:Cost
C	-	Carbon
CD	-	Critical Difference
cm	-	centimetre
Cu	-	Copper
DAS	-	Days after sowing
dS	-	deci Siemens
et al.	-	And others
Fe	-	Iron
Fig.	-	Figure
FYM	-	Farm Yard Maure
g	-	gram
h	-	hour
ha^{-1}	-	per hectare
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	kilogram
m	-	metre
mg	-	milligram
Mn	-	Manganese
MSL	-	Mean Sea Level
N	-	Nitrogen
nm	-	nanometre
P	-	Phosphorous
POP	-	Package of Practices
ppm	-	parts per million
s	-	seconds

t	-	tonnes
TPF	-	Triphenyl Formazone
TTC	-	Triphenyltetrazolium chloride
Var.	-	Variety
Zn	-	Zinc

1. INTRODUCTION

India is the second largest producer and consumer of chemical fertilizers after China. Total fertilizer nutrient consumption in India during 2021-22 was estimated at 29.80 million metric tonnes with consumption of N, P_2O_5 and K_2O at the rate of 19.44 million metric tonnes, 7.83 million metric tonnes and 2.53 million metric tonnes respectively (FAI, 2022). As every technology has pros and cons, the advance in agriculture has imbalanced our ecosystem through the unsystematic application of an enormous quantity of chemical fertilizers. Indiscriminate and non-judicial use of chemical fertilizers results in environmental pollution, soil degradation, eutrophication, greenhouse gas emission, poor quality and hazard to human health which raises concerns about sustainability (Savci, 2012). Various measures have been taken over the years to overcome some of the ill effects common to intensive agriculture.

Organic farming is one of the solutions to nurture the land and to regenerate the soil by going back to our traditional method of farming which is free from chemicals, pesticides and fertilizers. Organic farming keeps soil healthy and maintains environmental integrity there by promoting health of consumers (Das *et al*., 2020). Organic farming is an agricultural system that not only aims to reduce or even eliminate pesticide residues in products but also searches for a broader context of agricultural sustainability in economic, environmental and social sphere.

Composting is an important technology of organic farming. Composting is defined as a process where degradable materials, such as manure and leaves, are decomposed and transformed in to a humus like substance called compost, CO_2, water and minerals by microorganisms through controlled biological process (Manyapu *et al.*, 2022). Once the organic matter is placed in the soil, if it is not partially humified, it will be degraded by the micro flora resulting in a production of intermediate metabolites which are not compatible with normal plant growth. Other disadvantages are competition for nitrogen between microorganisms and root, a high C:N ratio, and production of ammonia in soil (de Bertoldi *et al*., 1983). Composting is controlled decomposition, the natural break down process of organic residues which will reduce the C:N ratio of the organic residues. The product obtained is the compost which contributes to the improvement of physical, chemical and microbiological properties of the soil. The composts produced by bio conservation of agro residues viz. farm wastes, aquatic weeds, crop residues etc accrues several benefits such as enhanced soil fertility and soil health which can lead to increased agricultural productivity, improved soil biodiversity, reduced ecological risks and a healthier environment. Manipulation of organic wastes and their composts as a source of organic matter and nutrients is imperative for sustainable agriculture. Among the various types of composting like vermicomposting, coir pith composting, Bangalore method of composting, Indore composting, Thumboormuzhi composting, smart biobin etc. one of the most popular and efficient technology is the Bokashi composting.

Bokashi compost is an organic amendment prepared with a mixture of fermented organic matter (lactic, acetic, alcoholic, propionic and butyric fermentation) of animal and plant origin, with microbial inoculum that reduce time of preparation resulting in rich source of microorganisms (Siqueira and Siqueira, 2013). Bokashi compost is made by using an organic material which inoculated with EM. The concept of EM Bokashi was discovered and developed by Professor Teruo Higa in 1980s (Higa and Parr, 1994). EM consists of mixed cultures of beneficial and naturally occurring microorganisms applying as inoculants to increase the microbial diversity in soils and plants. EM solution consists up to 80 different species belonging to five primary groups of microorganisms, such as predominant populations of lactic acid bacteria and yeasts, smaller number of photosynthetic bacteria, actinomycetes and fungi (Ndona *et al*., 2011; Olle and Williams, 2013 and Iriti *et al*., 2019). The fermented composts have the advantage of eliminating possible contaminants due to the high temperatures used in the fermentation process.

The fermentation process in Bokashi composting conserves nutrients in the organic material better than the process of decomposition that takes place during conventional aerobic composting and the conservation is even higher in anaerobic

Bokashi composting compared to aerobic Bokashi composting (Inckel *et al*., 2005). The Bokashi compost produced is a rich source of organic carbon and nutrients. The nutritional composition of Bokashi compost changes according to the materials used for composting and the type of inoculum. Application of Bokashi composts to the soil improves the physical, chemical (increases the soil nutrient content) and biological properties of the soil and also found to be effective in controlling the secondary soil salinization (Xiaohou *et al.,* 2008; Lasmini *et al*., 2018) besides increasing the plant growth and yield of crop plants. The availability of organic compounds, good soil structure, high humus and life of microorganisms contained in Bokashi compost results in increase in yield (Mohan, 2008; Prisa, 2020; Reddy *et al*., 2021). Bokashi compost has an ability to effectively control the plant pathogens like *Pythium aphanidermatum* and *Rhizoctonia solani* and also helps in controlling the population of *Meloidogyne incognita* (Roldi *et al.,* 2013; Al-Jarah *et al.,* 2016). Bokashi compost could be adopted as a cheap technology owing to its low cost, safe easy method of preparation and its effectiveness. It is also an innovative technology to recycle and valorise various kinds of biowaste in to nutrient rich products that can be used as an organic manure.

Various additives may be added to the organic wastes during Bokashi composting process which are either organic, biological, mineral or a mixture of additives. These additives are used to enhance the composting process by reducing leaching and gas emissions, improving compost aeration or accelerating organic matter degradation and improving nutrient content and availability of the final product (Barthod *et al.,* 2018). Enrichment of compost with the minerals along with microbial inoculation enhance the biodegradation process of organic matter as well as improve the nutrient content and quality of composts (Biswas, 2011).

Wetland plants like water cabbage (*Limnocharis flava*) have now emerged as very devastating weed plants in the wetland ecosystem especially in Kerala. The spread of invasive alien plant species is neither easy to manage nor easy to reverse, threatening not only biodiversity but also to economic development. These troublesome weeds can be utilized for the production of good quality Bokashi composts.

Hence with the aforesaid points in mind, a study has been envisaged with the following title "Biomineral enriched composts (Bokashi) – A tool for enhancing nutrient availability and enzyme activity in rhizosphere" with the following objectives.

- Production and characterization of Biomineral (Bokashi) composts from different organic sources.
- To evaluate the nutrient release pattern under laboratory conditions.
- To evaluate the performance of biomineral enriched (Bokashi) compost in field conditions using bhindi as a test crop and amaranthus as a residual crop.

2. REVIEW OF LITERATURE

Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effect. The four major principles of organic farming are the principle of health, care, fairness and ecology (IFOAM, 2008). Organic fertilizers used in organic farming systems helped to enhance soil fertility for protecting and improving the physical condition of soil, achieving good soil buffering capacity, minimizing nutrient losses and obtaining good quality products. Composts are one of the most used organic nutrient sources, which also acts as a soil improver. Composting is the natural process of decomposition of organic matter by microorganisms under controlled conditions which will increase organic material's suitability for application to the soil as a fertilizing resource (Raviv *et al.*, 2004). Bokashi composting is one of the latest types of composting methods. Bokashi compost is an organic amendment prepared by fermentation of organic matter of plant and animal origin, with microbial inoculum that reduce time of preparation resulting in rich source of beneficial microorganisms. Addition of minerals to composts increase the nutritive value of composts.

2.1. ORGANIC AGRICULTURE IN INDIA

Organic agriculture is a holistic method of farming that aims to develop and conserve natural resources while producing high-quality agricultural products (Aulakh and Ravisankar, 2017). The existing energy crisis, rising fertilizer costs, sustainability in the agricultural production system, and ecological stability have rekindled the interest of farmers and researchers in using non-chemical sources (Eagan and Dhandayuthapani, 2018). Due to mounting evidence of the detrimental effects of excessive use of pesticides and fertilizers in farming, environmental degradation, and increased consumer demand for organic food, farmers around the world, including India, are progressively transitioning to organic farming (Das and Mohanty, 2021).

According to data from 2020, India ranked first in terms of the overall number of producers and ninth in terms of the amount of organic agricultural land worldwide (FiBL, 2021). The total area in India undergoing the organic certification process is 4.33 million hectares (2020–21), of which 2.65 million hectares are suitable for cultivation and another 1.68 million hectares are used for collecting wild harvest. India produced around 3.49 million tons of certified organic products which includes all varieties of food products namely oil seeds, sugar cane, cereals and millets, cotton and pulses (APEDA, 2021).

India has the capacity to generate a variety of organic goods due to its diverse agro-climate. Long-standing practise of organic farming in several regions of the nation offers hope for organic producers to access the constantly expanding local market in relation to the export market (Nandan *et al.*, 2022).

2.2. ORGANIC AGRICULTURE IN KERALA

Kerala is currently experiencing a growth and expansion of organic farming. The improved use of natural resources, cheaper cultivation costs, higher soil fertility, better input usage efficiency, increased self-reliance, etc. make it superior (Prabhu, 2021).

The Fair Trade Alliance of Kerala supports sustainable organic farming by ensuring fair prices, food safety, and better socioeconomic situations for farmers. It is a small farmers' organisation which was established to gain access to the global market for fair trade and equitable trading in order to increase farmers' incomes through the fair trade minimum price and premium (Karunakaran and Sadiq, 2019).

Self-help organisations, Kudumbasree, and participatory technology development programmes all contribute significantly to the promotion of organic farming in Kerala (Sajeesh, 2021)

Kerala's governmental institutions were prompted by the agrarian crisis of the 1990s to start an organic farming movement in the late twentieth century. Therefore, one may be contended that environmental and health concerns have mostly influenced Kerala's organic farming policy (Radhika, 2017).

The Department of Agriculture in Kerala has set up a cell entitled “Organic Cell” for promotion of sustainable agriculture and organic farming. It has also launched two brands namely ‘Kerala Organic’ and ‘Kerala Naturals’ to market organic farm products (Antony, 2019).

Kerala has 43681.18 ha of total area under organic certification process, 31965.48 MT organic production during the year 2021-22 (APEDA, 2021).

2.3. COMPOSTING

Composts are one of the most used organic nutrient sources, which also acts as a soil improver. Composting is the natural process of decomposition of organic matter by microorganisms under controlled conditions which will increase organic material’s suitability for application to the soil as a fertilizing resource (Misra *et al*., 2003). Composting is largely a biological process in which microorganisms (both aerobic and anaerobic) decompose organic matter and lower the carbon-nitrogen ratio of refuse resulting in a final product of well rotten compost. Composting will lead to waste reduction, job creation and production of organically produced food crops (Taiwo, 2011). Compost applied as a soil amendment can improve the soil organic matter, water and nutrient retention in soil susceptible to leaching, and stabilize pH. Compost can also be a source of macro and micro nutrients (Obreza and Reeder, 1994).

Compost produced by the bio conservation of agro residues like farm wastes, aquatic weeds and crop residues accrues several benefits such as enhanced soil fertility and soil health which can lead to increased agricultural productivity, improved soil biodiversity, reduced ecological risks and a healthier environment. The use of composts ensure sustainability, reduced the volume of waste and reduce C:N ratio . Some of the important composting methods are Indian Banglore composting, vessel composting, vermicomposting, Indore composting etc (Ayilara *et al.,* 2020). Smart biobin and Thumboormuzhi composting are the composting techniques developed by Kerala Agricultural University. Of the various methods of composting, Bokashi method is gaining popularity among the farming and scientific community. It is an innovative technology to recycle and valorise various kinds of biowastes in to nutrient rich products that can be used as an organic manure.

2.4. BOKASHI COMPOST

The name Bokashi is a Japanese word, which means “fermented organic matter”. Traditionally Japanese farmers use Bokashi compost to improve soil fertility and supply the crops with nutrients. Bokashi composting originated in East, with many researchers specifying Japan or Korea as the first country to use it. Ancient farmers would bury their food waste in soil rich in microorganisms. Once the food waste was fermented, they would mix it with the soil they used for planting and the resulting crops grew faster and healthier than non-fertilized crops (Ginting, 2019).

Dr. Teruo Higa of Japan developed around 1982, a technology in which effective microorganisms (EM) were used for Bokashi composting, which is the modern Bokashi composting. He ended up with a patented mix of yeast, phototrophic bacteria and lactic acid bacteria (Nene, 2017). Bokashi composts are highly versatile as it can be prepared by mixing almost any available agricultural by product with the microorganisms which makes it a very attractive organic amendment. Bokashi composting is a fast, easy, minimal space required, and odour free method of composting and it can be used as a way to manage household and kitchen wastes as well (Christel, 2017).

The concept of Bokashi composting is to add an inoculum of microorganisms to organic material that will result in lactic acid fermentation and is routinely done in enclosed fermenters with liquid drainage under anaerobic conditions (Hillberg, 2020). Anaerobic fermenters comprises of a main lid, a compressing lid, incubation reservoir and a leachate reservoir (Alattar *et al*., 2016). Microbes consume a small proportion of complex organic compounds and energy in the starting material to produce a range of compounds like organic acids (lactic acid, butyric and acetic acid) and biologically active compounds (antibiotics) like streptomycin which will inhibit the decomposition process. During this process nutrient elements cannot escape and only a small energy is liberated (Merfield, 2012). When processing vegetable materials, the fermentation process takes about 2-5 weeks (Maso and Blasi, 2008). The fermentation process of Bokashi composting conserves nutrients in the organic matter better than the process of decomposition that takes place when composting (Higa and Purr, 1994). In EM fermentation process the elements of the organic matter remain apparently intact, but are instead completely reworked in an extremely enriched form with nutrients released by microorganisms (Prisa, 2020).

Bokashi is prepared through fermenting organic matter either in the open air or in a closed off situation based on which it can be classified as aerobic or anaerobic Bokashi. In the open air the mixture is in contact with oxygen from the air; this is called an aerobic Bokashi. It means partial anaerobic conditions occur in the middle of compost while the outer layer remain aerobic (Formowitz *et al.*, 2007). It is somewhat similar to traditional composting with additional usage of cover such as jute bag, straw mat or similar material. When the fermenting mixture is closed off from the air it is called an anaerobic Bokashi compost (Wakui, 2009).

Effective microorganisms (EM) was developed at the University of Ryukyus, Okinawa, Japan in the early 1980's by a distinguished professor of Horticulture, Dr. Teruo Higa. All microbes in EM are derived from nature and are mutually compatible with one another and can co-exist in liquid culture (Merfield, 2012). The inoculum used for Bokashi composting is a mixed culture of lactic acid bacteria (LAB) (eg, *Lactobacillus plantarum, Lactobacillus casei* and *Streptococcus lactis*), purple non-sulphur Bacteria (PNSB) (eg, *Rhodopseudomonas palustris, Rhodobacter sphaeroides*), yeasts (*saccharomyces spp*.), actinomycetes, (Plant Growth Promoting Rhizobacteria, nitrogen fixers, phosphorus solubilizers and various fungi and each microorganism have its own beneficial role in nutrient cycling, plant protection, soil health and fertility enrichment (Nene, 2017; Olle and Williams, 2013).

Lactic acid bacteria perform a vital role in the preservation and production of wholesome foods. The lactic acid fermentations are generally inexpensive, and often little or no heat required in their preparations (Steinkraus, 1992)

The use of EM in agriculture has significant beneficial impact as they promote germination, growth, flowering, fruiting and ripening of crop plants, enhances photosynthetic capacity of plants, increases the efficacy of organic matter as fertilizers, develops resistance of plants to pests and diseases, improves the physical, chemical and biological environments of the soil (Kyan *et al*., 1999). Effective microorganisms contribute to soil enrichment, by harmonizing and diversifying native microorganisms (Joshi *et al.,* 2019). The concept of EM is based on the inoculation of substrates to shift the microbial equilibrium and thus create an improved microbiome that favours improved productivity and the secondary metabolites produced by these modified microbiome (eg, inositol, ubiquinone, saponin, low-molecular polysaccharides, polyphenols and chelating agents) may inhibit harmful microbial species, enhance the proliferation of beneficial microorganisms and detoxify harmful substances simultaneously (Mayer *et al.,* 2010; Boechat *et al*., 2013).

The advantage of using EM along with organic matter is the ability of EM to ferment the organic matter thereby releasing nutrients and nutrient rich organic acids which could be utilized by plants and there by soil fertility will be improved (Higa and Purr, 1994). The use of EM as an activator will reduce composting period from 12 to 4 weeks (Misra *et al.,* 2003). Hu and Qi (2013) observed that addition of Bokashi compost containing EM increased the yield and nutrient content of wheat. In addition effective microbes in Bokashi starter especially lactic acid bacteria, purple non-sulphur bacteria and yeast have the ability to perform a variety of beneficial environmental functions, including breaking down harmful chemicals and immobilising heavy metals (Olle and Williams, 2013). Fertilization with Bokashi compost at the rate of 10 kg per square meter increased the growth and weight of onion plants by promoting higher diameter and weight of onion bulb which resulted in an increased yield (Alvarez-Solis *et al.,* 2016).

2.5. NUTRIENT STATUS OF BOKASHI COMPOST

Hernandez *et al.* (2014) observed a high nitrogen and phosphorus content in Bokashi composts compared to vermicompost produced from same substrate.

Pohan *et al.* (2018) observed that Bokashi prepared from vegetable scrapes contained a higher phosphorus (2.15 percent) and potassium (2.68 percent) than cow dung.

The Bokashi compost produced from goat manure has a nutrient composition of nitogen (1.9 percent), Phosphorus (0.17 percent), potassium (2.85 percent), calcium (1.39 percent) and magnesium (0.72 percent) (Adiarti *et al.*, 2019).

Faozi *et al.* (2018) observed that during the fermentation period of Bokashi composting with banana pseudostem as substrate, the organic matter content was found to be decreased from 56.79 percent on 0^{th} day to 31.53 percent on the 28^{th} day, nitrogen content was increased from 0.65 percent on 0^{th} day to 1.16 percent on 28^{th} day thus there was a gradual decrease in the C:N ratio of the compost. It was also observed that there was a gradual decrease in the Bokashi moisture content. Total P_2O_5 content was increased from 0.99 percent on 0^{th} day to 1.16 percent on 28^{th} day and total calcium content was increased from 2.17 percent on 0^{th} day to 5.77 percent on 28^{th} day. Total potassium of the material actually decreases after fermentation from 3.18 percent on 0^{th} day to 2 percent on 28^{th} day.

The Bokashi compost produced from wheat bran (60%) and castor bran (40%) have a nitrogen content of 0.35%, phosphorus content of 0.87 %, potassium content of 1.175 % and a C:N ratio of 11.93 (Pian *et al.*, 2023).

The Bokashi compost produced from cattle manure has a moisture content of 23.5 %, nitogen content of 1.98 %, carbon content of 19.71 % while the Bokashi compost produced from vegetable wastes shows a nitrogen content of 3.10 % and carbon content of 26.20 % (Lima *et al.*, 2015).

The pH of Bokashi compost produced from horse bedding waste, cowdung and rice husk charcoal in various combinations ranges from 7.28 to 7.55 and electrical conductivity ranges from 0.27 to 1.51 dS m^{-1}. The calcium content ranges from 8.28 to 16.93 Cmol kg^{-1} and magnesium content ranges from 4.23 to 8.86 Cmol kg^{-1}(Gashua *et al.*, 2022).

The Bokashi compost produced from chopped grass and bovine manure reported to have a bulk density of 0.39 g cm^{-3}, total porespace of 59.43%, available nitrogen of 27.18 ppm and C:N ratio of 24.20 (Sagaseta *et al.,* 2021).

2.6. EFFECT OF BOKASHI COMPOST ON PLANT GROWTH AND YIELD

The microorganisms present in the EM solution used for the preparation of Bokashi compost can ferment organic materials in to inorganic sugars, alcohols, aminoacids and various biogenic substances that can be absorbed directly by the roots of plants to accelerate the growth and development of plants (Anhar *et al*., 2018).

Prisa (2020) observed that the addition of Bokashi to the growing medium of *Kalanchoe blossfeldiana* can improve plant quality in particular agronomic and physiological characteristics and increased water and nutrient uptake. It was also observed that the qualitative and physiological improvement of plants probably determined by the presence of beneficial bacteria in the Bokashi soil conditioner which stimulate plant and improve nutrient uptake.

The fruit yield of brinjal was the highest when Bokashi compost was applied at the rate of 750 kg ha^{-1} compared to the application of panchagavya and amrit pani (Mohan, 2008).

Yan and Xu (2008) observed that the application of Bokashi compost in peanut increased fresh weight as well as nodule numbers. Root and dry matter weight of Bokashi applied treatments were significantly higher than chemical treatment.

Anhar *et al.* (2018) showed that application of Bokashi compost to tomato plants increases the weight of tomatoes when applied at a rate of 120 gram per polybag and thus the Bokashi can be utilized as a substitute for synthetic NPK for tomato plants.

Addition of Bokashi compost has a positive effect on chlorophyll index and drymatter production of parsley plants. The dry matter production was maximum in the treatment were Bokashi enriched with rock phosphate was added. The chlorophyll index was maximum in the treatment where Bokashi and rock phosphate were added to the pot separately at a 30% rate (Maass *et al.,* 2020).

Bokashi compost when applied to the potato crops, significantly increased the phenol content and activity of various enzymes like pectin methyl esterase, polyphenol oxidase and peroxidase (Mbouobda, 2014).

Addition of Bokashi compost improved the local soil conditions and seedling survival as well as increased seedling heights of *Pinus pseudostrobus* (Lopez *et al.,* 2015).

Kumar *et al.* (2020) suggested the use of Bokashi composting for wheat production under certified organic farm at a rate of 2.5 to 3 tonnes per hectare over the root zone of established plants or mixed in to the soil where new plants are being established.

Bhattarai and Budathoki (2005) observed that organic manures especially Bokashi compost had exerted remarkable effects on postharvest physiological parameters of cauliflower. All physiological parameters like percentage weight loss, colour deterioration and shelf life of cauliflower were markedly influenced by it and the postharvest physiology was found to be the best by applying 200 g ha^{-1} of Bokashi compost coupled with compost 20 t ha^{-1}.

Wijayanto *et al.* (2016) observed an increase in soybean yield with the application of Bokashi compost prepared from water hyacinth at the rate of 10 t ha^{-1} compared to treatment without Bokashi application.

Addition of Bokashi compost along with organo super or poultry manure increased the growth characteristics, photosynthetic pigments, biomass production, and plant quality of bael (Santos *et al*., 2020).

Co-composted Biochar-Bokashi (60 t ha^{-1}) was shown better than conventional and aerobic composting with improved biomass by 243% compared to inorganic NPK fertilizer (Pandit *et al*., 2020).

Yuliana *et al.* (2015) observed that the application of Bokashi, sunhemp and combination of both along with inorganic fertilizers increased the yield of maize.

Addition of Bokashi compost of cowdung had that a dosage of 8 t ha^{-1} resulted in a test yield 20.4 t ha^{-1} of dry millet grain (Silea *et al*., 2017).

Application of Bokashi made from green plant improved significantly the growth (height, diameter and number of leaf) and yield (diameter, length and weight of cob) of maize grown in acid soils. The application of Bokashi increased the cob unhusk weight of maize by 50% (Ginting , 2019).

2.7. EFFECT OF BOKASHI COMPOST ON SOIL PROPERTIES

Bokashi compost has a high content of organic matter and nutrients required for plants, presents high porosity and water holding capacity. In addition it contributes to the soil with different types of microorganisms including bacteria, fungi and actinomycetes, which can improve the health of the soil (Silva *et al.*, 2014; Restrepo and Hensel 2015).

Applying Bokashi compost to the soil increases the organic matter content and improves its properties, providing nutrients and reducing nutrient leaching (Murillo-Amador *et al*., 2015).

Lasmini *et al.* (2018) conducted a study on the improvement of soil quality using Bokashi composts on dry land and came to a conclusion that application of Bokashi compost improved the physical and chemical properties of the soil and significantly increased the organic carbon, nitrogen fixing bacteria, phosphorus solubilizing bacteria and bulb production of shallot..

Bokashi compost treatment combined with sub surface drainage were more effective in controlling secondary salinization of soil and raising grain yield and quality of rice than farm yard manure and chemical fertilizer treatments. This may be due to the increased permeability and aeration of soil which helps in the leaching away of salts (Xiaohou *et al*., 2008).

The combination of legume cover crop and Bokashi fertilizer gave a positive influence in increasing soil fertility as seen from the increase of essential nutrients in the soil such as organic carbon, available soil phosphorus and potassium (Prayogo and Ihsan, 2018).

An increase in organic carbon, total nitrogen, available phosphorus and exchangeable potassium content of soil increased by the application of Bokashi compost (Hernandez *et al.*, 2014).

The accumulation of available phosphorus, exchangeable potassium and exchangeable magnesium increased following the incorporation of Bokashi compost to the soil (Pian *et al*., 2023).

Application of Bokashi effectively increased the soil total organic carbon (2.1 %) and iron concentraions (58 cmol kg^{-1}) compared to the control (Searson, 2016).

Total nitrogen and other water extractable nutrients (phosphate and potassium) were higher in soils amended with Bokashi compost compared to that of control (Luo *et al*., 2022).

Addition of Bokashi compost produced from water hyacinth (*Eichornia crassipes*) could provide a better soil condition for growth and production of soybean, corn and rice grown in dry land soil (Asrijal *et al*., 2018).

2.8. EFFECT OF BOKASHI COMPOST ON SOIL BIOLOGICAL PROPERTIES

Addition of Bokashi composts on soil increased the population of phosphorus solubilizing and nitrogen fixing bacteria in soil (Lasmini *et al*, 2018). The microbial biomass carbon and basal respiration was found to be higher for the Bokashi applied soil compared to the control (Hata *et al*., 2020).

The increasing total number of microbes (Bacteria, Fungi and Actinomycetes) and macro and micro nutrients contents in Bokashi amended soil promotes root activity and cation exchange capacity (El- Hamied, 2014)

Application of Bokashi compost along with organic wastes reduced the C:N ratio, increased nitrogen mineralisation and increased microbial biomass (Boechat *et al.,* 2013).

Addition of Bokashi compost to soil increased favorable microorganisms that might have accelerated the cycling and availability of nutrients. As Bokashi contains nitrogen fixers, the availability of nitrogen and other nutrients increased (Alvares-Solis *et al.,* 2016).

The effective microorganisms present in the Bokashi increase the level of microbial diversity in the soil which play their roles in decomposition process and mineralisation of organic matters of the soil, so that they can increase the essential nutrient availability in the soil (Yuliana *et al.,* 2015).

The bacterial population (30.66×10^5 cfu) fungal population (106×10^4 cfu) and actinomyces population (166.6×10^4 cfu) was higher in Bokashi added pots compared to the pot in which full dose of mineral fertilizer was added (Ghanem *et al.,* 2017).

Addition of Bokashi causes an increase of 8.3%, 4.8% and 3.7% in average number of *Dyella, Luteibacter* and *Edaphobacter* respectively. Addition of Bokashi also causes an increase in *Rhizobium, Azotobacter, Chitinophaga, Gluconacetobacter* and *Thermomonas* in soil compared to control (Abo-Sido *et al.*, 2021).

A two week period of soil restoration with a 1:2 soil-to-Bokashi compost ratio was found to improve soil urease activity and soil moisture content (Phooi *et al*., 2022).

Application of Bokashi compost changed the intra and inter kingdom co-occurance patterns of microorganisms in soil. Soil microbial communities appeared to have a higher level of non-randomness in the networks after applying Bokashi compost (Luo *et al*., 2022).

Gomez - velasco *et al*. (2014) conducted an agronomic study with coffee using Bokashi as a treatment made from sheep manure and sugarcane molasses and reported a C:N ratio of 11:1 of the final product. Result of the study showed that Bokashi application increased the coffee shoot growth and soil enzyme activity like acid and alkaline phosphatase and urease activity.

2.9. EFFECT OF BOKASHI COMPOST ON PLANT DISEASE CONTROL

The result of the study conducted by Khaeruni *et al.* (2020) showed that application of Bokashi compost had significantly reduced the severity of sheath blight disease in maize plants compared to the application of chemical fertilizers alone. Salicylic acid content and peroxidase activity was found to be increased by the application of Bokashi, which induced resistance of maize plants against *Rhizoctonia solani*.

Roldi *et al.* (2013) observed that application of Bokashi compost at the rate of 20g per pot to tomato plants effectively reduced the number of galls, eggs per root system and eggs per gram of root in tomato plants treated at 60 days after inoculation with *Meloidogyne incognita*. So he came to a conclusion that Bokashi compost can be used for controlling *Melodogyne incognita* and promoting growth in tomato.

The study conducted by Al-Jarah *et al.* (2016) showed that the percentage of healthy cucumber plant in soil treated with Bokashi compost and contaminated with *Pythium aphanidermatum* and *Rhizoctonia solani* was high compared to the percentage of healthy seedlings in non-treated but contaminated soil. So that Bokashi compost application can be effective in controlling damping off disease in cucumber.

2.10. SYLVINITE

Sylvinite is a sedimentary rock made of mechanical mixture of the mineral sylvite (KCl or potassium chloride) and halite (NaCl or Sodium chloride). Unprocessed sylvinite contains approximately 17 percent K (Mikkelsen, 2008).

Chemical composition of a sylvinite was analysed by Rattanakawin *et al.* (2017) and reported that sylvinite contains 32.2 percent KCl, 6.12 percent NaCl, 0.15 percent $KCl.MgCl_2.H_2O$ and 6.09 percent other elements.

Webb *et al.* (1990) reported that the use of sylvinite was effective to maintain the yield as a source of potassium and maintain the herbage as a source of sodium in cut grass.

2.11. ROCK PHOSPHATE

Rock phosphate is one of the basic raw materials needed in the manufacture of phosphatic fertilizers like single super phosphate, diammonium phosphate, nitro phosphates etc. The solubility and availability of low grade rock phosphate can be increased by various methods including composting with farm manure, use of phosphorus solubilizing microbes, green manuring etc (Kumari and Phogat, 2008).

The basic principle underlying the composting of rock phosphate with organic manure or farm waste is production of organic and mineral acids as a result of their decomposition. Release of these acids creates a localised high acidity in the immediate vicinity leads to the complexation of calcium (Rajan *et al*., 1996).

Noor *et al*. (2021) observed that phosphorus rich organic manure application produced the highest value of organic matter (0.94%), soil phosphorus (20.06 mg kg^{-1}), soil potassium concentration (286.2 mg kg^{-1}), nitrogen concentration in plants (3.12 %), phosphorus concentration in plants (0.31%) and potassium concentration in plants (3.50%).

The purpose of compost supplementation with phosphorus is not only to contribute to increase the levels of this element in an available way, but also to rise the amount of phosphate solubilizing microorganisms in the soil (Sanchez *et al.*, 2017).

2.12. MINERAL ENRICHED COMPOSTS

Production of fertilizers supplying both nutrients and organic matter is needed. Supplementation of composts with nutrients and with addition of bacteria and other microorganisms promoting plant growth is an important strategy to enhance its nutritional properties (Ahmad *et al.,* 2008)

Nishanth and Biswas (2008) reported that enriched composts prepared with rice straw, low grade rock phosphate along with biological agent *Aspergillus awamori* can be an alternative source of fertilizer and a viable technology for the management of biodegradable waste like crop residue and efficient use of non-renewable sources of phosphorus and potassium in crop production which can help to reduce the reliance on costly chemical fertilizers.

The addition of rock phosphate to the Bokashi compost increased the soluble phosphorus content by 17.7 % and nearly doubled the soluble calcium (Maass, 2020).

Application of potassium enriched compost with potassium solubilizing bacteria improved the shoot and root growth, plant potassium nutrition, as well as grain quality of maize (Imran *et al.,* 2020).

Hellal *et al*. (2013) reported that the application of natural potassium source combined with compost was suited for increasing sugar beet yield grown in newly reclaimed calcareous soil.

Srikanth *et al.* (2000) studied the direct and residual effect of enriched compost, farm yard manure, vermicompost and fertilizers on alfisol and reported that soil nutrient value was found to be high in enriched compost amended soil after the harvest of first or second crop and a slight decrease in bulk density of soil after the harvest of second crop in soil amended with compost compared to inorganic fertilizer treatment alone.

Akbari *et al.* (2010) conducted an experiment to study the effect of inoculants (compost culture, Phosphorus solubilizing microorganism and

Azotobacter) and natural amendments (rock phosphate and iron pyrite) on nutritional composition of compost and observed that organic carbon and C:N ratio decreased during maturation of the compost irrespective of the treatment. Irrespective of the treatment the total nitrogen, phosphorus, potassium, sulphur and micronutrient (Fe, Mn, Zn, Cu) were increased with advancement in maturity period of composting.

A study conducted by Kavitha and Subramanian (2007) observed that transformation of a normal compost to a bioactive compost by the addition of various additives like *Azotobacter,* phosphobacteria, *Pseudomonas*, composted poultry litter, rock phosphate and diluted spent wash increased the nutritive value of the compost. The highest nitrogen content (1.75 %) and phosphorus content (1.16%) was observed in compost enriched with composted poultry litter, spent wash microbial inoculants and rock phosphate.

The grain yield of rice and wheat (5.45 and 3.92 t ha^{-1}) was found to be 29.45 % and 110.75 % higher over control for treatment where microbial enriched municipal solid waste at 10 t ha^{-1} in conjuction with gypsum (Singh *et al*., 2022).

Microorganisms play an important role in the recycling of agricultural wastes. The compost generated by bioconversion of agro residues offers several benefits such as enhanced soil fertility and soil health which can lead to increased agricultural productivity, improved soil biodiversity, reduced ecological risks and a healthier environment (Singh and Nain, 2014).

Biswas (2011) observed that enriched compost prepared using rice straw, low grade rock phosphate and waste mica along with *Aspergillus awamori* have higher total as well as bioavailable P and K content than ordinary compost. Application of 50% recommended dose of fertilizers along with 4 Mg ha^{-1} of enriched compost resulted in 43.3 % additional yield and 102.3, 67.0 and 62.2% additional N, P and K uptake by potato over control respectively.

Billah *et al.* (2020) observed that the application of rock phosphate enriched composts increased the yield of the wheat crop, chemical and biological properties of the post harvest soil compared to the full recommended dose of inorganic fertilizers and control.

Sailajakumari (1999) reported that maximum grain yield of cowpea for soil treated with vermicompost enriched with rock phosphate compared to control.

Rock phosphate enriched composts releases phosphorus for a longer period of time thus providing supply of phosphorus to the crops for a longer period of time (Mohrana *et al.*, 2015).

Maass *et al.* (2020) observed that the addition of rock phosphate to the Bokashi compost had improved the calcium and phosphorus content of the compost. The dry matter production and chlorophyll content of parsley was also improved by the addition of Bokashi compost enriched with rock phosphate.

Dahia *et al*. (2003) observed that application of sugarcane trash enriched with Mussorie rock phosphate and photosynthetic bacteria decreased bulk density, increased nutrient use efficiency mainly N and P, increased the availability of N, P, Ca, Fe, Mn, Zn, enzyme activity, pH, EC and favoured soil conditioning, aggregate stability and nutrient recycling.

Addition of rock phosphate enriched aerobic compost increased the microbial and enzyme activities of the soil (Oliveira and Ferreira, 2014).

2.13. BANANA PSEUDOSTEM

In India, particularly in the Southern states, among the major fruit crops cultivated, *Musa* sp. (Banana) belonging to the family Musaceae, has a major role in the generation of postharvest residues. Banana pseudostems are reported to contain 58% carbohydrate, high levels of nutrients including calcium and phosphorus (Aziz *et al.*, 2011).

The presence of IAA was detected in the spathe extracts of banana and this could have led to the promotion of root and shoot lengths of the rice plant (Selvam and Kumar, 2022).

In a study conducted by Lekshmi (2011), banana pseudostem was utilized as a substrate for the production of enriched composts and observed significant influence on yield and yield attributes of the crops as well as improvement in the soil physico-chemical and biological properties.

Virk *et al*. (2021) observed that the banana residue have higher nitrogen (1.5%) and potassium (3.10%) than the farm yard manure. It was also observed that co composting banana pseudostem with farm yard manure resulted in a narrow C:N ratio, enhanced NPK contents of composted products and ultimately maize growth, nutrient concentration and fertility of the soil.

A study conducted by Shah *et al*. (2005) revealed that the banana waste can be used as an alternative substrate to other agricultural or agro-industrial waste, wheat bran/straw, sawdust and bagasse, which are already in use for the production of ligno and cellulolytic enzyme production using two ligno cellulolytic fungi.

2.14. WATER CABBAGE *(Limnocharis flava)*

Water cabbage (*L. flava*) is considered to be a major weed in many countries. In India the occurrence of this noxious aquatic weed was first reported from Kerala. The seeds are generally dispersed by mud sticking on to the feet of birds, animals, man and agricultural implements. The weed clogs irrigation tanks, channels, and drainage ditches resulting in poor drainage, making lower regions of the cultivated tracks unsuitable for farming (Kaliyamurthy *et al.,* 2004)

Water cabbage (*Limnocharis flava*) can be converted to a quality compost with high nutritive value using various methods like vermicomposting, composting using KAU inoculum and composting using enriched *Pleurotus florida* (Jayapal *et al*., 2021).

Saupi *et al*. (2009) reported a relatively high moisture content of 79.34 % when compared to ash (0.79%), crude fat (1.22%), crude fibre (3.81%) and total carbohydrate (14.56 %) in *L. flava*.

Anushma (2014) reported water cabbage (*L. flava*) as the best substrate for composting in terms of chemical composition and compost produced by using water cabbage and composting inoculum as the best compost which recorded highest yield for amaranthus in pot culture experiment.

3. MATERIALS AND METHODS

The present study entitled ‘ Biomineral enriched composts (Bokashi) – A tool for enhancing nutrient availability and enzyme activity in rhizosphere’ has been carried out at College of Agriculture, Vellayani during 2021-2022 with an objective of production and evaluation of biomineral enriched composts for enhanced nutrient availability, yield of test crop (Bhindi) and enzyme activity in the rhizosphere. The study was carried out in three parts.

Part – 1: Production and characterization of biomineral enriched (Bokashi) composts from different organic sources.

Part – 2: Soil incubation study for evaluating the nutrient release pattern.

Part – 3: Field experiment for evaluating the performance of the biomineral enriched (Bokashi) compost.

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

3.1. PRODUCTION AND CHARACTERISATION OF COMPOSTS

3.1.1. Production of composts

The Bokashi compost was prepared using two substrates Aquatic weed (*Limnocharis flava*) (S_1) and Banana pseudostem + Aquatic weed *L. flava* in 1:1 ratio (S_2) by using EM solution 1 and allowed to ferment anaerobically. Two liters of EM solution was added to 100 kg of substrates along with 10 kg of cowdung. The aquatic weed was collected from Vellayani lake and banana pseudostem was collected from Model Organic Farm, College of Agriculture, Vellayani. The composts were produced in the Bokashi units established at the Model Organic Farm, College of Agriculture, Vellayani. The prepared composts were enriched with minerals like calcium apatite (M_1), epsom salt (M_2) and sylvinite (M_3) at 2% rate.

Design : CRD

Treatment : 14

Replication : 3

Table 1. Treatment combinations

T_1	S_1M_1
T_2	S_1M_2
T_3	S_1 M_3
T_4	S_2 M_1
T_5	S_2 M_2
T_6	S_2 M_3
T_7	S_1 M_1 M_2
T_8	S_1 M_2 M_3
T_9	S_1 M_1 M_3
T_{10}	S_2 M_1 M_2
T_{11}	S_2 M_2 M_3
T_{12}	S_2 M_1 M_3
T_{13}	S_1 M_1 M_2 M_3
T_{14}	S_2 M_1 M_2 M_3

Substrates

S_1 – Aquatic weed (*Limnocharis flava*)

S_2 – Banana pseudostem + Aquatic weed (*L. flava*) (1:1 ratio)

Enrichment materials

M_1 – Calcium apatite

M_2 – Epsom salt

M_3 – Sylvinite

The rate of enrichment of minerals is 2 kg per 100 kg of matured compost (2 %). In all the treatments zeolite was added at a rate of 0.5 percent.

3.1.2. Characterization of composts

The physical, chemical, electrochemical and biological properties of the composts were characterized by standard analytical procedures (Table 2)

S_1: *Limnocharis flava*

S_2: *Limnocharis flava* and banana pseudo stem in 1:1 ratio

Anaerobic fermentation using microbes

Plate 1. Production of Bokashi compost

Plate 2. Bokashi compost produced from S_1 (aquatic weed *L. flava*)

Plate 3. Bokashi compost produced from S_2 (aquatic weed *L. flava* and banana pseudostem in 1:1 ratio)

Table 2. Analytical methods followed in the analysis of biomineral enriched (Bokashi) composts

Sl No.	Properties	Methods	Reference
1	Colour	Visual observation	
2	Moisture content	Gravimetric method	Jackson (1973)
3	Water holding capacity	Water soaking and draining through filter paper followed by weighing	Ahn *et al*. (2008)
4	Bulk density	Tap volume	Saha *et al*. (2010)
5	pH	pH meter	Jackson (1973)
6	EC	Conductivity meter	Jackson (1973)
7	Total Organic carbon	Loss on ignition method	Jackson (1973)
8	Total Nitrogen	Microkjedahl digestion and distillation	Jackson (1973)
9	Total Phosphorus	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer	Jackson (1973)
10	Total Potassium	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using flame photometer	Jackson (1973)
11	Total Ca and Mg	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation by EDTA method	Jackson (1973)
12	Total S	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion followed by turbidimetry	Chesnin and Yien (1951)
13	Micronutrients (Fe,Mn,Zn,Cu)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS	Jackson (1973)
14	Heavy metal content (Cd, Pb, Ni, Cr)	Nitric – perchloric acid digestion (9:4) and emission spectroscopy (ICP-OES)	Wei and Yang (2010)
15	Boron	Diacid digestion and estimation using azomethane-H	Gupta (1967)
16	Microbial count (cfu g^{-1})	Serial dilution plate technique	Timonin (1940)

3.1.2.1 Physical, chemical and electrochemical characterization

Physical properties of composts like colour, water holding capacity, moisture content and bulk density, electro chemical properties like pH and EC and chemical properties like organic carbon, primary, secondary, micro nutrients were estimated as per standard procedures as furnished in Table 2.

3.1.2.2. Proximate analysis

3.1.2.2.1. Cellulose content

Determination of cellulose content of the substrate was carried out by treating the acetolysed plant sample with sulphuric acid and the hydrolysed glucose was treated with anthrone reagent (Hodge and Hofereiter, 1962).

Three millilitres of acetic : nitric reagent (150ml of 80 percent acetic acid +15ml of concentrated HNO_3) was added to 0.5g of sample and it was mixed with the help of vortex mixer followed by placing it in a water bath at 100^0C for a period of 30 minutes. After cooling, this mixture was centrifuged for 20 minutes and supernatant was discarded. After washing the residue with water, 10 ml of 67 percent H_2SO_4 was added to it and left for an hour. This solution is then diluted by adding 90 ml water to 1ml of this solution. 10 ml of anthrone reagent (200mg of anthrone reagent in 100ml of concentrated H_2SO_4 prepared fresh and chilled before use) was added to 1ml of the diluted solution and mixed well. After heating the tubes in a boiling water bath for 10 minutes, it was cooled and the absorbance was measured at 630 nm. A blank was also prepared with anthrone reagent and water. For the preparation of standard curve 0.4, 0.8, 1.2, 1.6 and 2 ml of standard cellulose solution were taken, equalised the volume and anthrone reagent was added and colour was developed. For the preparation of standard cellulose solution, 100 mg of cellulose was dissolved in 10 ml of 67 percent H_2SO_4 and kept of an hour. A working standard was prepared by diluting 1 ml of standard cellulose solution to 100 ml (100 µg ml^{-1}). The results obtained were expressed as percent cellulose.

3.1.2.2.2. Hemicellulose content

Hemicellulose content of composts were analysed gravimetrically by treating with neutral detergent solution. The samples were refluxed with neutral detergent solution to remove the water solubles and materials other than fibrous content. The left out content was weighed after filtration and expressed as neutral detergent fibre (NDF) (Thimmayya, 2004).

One gram of the powdered sample was taken in a refluxing flask and 10 ml of cold neutral detergent solution was added (neutral detergent solution – dissolved 18.61g of sodium borate decahydrate dissolved in 200 ml of water by heating. To this, added 100 ml of solution containing 30 g of sodium lauryl sulphate and 10 ml of 2-ethoxy ethanol. Then added 100 ml of a solution containing 4.5 g of disodium hydrogen phosphate. The pH was adjusted to 7.0 and made up the volume to one litre). 2 ml of decahydronaphthalene and 0.5 g sodium sulphite was added to the sample and boiled and refluxed for 60 minutes. The sample mixture was filtered through sintered glass crucible (G-2) by suction and washed with hot water. The residue was washed twice with acetone, transferred to a crucible and dried at 100^0C for 8 hours. The crucible was cooled in a desiccator and weighed.

Hemicellulose = Neutral detergent fibre (NDF) – Acid detergent fibre (ADF)

Acid detergent fibre (ADF) was found from lignin estimation.

3.1.2.2.3. Lignin content

Lignin content of various substrates was analysed gravimetrically by analysing with acid detergent solution. The sample material refluxing in acid detergent solution removed the water solubles and materials other than fibrous component. The left out material was weighed after filtration and treated with 72 percent H_2SO_4, filtered, dried and ashed. The loss of weight on ignition was expressed as the acid detergent lignin (ADL). (Thimmayya, 2004).

3.1.2.2.3.1. Acid Detergent Fibre (ADF)

One gram of powdered sample was placed in a round bottom flask and added 100 ml of acid detergent solution prepared by dissolving 20 g of cetyl trimethyl ammonium bromide in one litre of 1N H_2SO_4. Sample was heated to boil in 10 minutes. The heating was reduced to avoid foaming as boiling begins. It was then refluxed for 1 hour after the onset of boiling. The container was removed, swirled and the contents were filtered through a pre-weighed sintered glass crucible (G-2) by suction and washed with hot water twice. The residues were washed with acetone and the lumps were broken. Acetone washing was repeated until the filtrate was colourless. The residues were dried at 100^0C overnight, weighed after cooling in a desiccator. ADF content was expressed in percentage *i.e.* W/S × 100 where W was the weight of the fibre and S was the weight of the sample.

3.1.2.2.3.2. Determination of Acid Detergent Lignin (ADL)

Acid Detergent Fibre was transferred to a 100 ml beaker with 50 ml of 72 percent H_2SO_4. 1 g asbestos was added and allowed to stand for 3 hours with intermittent stirring with a glass rod. The acid was diluted with distilled water and filtered with pre weighed Whatman No.1 filter paper (wet the filter paper in hot water, dried in oven at 102^0C for 2 hours. It was then cooled in a desiccator and weighed in a cover dish. Glass rod and residue were washed several times to get rid of the acid. The filter paper with the content in a muffle furnace at 550^0C for about 3 hours. The crucible was cooled in a desiccator and weighed. The ash content was calculated. For blank 1 g asbestos was taken, 72 percent H_2SO_4 was added and followed the above steps (If the weight loss of asbestos blank on ashing is below 0.002g g^{-1}, the determination of blank was discontinued.

$$Acid\ detergent\ lignin\ (\%) = \frac{Washed\ fibre\ (Test - asbestos\ blank) - Ash(Test - asbestos\ blank}{weight\ of\ sample} \times 100$$

3.1.2.3. Biological properties

3.1.2.3.1. Microbial load

The total bacteria, fungi and actinomycetes (cfu g^{-1}) in the compost sample were determined using specific media (Table 3, Media composition in Appendix I).

Table 3. 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 Sheman (1996)

3.1.2.3.2. Dehydrogenase activity

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 of $CaCO_3$ and 1 ml of 3 percent 2,3,5 - triphenyl tetrazolium chloride (TTC) and 2.5 ml of distilled water , mixed well and kept for incubation for 24 hours at room temperature. After 24 hours, methanol (10ml) was added and 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 was transferred to the funnel by washing with methanol. The tube was washed and the soil was transferred to the funnel. The reddish colour of absorbent cotton vanished while washing with methanol. The reddish coloured filtrate was made up to 100 ml using 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 formazan (TPF) as standard.

3.1.2.3.3. Cellulase activity

Cellulase activity was estimated as per the method suggested by Pancholy and Rice (1973). Five gram of air dried compost was taken in a 100 ml Erlen Meyer flask. Ten ml of acetate buffer and 1 percent carboxy methyl cellulose were added. Flasks were incubated for 24 hrs at 37^0C and left undisturbed. After the incubation, 50 ml of the filtrate was taken and 4 ml anthrone reagent was added. The intensity of the green colour developed was read in the spectrophotometer at 620 nm. Glucose was used as standard at different concentrations for the preparation of standard calibration graph. The results were then expressed as the amount of glucose hydrolysed g^{-1} of soil 24 h^{-1} in ppm.

3.1.2.3.4. CO_2 emission

The respiratory activity of composts was estimated using the method outlined by Jenkinson and Powlson (1976).

3.1.2.4. Fertilizing Index and clean Index

Fertilizing index is the measure of nutrient supplying potential of compost while clean index is used by the regulatory authority for restricting the entry of heavy metals in to sensitive components of environment.

The fertilizing index and clean index of the composts were computed using the formula described by Saha *et al.,* (2010).

1. Fertilizing index = $\frac{\sum S_i}{\sum W_i}$

S_i is the score value of the analytical data and W_i is the weighing factor of i^{th} fertility parameters are presented in Table 4.

2. Clean index = $\frac{\sum S_j}{\sum W_j}$

S_j is the score value of the analytical data and W_j is the weighing factor of heavy metal parameters as per Table 5.

Table 4. Assigning weighing factor to fertility parameters and score value to the analytical data (Saha *et al.*, 2010)

Fertility parameters	**Score value (S_i)**					**Weighing factor (W_i)**
	5	4	3	2	1	
Total organic carbon (%)	>20	15.1-20	12.1-15	9.1-12	<9.1	5
Total nitrogen (%)	>1.25	1.01-1.25	0.81-1.00	0.51-0.80	<0.51	3
Total phosphorous (%)	>0.60	0.41-0.60	0.21-0.40	0.11-0.20	<0.11	3
Total potassium (%	>1.00	0.76-1	0.51-0.75	0.26-0.50	<0.26	1
C:N ratio	<10.1	10.1-15	15.1-20	20.1-25	>25	3

Table 5. Assigning weighing factor to heavy metal parameters and score value to analytical data (Saha *et al.*, 2010)

Heavy metals (mg kg^{-1})	**Score value (S_j)**						**Weighing factor (W_j)**
	5	4	3	2	1	0	
Zn	< 151	151-300	301-500	501-700	701-900	>900	1
Cu	< 51	51-100	101-200	201-400	401-600	>600	2
Cd	< 0.3	0.3-0.6	0.7-1.0	1.1-2.0	2.0-4.0	>4	5
Pb	< 21	51-100	101-150	151-250	251-400	>400	3
Ni	<10.1	21-40	41-80	81-120	121-160	>160	1
Cr	< 51	51-100	101-150	151-250	251-350	>350	3

Plate 4. Best seven biomineral enriched (Bokashi) composts

3.1.2.5. C:N Ratio

It is the ratio between total organic carbon and total nitrogen of the composts.

After characterisation of composts, based on the selection indices like maturity of composts, fertilizing index, available major and minor nutrients, enzyme status and C:N ratio seven best treatments were identified. These treatments were subjected to incubation study.

3.2. LABORATORY INCUBATION STUDY

To monitor the nutrient release pattern of biomineral enriched Bokashi composts, at periodic intervals a laboratory study was conducted for a period of four months from June 2022 to September 2022. Samplings were done at 1^{st}, 4^{th}, 8^{th}, 12^{th} and 16^{th} week 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, College of Agriculture Vellayani. One kilogram of soil sieved through 2mm sieve was filled in the plastic pots and 20 g of best seven treatments were imposed at the soil surface followed by thorough mixing. The soil was incubated for a period of four months at field capacity. The details of the experiment are presented below.

3.2.2. Design and layout of the Experiment

Design : CRD

Treatments : 8

Replication : 3

3.2.3. Treatment Details

T_1: Soil 1 kg (Absolute control)

T_2: Soil 1 kg + 20g Best enriched compost 1 (Bokashi compost prepared from aquatic weed *Limnocharis flava* enriched with epsom salt)

T_3: Soil 1 kg + 20 g Best enriched compost 2 (Bokashi compost prepared from aquatic weed *Limnocharis flava* enriched with calcium apatite and epsom salt)

T_4: Soil 1 kg + 20g Best enriched compost 3 (Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with calcium apatite and epsom salt)

T_5: Soil 1 kg + 20g Best enriched compost 4 (Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with epsom salt and sylvinite)

$T_{6:}$ Soil 1 kg + 20g Best enriched compost 5 (Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with calcium apatite and sylvinite)

T_7: Soil 1 kg + 20g Best enriched compost 6 (Bokashi compost prepared from aquatic weed *Limnocharis flava* enriched with calcium apatite, epsom salt and sylvinite)

T_8: Soil 1 kg + 20g Best enriched compost 7 ((Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite).

3.2.4. Soil sampling

Soil samples were drawn at 1^{st}, 4^{th}, 8^{th}, 12^{th} and 16^{th} week of incubation and was analysed for the following parameters.

3.2.5. Analysis of soil samples

Chemical parameters like organic carbon, available N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and biological properties like dehydrogenase and cellulase activity was determined by standard analytical procedures (Table 6).

T_2R_3	T_6R_2	T_7R_1
T_7R_2	T_4R_1	T_1R_3
T_5R_1	T_5R_3	T_4R3
T_3R_1	T_1R_1	T_8R_2
T_3R_2	T_7R_3	T_6R_3
T_6R_1	T_4R_2	T_2R_1
T_1R_2	T_5R_2	T_8R_1
T_8R_3	T_2R_2	T_3R_3

Fig 1. Lay out of incubation study

Plate 5. General view of laboratory incubation study

Table 6. Analytical procedures followed for soil analysis

Sl No.	Properties	Methods	References
1	pH	pH meter	Jackson (1958)
2	EC	Conductivity meter	Jackson (1958)
3	Organic carbon	Walkley and Black rapid titration method	Walkley and Black (1934)
4	Available N	Alkaline potassium permanganate method	Subbiah and Asija (1956)
4	Available P	Bray No.1 extraction and estimation using spectrophotometer	Bray and Kurtz (1945)
5	Available K	Neutral normal ammonium acetate and flame photometry	Jackson (1973)
6	Exchangeable Ca	Neutral normal ammonium acetate and EDTA method	Jackson (1973)
7	Exchangeable Mg	Neutral normal ammonium acetate and EDTA method	Jackson (1973)
8	Available S	$CaCl_2$ extraction and estimation using spectrophotometer	Massoumi and Cornfield (1963)
9	Micronutrients Fe, Mn, Zn and Cu	0.1 N HCl extraction and AAS	Sims and Johnson (1991)
10	Heavy metal content (Cd, Pb, Ni, Cr)	Emission Spectroscopy (ICP-OES)	Wei and Yang (2010)
11	Dehydrogenase activity	Spectrophotometric method	Casida *et al.* (1964)
12	Cellualse activity	Spectrophotometric method	Pancholy and Rice (1973)
13	Bacteria	Nutrient Agar medium	Atlas and Parks (1993)
14	Fungi	Martin’s Rose Bengal Agar	Martin (1950)
15	Actinomycetes	Ken knight’s Agar medium	Cappuccino and Sheman (1996)

3.3. FIELD EXPERIMENT

A field experiment was conducted using bhindi as test crop followed by amaranthus as residual crop during Feb-May, 2022.

3.3.1 Experimental site

The field experiment was conducted at Model Organic Farm, College of agriculture Vellyani. The geographic location of the site is $76^0 90^{'}$ East longitude and at an altitude of 29 m above MSL.

3.3.1.1. Season

The details regarding weekly average of temperature, evaporation, relative humidity and average rainfall were collected from meteorological observatory attached to the College of Agriculture, Vellayani during the cropping period and are furnished in Appendix II and are graphically presented in Fig 2.

3.3.1.2. Soil

The soil of the experimental site was sandy loam belonging to family Loamy kaolinitic isohyperthermic Typic Kandiustults.

3.3.1.3. Crop

The bhindi variety used for cultivation was Anjitha, the seeds of which was procured from Instructionl Farm, College of Agriculture, Vellayani.

3.3.1.4. Manures and Fertilizers

Farm Yard Manure required for the experiment was purchased from Model Organic Farm, College of Agriculture, Vellayani. The POP recommendation (KAU, 2016) for bhindi is 110:35:70 kg ha^{-1} and FYM 20 t ha^{-1}.

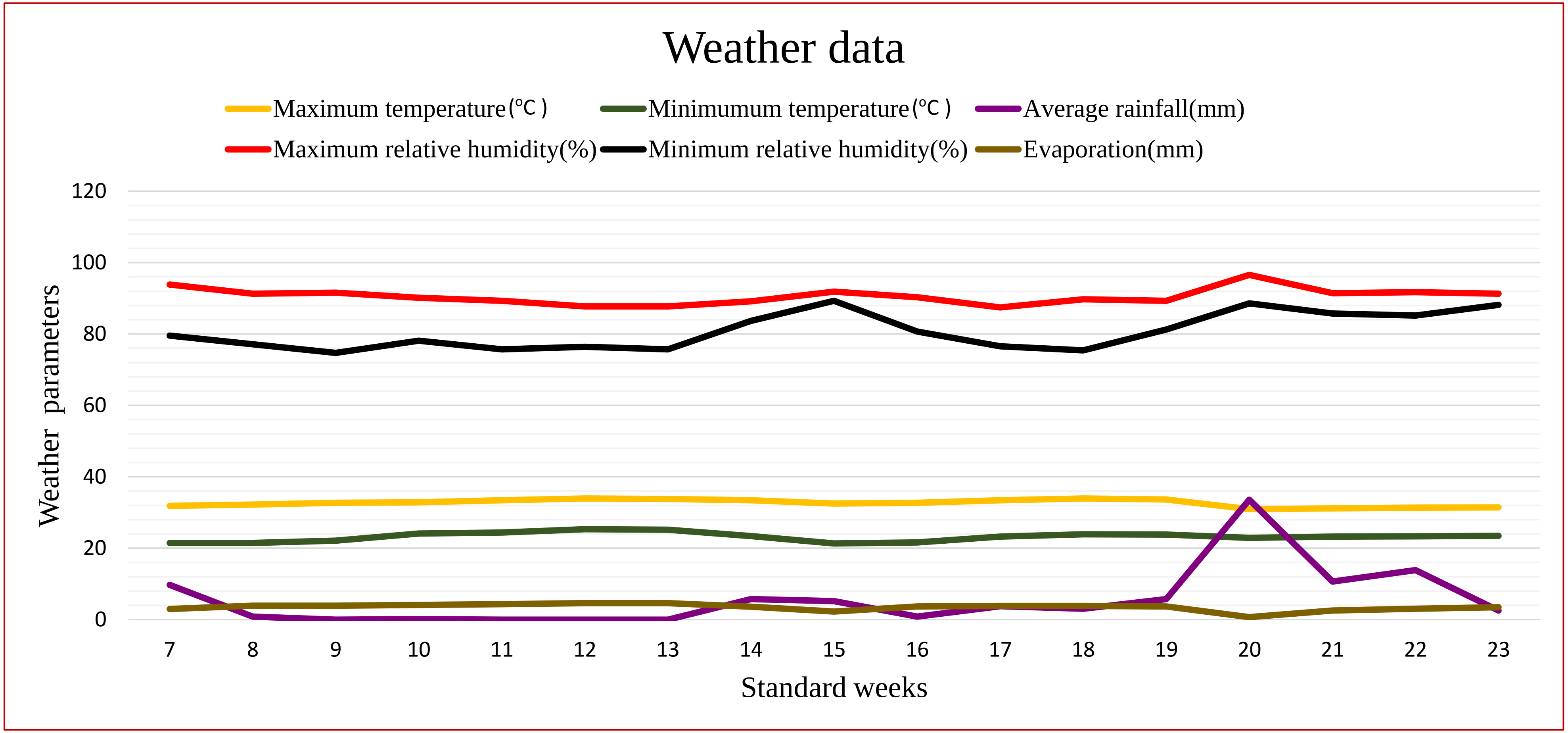


Fig 2. Weather parameters during field experiment

3.3.2. Methods

3.3.2.1. Design and layout of experiment

Design : RBD

Replication : 3

Treatment : 9

Crop : Bhindi (var. Anjitha)

Spacing : 60cm × 45cm

Season : February-March

Residual crop : Amaranthus (var. Arun)

3.3.2.2. Treatment details

T_1: Absolute control

T_2: Best enriched compost 1 (Bokashi compost prepared from aquatic weed *Limnocharis flava* enriched with epsom salt)

T_3: Best enriched compost 2 (Bokashi compost prepared from aquatic weed *Limnocharis flava* enriched with calcium apatite and epsom salt)

T_4: Best enriched compost 3 (Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with calcium apatite and epsom salt

T_5: Best enriched compost 4 (Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with epsom salt and sylvinite)

T_6: Best enriched compost 5 (Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with calcium apatite and sylvinite)

T_7: Best enriched compost 6 (Bokashi compost prepared from aquatic weed *Limnocharis flava* enriched with calcium apatite, epsom salt and sylvinite)

T_8: Best enriched compost 7 ((Bokashi compost prepared from 1:1 mixture of aquatic weed *Limnocharis flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite)

T_9: KAU POP recommendation

3.3.2.3. Field preparation and layout

The main field was cleared and ploughed thoroughly with power tiller. The land was the laid out in to three blocks with nine plots in randomized design.

3.3.2.4. Application of fertilizers and manures

Lime was applied at the rate of 350 kg ha^{-1}. Farm yard maure was applied in all the plots except T_1 (Absolute control) at rate of 20 t ha^{-1}. Chemical fertilizers like urea, Single Super Phosphate and MOP were applied as per KAU POP recommendation (KAU POP, 2016) (T_9). All the biomineral enriched Bokashi composts were supplemented on N equivalent basis as basal and topdressing at one month after sowing. Remaining dose of P and K was supplemented in the form of Single Super Phosphate and Muriate of Potash as basal.

3.3.2.5. Sowing and after cultivation

Seeds were dibbled at the rate of 2-3 seeds per hole at a spacing of 60 × 45 cm. A uniform population of plants were maintained by thinning and gap filling. All the intercultural operations were done as per the requirement.

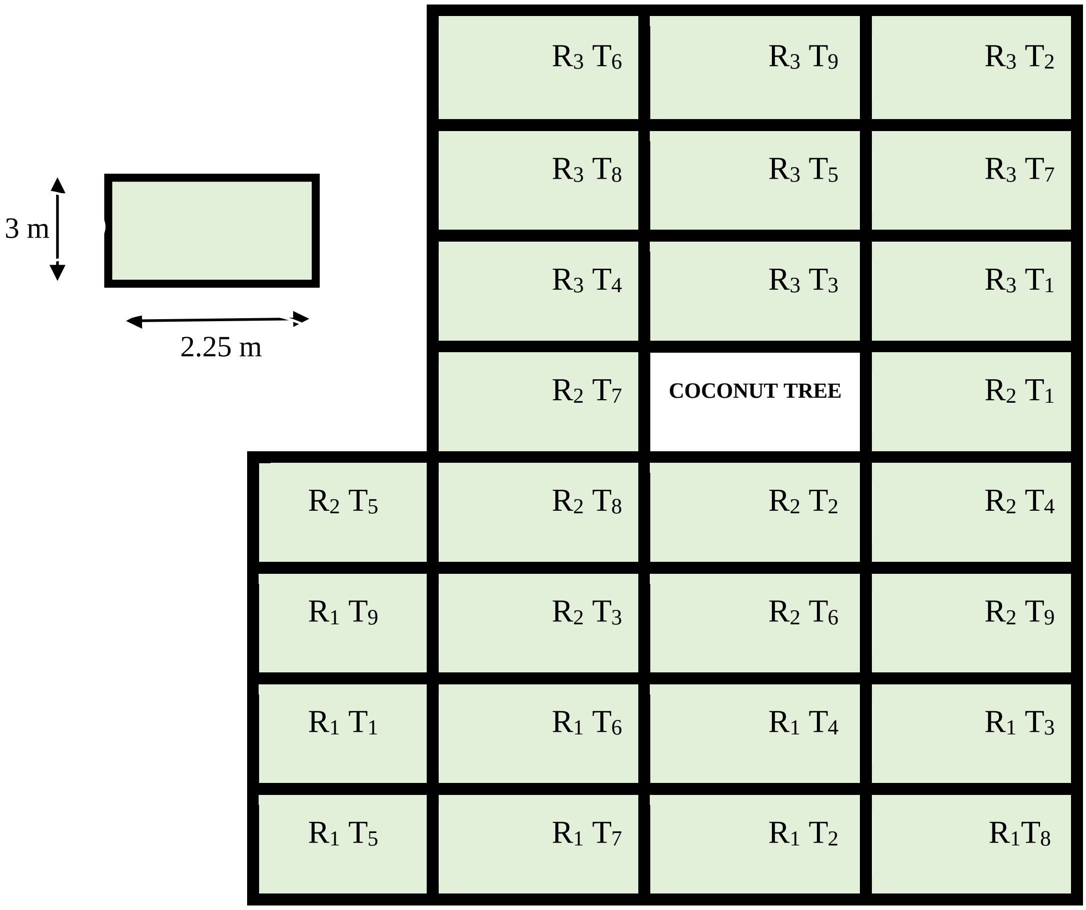


Fig 3. Lay out of field experiment

Plate 6. Lay out of the field

Plate 7. General field view

3.3.2.6. Plant protection

Yellow Vein Mosaic was observed in some plants during early stages of growth. For managing rouging was done followed by the application of neem oil at 2 percent dilution at weekly intervals and *Pseudomonas fluorescens* application was done at 2 percent thrice at 14 days interval.

3.3.2.7. Harvesting

Harvest of matured green fruits was done once in two days. Staggered harvesting was done.

3.3.2.8. Land preparation and sowing of residual crop

After uprooting bhindi a light ploughing was given and amaranthus seeds were broadcasted on all the plots at a rate of 1.5 kg ha^{-1}.

3.3.2.9. Harvesting of residual crop

The residual crop was harvested two months after sowing by up rooting.

3.3.3. Post harvest soil analysis

Soil samples for analysis was collected from each plot. The collected samples were sieved through 2mm sieve after shade drying. The samples were analysed for pH, EC, Available N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu. Dehydrogenase and cellulase enzyme activity was also assessed. The procedures adopted for all the above analysis were given in Table 6.

3.3.4. Rhizosphere soil analysis

Rhizosphere soils were collected by destructive sampling method. Plants were uprooted and the soils were collected in polythene bags and stored in deep freezers inorder to maintain the viability of microorganisms. The rhizosphere soil was analysed for total microbial load, soil respiratory activity, microbial biomass carbon, glomalin and humic acid fractions.

3.3.4.1 Total microbial load

Microbial count in the soil was enumerated using serial dilution technique proposed by Timonin (1940). The composition of media is presented in Appendix I.

3.3.4.2. Soil respiratory activity

The respiratory activity of the soil samples was estimated using the method outlined by Jenkinson and Powlson (1976).

3.3.4.3. Microbial biomass carbon

Fumigation – incubation method was used to estimate microbial biomass carbon which was outlined by Jenkinson and Ladd (1981).

3.3.4.4. Glomalin

Glomalin was extracted by the method described by Wright and Upadhyaya (1996). One gram of air dried sample was taken, 8ml of citrate (pH 7) was added and autoclaved and centrifuged a number of times to extract glomalin. The extract was then estimated for protein using Bradford dye binding protein assay (Bradford, 1976).

3.3.4.5. Humic acid fractions

Humic acid fraction was determined using the method outlined by Tan (1996).

3.3.4.6. Microbial respiratory Quotient

Microbial respiratory quotient was measured as µg CO_2 evolved per hour per mg microbial biomass carbon (Rudrappa *et al.,* 2006).

Microbial respiratory quotient = $\frac{Carbon\ dioxide\ evolved\ per\ hour}{Microbial\ biomass\ carbon}$

3.3.4.7. Enzyme kinetics [Michaelis – Menten Constant] (V_{max} and K_m)

The kinetics parameters K_m and V_{max} of the soil enzyme dehydrogenase was worked out based on Line – Weaver – Burk plot for all the rhizosphere soil samples. Varying concentrations of substrate were added to the soil and the activity of enzyme was estimated and the values of V_{max} and K_m were determined..

When 1/V is plotted against 1/S, a straight line graph is obtained in the Line-Weaver-Burk method, where V is the velocity and S is the substrate concentration. The slope is K_m / V_{max} the intercept on the ordinate is 1/V_{max} (Vaughan and Ord, 1991).

Six concentrations of Triphenyl Tetrazolium chloride solution (0.003, 0.007, 0.010, 0.020, 0.030 and 0.050 mol l^{-1}) were the substrates for the enzyme.

3.3.5. Biometric observations

To record the biometric observations regularly four plants from the middle row was tagged.

3.3.5.1. Days to germination

In each plot number of days required for germination from the date of sowing was recorded

3.3.5.2. Number of plants per plot

The number of plants present in each plot was noted.

3.3.5.3. Plant height at first harvest (cm)

Plant height of tagged plants in each plot from the base of the plant to the terminal leaf at the time of first harvest was noted.

3.3.5.4. Inter nodal length at final harvest (cm)

At the time of final harvest vertical distance between two adjacent leaf axils of tagged plants in each plot was measured as inter nodal length.

3.3.5.5. Number of branches at final harvest

Number of branches present in the tagged plants from each plot were noted.

3.3.5.6. Root weight and root volume

The root weight was measured after shade drying the cut root portion of tagged plants from each plot. Root volume was measured by immersing the roots of tagged plants from each plot in water taken in a volumetric flask.

3.3.5.7.. Dry matter production (t ha^{-1})

Fresh weight and oven dry weight of the plant samples were recorded. The fresh samples were shade dried and put in the oven at 70^0 C until a constant weight is obtained.

3.3.6 Yield attributes

From the tagged plants yield and yield attributing characters were recorded

3.3.6.1. Number of days to first flowering

Number of days required from sowing for first flowering was recorded from each plot

3.3.6.2. Number of days to 50% flowering

From each plot number of days required for 50% of plants in the plot to flower from the date of sowing was recorded.

3.3.6.3. Number of fruits per plant

Number of fruits harvested from tagged plants from each plot at every harvest were noted and the average was calculated.

3.3.6.4. Fruit length (cm)

Length of fruits harvested from the tagged plants were recorded and the mean length was noted.

3.3.6.5. Girth of fruit (cm)

Girth of fruit was measured by winding a thread around the centre of the fruit and the average value was taken.

3.3.6.6. Yield per plant (g plant $^{-1}$)

From the observation plants total weight of fruits from each plot at each harvest was taken and mean value was noted.

3.3.6.7. Yield (t ha^{-1})

Total weight of fruits from each plot at each harvest was noted and calculated as yield per hectare.

3.3.7. Scoring of pest and diseases

Percentage of disease incidence (for Yellow Vein Mosaic) was calculated using the formula

$$PDI\ (\%) = \frac{Number\ of\ affected\ plants}{Total\ number\ of\ plants} \times 100$$

3.3.8. Benefit cost ratio

The benefit cost ratio was calculated by the formula

$$Benefit\ Cost\ Ratio = \frac{Gross\ income}{Cost\ of\ cultivation}$$

3.3.9. Yield of residual crop

Yield obtained from each plot was calculated and represented as tons per hectare (t ha^{-1}).

3.3.10. Statistical analysis of data

Statistical analysis of the experimental data was subjected to analysis of variance 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 where reported to be significant.

4. RESULTS

4.1. PRODUCTION AND CHARACTERIZATION OF BIOMINERAL ENRICHED (BOKASHI) COMPOSTS FROM DIFFERENT ORGANIC SOURCES

The Bokashi composts were prepared from two substrates namely S_1 (*L.flava*) and S_2 (1:1 mixture of *L.flava* and banana pseudostem). The aquatic weed *L.flava* and banana pseudostem used for the production of composts were subjected to nutrient analysis and the values obtained are presented in Table 7.

L.flava recorded the highest values for total organic carbon (61.30%), nitrogen (2.30 %), phosphorus (0.21%), calcium (0.19%), magnesium (0.10%), sulphur (13.17 mg kg^{-1}), iron (0.95 %), manganese (129 mg kg^{-1}), zinc (95.50 mg kg^{-1}) and copper (29 mg kg^{-1}). Banana pseudostem has reported a nutrient content of total organic carbon (46.52%), nitrogen (1.09%), phosphorus (0.15%), calcium (0.17%), magnesium (0.03%), sulphur (9.15 mg kg^{-1}), iron (0.05%), manganese (114 mg kg^{-1}), zinc (49 mg kg^{-1}) and copper (21.6 mg kg^{-1}). The potassium and boron content was found to be higher for banana pseudostem with value of 1.97 % and 44 mg kg^{-1} respectively.

The Bokashi composts prepared were also subjected to nutrient analysis before mineral enrichment and are presented in Table 8. The Bokashi compost prepared from *L.flava* recorded higher values for total organic carbon (38.31 %), nitrogen (3.07%), Phosphorus (0.28%), calcium (0.25%), magnesium (0.15 %), sulphur (15.18 mg kg^{-1}), iron (1.03 %), manganese (135 mg kg^{-1}), zinc (35.5 mg kg^{-1}), copper (22.03 mg kg^{-1}) and boron (61 mg kg^{-1}) when compared to Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem with a nutrient content of total organic carbon (35.75 %), nitrogen (2.76 %), Phosphorus (0.24 %), calcium (0.21%), magnesium (0.07 %), sulphur (12.09 mg kg^{-1}), iron (0.85 %), manganese (124.5 mg kg^{-1}), zinc (29.5 mg kg^{-1}), copper (19.81 mg kg^{-1}) and boron (58 mg kg^{-1}). It is observed from Table 8 that the potassium content was found to be higher for Bokashi compost prepared from 1:1 mixture of *L.flava* and

Table 7. Nutrient composition of the substrates used for the production of biomineral enriched (Bokashi) composts

Particulars	**Total OC (%)**	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**S (mg kg^{-1})**	**Fe (%)**	**Mn (mg kg^{-1})**	**Zn (mg kg^{-1})**	**Cu (mg kg^{-1})**	**B (mg kg^{-1})**
L. flava	61.30	2.30	0.21	0.92	0.19	0.10	13.17	0.95	129	95.5	29	43
Banana pseudostem	46.52	1.09	0.15	1.97	0.17	0.03	9.15	0.05	114	49	21.6	44

Table 8. Nutrient composition of produced Bokashi composts before mineral enrichment

Particulars	**Total OC %**	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**S (mg kg^{-1})**	**Fe (%)**	**Mn (mg kg^{-1})**	**Zn (mg kg^{-1})**	**Cu (mg kg^{-1})**	**B (mg kg^{-1})**
Bokashi compost prepared from *L. flava*	38.31	3.07	0.28	1.23	0.25	0.15	15.18	1.03	135	35.5	22.03	61
Bokashi composts prepared from *L.flava* and banana pseudostem in 1:1 ratio	35.75	2.76	0.24	2.06	0.21	0.07	12.09	0.85	124.5	29.5	19.81	58

Table 9. Physical properties of resultant biomineral enriched (Bokashi) composts

Treatments	Colour	Water holding capacity (%)	Bulk density (Mg m^{-3})	Moisture content (%)
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	Dark brown	84.42	0.29	25.61
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	Dark brown	85.94	0.24	26.47
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	Dark brown	86.11	0.32	24.76
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	Dark brown	77.64	0.36	27.84
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	Dark brown	79.71	0.35	30.75
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	Dark brown	77.12	0.33	28.13
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	Dark brown	84.41	0.27	25.22
T_8: Bokashi compost prepared from *L. flava* enriched with epsom salt and sylvinite	Dark brown	86.43	0.29	27.26
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	Dark brown	85.97	0.27	23.19
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	Dark brown	78.71	0.36	30.63
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	Dark brown	77.28	0.35	30.94
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	Dark brown	78.39	0.32	31.34
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	Dark brown	86.56	0.21	25.68
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	Dark brown	80.13	0.31	31.83
SEm(±)		0.817	0.006	0.87
CD(0.05)		2.368	0.018	2.519

Table 10. Electrochemical properties of resultant biomineral enriched (Bokashi) composts

Treatments	pH	EC (dSm^{-1})
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	7.34	3.31
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	7.04	3.27
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	7.14	3.21
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	7.39	3.33
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	6.83	3.28
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	7.21	3.32
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	7.28	3.31
T_8: Bokashi compost prepared from *L. flava* enriched with Epsom salt and sylvinite	6.97	3.28
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	7.22	3.29
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	7.16	3.33
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	6.66	3.21
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	7.01	3.38
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	7.27	3.25
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	7.19	3.23
SEm(±)	0.137	0.125
CD(0.05)	0.396	NS

(NS- Not Significant)

banana pseudostem (2.06%) compared to Bokashi compost prepared from *L.flava* (1.23%).

The prepared Bokashi composts were enriched with minerals at different combinations. The physical, electro chemical, chemical and biological properties of the prepared biomineral enriched (Bokashi) composts are depicted in the below section.

4.1.1. Physical properties of the resultant biomineral enriched (Bokashi) compost

The physical properties of the resultant composts like colour, water holding capacity, bulk density and moisture content are presented in Table 9.

4.1.1.1. Colour

All the resultant biomineral enriched (Bokashi) composts were dark brown in colour.

4.1.1.2. Water holding capacity

Table 9 shows the water holding capacity of the resultant biomineral enriched Bokashi composts. The water holding capacity of resultant biomineral enriched (Bokashi) composts ranged from 77.12% to 86.56%. The water holding capacity was found to be higher for T_{13} (86.56%) which is Bokashi compost prepared from *L.flava* and enriched with calcium apatite, epsom salt and sylvinite. Treatments T_8 (86.43%), T_3 (86.11 %), T_9 (85.97%), T_2 (85.94%), T_1 (84.42%) and T_7 (84.41%) were found to be on par with T_{13}. The lowest value for water holding capacity was reported by T_6 (77.12%) which was Bokashi compost prepared from the mixture of *L.flava* and banana pseudostem enriched with sylvinite.

4.1.1.3. Bulk density

The bulk density of the resultant biomineral enriched (Bokashi) composts are presented in Table 9. The mean values of bulk density ranged between 0.21 Mg m^{-3} to 0.36 Mg m^{-3}. The lowest bulk density was registered for T_{13} (0.21 Mg m^{-3})

which was the Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite and was significantly lower than all the other resultant composts. The highest value of bulk density was reported by T_{10} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt) and T_4 with a value of 0.36 Mg m^{-3} which was on par with T_{11} (0.35 Mg m^{-3}) and T_5 (0.35 Mg m^{-3}).

4.1.1.4. Moisture content

Data on moisture content of resultant biomineral enriched (Bokashi) composts are presented in Table 9. The moisture content values ranged from 23.19 % to 31.83 %. The highest moisture content was recorded for T_{14} (31.83%) which was Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. It was observed from the Table 9 that treatments T_{12} (31.34%), T_{11} (30.94%), T_5 (30.75%) and T_{10} (30.63%) was found to be on par with the highest value. The lowest mean value was registered by T_9 (23.19%).

4.1.2. Electrochemical properties of the resultant biomineral enriched (Bokashi) compost

The electro chemical properties of the resultant biomineral enriched (Bokashi) composts (pH and Electrical Conductivity) are presented in Table 10.

4.1.2.1. pH

The pH of the resultant biomineral enriched (Bokashi) composts are presented in Table 10. The pH values of composts ranged from 6.66 to 7.39. The highest value of pH was reported by T_4 (Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite) with a value of 7.39. T_4 was found to be on par with T_1 (7.34), T_2 (7.04), T_3(7.14), T_6(7.21), T_7 (7.28), T_9 (7.22), T_{10} (7.16), T_{12} (7.01), T_{13} (7.27) and T_{14} (7.19). The lowest value of pH was registered by T_{11} (6.66).

Table 11. Proximate constituents (cellulose, hemicellulose and lignin) of resultant biomineral enriched (Bokashi) composts

Treatments	Cellulose (%)	Hemicellulose (%)	Lignin (%)
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	16.50	4.78	5.57
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	15.40	3.72	5.49
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	17.05	3.61	4.56
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	22.18	7.79	11.08
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	22.00	7.93	11.12
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	21.84	8.13	10.41
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	15.14	4.00	5.35
T_8: Bokashi compost prepared from *L. flava* enriched with epsom salt and sylvinite	16.84	4.36	6.09
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	17.07	3.93	4.98
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	22.09	7.91	10.03
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	21.57	7.65	9.74
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	21.26	8.03	9.68
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	17.16	4.05	5.36
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	22.22	8.09	9.04
SEm(±)	0.578	0.103	0.095
CD(0.05)	0.199	0.300	0.275

Table 12. Total organic carbon and NPK content of biomineral enriched (Bokashi) composts

Treatments	Total organic carbon (%)	Total N (%)	Total P (%)	Total K (%)
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	35.90	3.01	0.58	2.64
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	36.15	3.58	0.38	1.96
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	35.93	3.33	0.31	3.03
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	33.70	3.21	0.52	2.89
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	30.44	2.77	0.37	2.02
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	31.93	2.85	0.36	3.41
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	36.05	3.51	0.57	1.86
T_8: Bokashi compost prepared from *L. flava* enriched with Epsom salt and sylvinite	35.97	3.27	0.30	3.10
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	36.00	3.30	0.55	3.22
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	29.70	2.83	0.59	2.86
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	30.01	2.87	0.41	3.48
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	30.27	2.91	0.57	3.86
T_{13}: Bokashi compost prepared from *L flava* enriched with calcium apatite, epsom salt and sylvinite	37.82	3.94	0.62	2.08
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	33.95	3.37	0.59	3.76
SEm(±)	0.172	0.077	0.013	0.112
CD(0.05)	0.498	0.224	0.038	0.323

Table 13. Secondary nutrient and boron content of resultant biomineral enriched (Bokashi) composts

Treatments	Ca (%)	Mg (%)	S (mg kg $^{-1}$)	B (mg kg $^{-1}$)
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	0.41	0.14	18.40	58
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	0.29	0.23	25.94	64
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	0.26	0.11	20.01	40
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	0.35	0.13	22.67	65
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	0.27	0.24	28.49	67
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	0.21	0.11	21.33	39
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	0.37	0.26	33.22	42
T_8: Bokashi compost prepared from *L. flava* enriched with epsom salt and sylvinite	0.24	0.22	28.91	54
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	0.37	0.15	23.34	60
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	0.39	0.27	29.65	51
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	0.28	0.20	29.50	64
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	0.44	0.12	23.26	62
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	0.36	0.22	32.19	73
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	0.38	0.24	30.52	75
SEm(±)	0.015	0.013	0.185	1.563
CD(0.05)	0.042	0.037	0.537	4.529

Table 14. Micronutrient and heavy metal content of resultant biomineral enriched (Bokashi) composts

Treatments	Fe (%)	Mn (mg kg $^{-1}$)	Zn (mg kg $^{-1}$)	Cu (mg kg $^{-1}$)	Cd (mg kg $^{-1}$)	Pb (mg kg $^{-1}$)	Ni (mg kg $^{-1}$)	Cr (mg kg $^{-1}$)
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	1.21	147.63	54.8	27.16	BDL	BDL	BDL	BDL
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	1.04	182.48	38.5	24.33	BDL	BDL	BDL	BDL
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	1.11	140.06	47.6	26.27	BDL	BDL	BDL	BDL
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	1.19	141.59	51.3	22.51	BDL	BDL	BDL	BDL
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	0.99	131.00	31.6	21.50	BDL	BDL	BDL	BDL
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	1.01	138.19	44.1	23.92	BDL	BDL	BDL	BDL
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	1.29	171.15	55.5	27.85	BDL	BDL	BDL	BDL
T_8: Bokashi compost prepared from *L. flava* enriched with Epsom salt and sylvinite	1.22	156.9	58.7	26.87	BDL	BDL	BDL	BDL
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	1.45	137.55	65.5	29.30	BDL	BDL	BDL	BDL
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	1.25	157.3	53.2	24.93	BDL	BDL	BDL	BDL
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	1.07	167.80	54.0	25.58	BDL	BDL	BDL	BDL
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	1.31	167.75	62.5	27.46	BDL	BDL	BDL	BDL
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	1.46	198.5	67.2	30.50	BDL	BDL	BDL	BDL
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	1.41	185.40	65.9	29.76	BDL	BDL	BDL	BDL
SEm(±)	0.014	1.594	1.251	1.294				
CD(0.05)	0.040	4.617	3.624	3.749				

(BDL- Below Detectable Level)

4.1.2.2. Electrical conductivity

The Table 10 shows the values of electrical conductivity of resultant biomineral enriched (Bokashi) composts. The values of electrical conductivity ranged from 3.21 dSm^{-1} to 3.38 dSm^{-1}.

4.1.3. Proximate constituents of the resultant biomineral enriched (Bokashi) compost

The proximate constituents (cellulose, hemicellulose and lignin) of resultant biomineral enriched (Bokashi) composts are depicted in Table 11.

4.1.3.1. Cellulose

Table 11 depicted the cellulose content of resultant biomineral enriched (Bokashi) composts. It can be seen from the Table 11 that the highest value of cellulose was reported by T_{14} (22.22 %) which was the Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The composts T_{10} (22.09 %) and T_4 (22.18%) was on par with the highest value. The lowest cellulose content was recorded for compost T_7 (Bokashi compost prepared from *L.flava* enriched with calcium apatite and epsom salt) with a value of 15.14%.

4.1.3.2. Hemicellulose

The mean values of hemicellulose content for different biomineral enriched (Bokashi) composts are presented in Table 11. The highest value of hemicellulose content was reported for compost T_6 (8.13%) which was prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite. It was also observed that T_{14} (8.09%), T_{12} (8.03%), T_{10} (7.91%) and T_5 (7.93%) recorded values which were on par with the highest value. The lowest mean value for hemicellulose content was registered for T_3 (Bokashi compost prepared from *L.flava* enriched with sylvinite) with a mean value of 3.61%.

4.1.3.3. Lignin

Critical appraisal of the Table 11 showed that the mean values of the lignin content of resultant biomineral enriched (Bokashi) composts ranged from 4.56% to 11.12 %. The highest mean value of 11.12% was recorded for compost T_5 which was the Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt which was found to be on par with compost T_4 (11.08 %) which was the Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite. The lowest value for lignin content was recorded for compost T_3 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite) with a value of 4.56 %.

4.1.4. Chemical properties of the resultant biomineral enriched (Bokashi) compost

The chemical properties of the biomineral enriched (Bokashi) composts like total organic carbon, total N, P, K, Ca, Mg, S, B and micronutrients are presented in Table 12 to 14.

4.1.4.1. Total organic carbon

Critical appraisal of the data (Table 12) reveals that the total organic carbon content of the resultant biomineral enriched (Bokashi) composts varied significantly in their total organic carbon content. The mean values of total organic carbon ranged from 29.70% to 37.82%. The highest mean value of total organic carbon was registered by compost T_{13} (37.82%) which was the Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite and was found to be superior than all the other composts. The lowest mean value for total organic carbon was reported for compost T_{10} (29.70%).

4.1.4.2. Total nitrogen

The results of the analysis of the composts revealed that all the resultant biomineral enriched (Bokashi) composts varied significantly in their total nitrogen content (Table 12). The mean values of total nitrogen ranged from 2.77% to 3.94%.

Compost T_{13} (3.94%) which was Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest total nitrogen content which was significantly higher than all the other treatments. The lowest mean value of 2.77% was recorded by T_5 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt).

4.1.4.3. Total phosphorus

Critical appraisal of data shown in Table 12 revealed that the total phosphorus content of the resultant biomineral enriched (Bokashi) composts varied significantly. The mean values of total phosphorus content ranged from 0.30% to 0.62%. The highest mean value of 0.62% of total phosphorus was recorded for compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which was found to be on par with compost T_{14} (0.59%) which was the Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite, T_{10} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt) with a value of 0.59% and T_1 (Bokashi compost prepared from *L.flava* enriched with calcium apatite) with a value of 0.58%. The lowest mean value of total phosphorus was recorded for compost T_8 (Bokashi compost prepared from *L.flava* enriched with epsom salt and sylvinite) with a value of 0.30%.

4.1.4.4. Total potassium

The mean values of total potassium content of resultant biomineral enriched (Bokashi) compost was presented in Table 12 and it was found that the values varied significantly among the composts. The mean value of total potassium content of composts ranged from 1.86% to 3.86%. Treatment T_{12} (3.86%), Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite recorded the highest mean value for total potassium which was found to be on par with T_{14} (3.76%) which was the Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The lowest value of total potassium content was registered for compost T_7 (1.86%) which was the Bokashi compost prepared from *L.flava* enriched with calcium apatite and epsom salt and was found to be significantly lower than all the other treatments.

4.1.4.5. Total calcium

The total calcium content of the resultant biomineral enriched (Bokashi) composts are depicted in Table 13. The mean values of total calcium content varied from 0.21% and 0.44%. Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite (T_{12}) recorded the highest value for total calcium content with a value of 0.44% which was found to be on par with T_1 (0.41%). The lowest mean value of 0.21% was registered for T_6 which was the Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite.

4.1.4.6. Total magnesium

The data revealed that the total magnesium content varied significantly for different prepared biomineral enriched (Bokashi) composts (Table 13). The mean values ranged from 0.11% to 0.27%. It was found that compost T_{10} (Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt) registered the highest mean value for total magnesium with a value of 0.27% which was found to be on par with T_7 (0.26%), T_5 (0.24%), T_{14} (0.24%) and T_2 (0.23%). The lowest mean value was recorded for compost T_3 (Bokashi compost prepared from *L.flava* enriched with sylvinite) with a mean value of 0.11%.

4.1.4.7. Total sulphur

It was obvious from the data given in Table 13 that all the resultant biomineral enriched (Bokashi) compost varied significantly in their total sulphur content. The highest amount of sulphur was recorded for compost T_7 (Bokashi compost prepared from *L.flava* enriched with calcium apatite and Epsom salt) with a value of 33.22 mg kg^{-1} which was significantly higher than all the other composts.

The lowest mean value of sulphur content was registered for compost T_1 (Bokashi compost prepared from *L.flava* enriched with calcium apatite) with a value of 18.40 mg kg^{-1} which was found to be significantly lower than all the other treatments.

4.1.4.8. Total boron

A perusal of data revealed that the boron content of the resultant biomineral enriched (Bokashi) composts was significantly varied (Table 13). Compost T_{14} which is the Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite with a value of 75 mg kg^{-1} was found to be the highest mean value which was on par with T_{13} (73 mg kg^{-1}) which was the Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. The lowest value of 39 mg kg^{-1} was recorded for compost T_6 (Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite) which was found to be on par with compost T_3 (40 mg kg^{-1}) and T_7 (42 mg kg^{-1}).

4.1.4.9. Total micronutrient content

The total micronutrient content of the resultant biomineral enriched (Bokashi) composts are presented in Table 14.

From Table 14 it was observed that the iron content of the composts varied significantly. The mean values of iron content ranged from 0.99% to 1.46%. The highest mean value of 1.46% was recorded by the Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (T_{13}) with a value of 1.46% which was found to be on par with the iron content of compost T_9 (Bokashi compost prepared from *L.flava* enriched with calcium apatite and sylvinite with a value of 1.45%. The lowest mean value of iron content was recorded for compost T_5 (Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt) with a value of 0.99%.

The mean values of manganese content of resultant biomineral enriched (Bokashi) composts are presented in the Table 14. From the analysis of data it was clear that the manganese content varied significantly for different composts. The highest mean value of 198.5 mg kg^{-1} was recorded for the compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which was found to be significantly higher than all the other treatments. The lowest recorded value of 131.00 mg kg^{-1} was registered for the compost T_5 (Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt).

Statistical appraisal of data shows that the composts have significant variation in their zinc content (Table 14). The mean values of zinc content of composts ranged from 31.6 mg kg^{-1} to 67.20 mg kg^{-1}. It was observed that compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) had recorded the highest value of zinc content with a mean value of 67.2 mg kg^{-1} which was found to be on par with composts T_{14} (65.9 mg kg^{-1}) and T_9 (65.5 mg kg^{-1}). The lowest value for zinc content was recorded for compost T_5 with a zinc content of 31.6 mg kg^{-1}.

The copper content of the resultant biomineral enriched (Bokashi) composts are presented in Table 14. The copper content was significantly influenced by different composts. The mean values of copper ranged from 21.50 mg kg^{-1} to 30.50 mg kg^{-1}. The highest mean value of 30.50 mg kg^{-1} was recorded for compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite), which was found to be on par with T_{14} (29.76 mg kg^{-1}), T_9 (29.30 mg kg^{-1}), T_7 (27.85 mg kg^{-1}), T_{12} (27.46 mg kg^{-1}), T_1 (27.16 mg kg^{-1}) and T_8 (26.87 mg kg^{-1}). It was observed that Bokashi compost T_5 recorded the lowest mean value of 21.50 mg kg^{-1}.

4.1.4.10. Total heavy metal content

The heavy metal content of the composts are presented in Table 14. The heavy metal contet (Cd, Pb, Ni, Cr) was found to be below detectable level for all the prepared composts.

4.1.5. Biological properties of the resultant biomineral enriched (Bokashi) compost

The biological properties of the resultant biomineral enriched (Bokashi) composts are presented in Table 15 and 16.

4.1.5.1. Microbial load

The bacterial, fungal and actinomycetes population are presented in Table 15.

It was evident from the data (Table 15) that there were significant variation of bacterial population for different composts. The bacterial population was the highest in compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) with a value of 8.54 log cfu g^{-1} which was on par with composts T_{14} (8.52 log cfu g^{-1}) and T_{11} (8.50 log cfu g^{-1}). The lowest value of bacterial population was recorded for compost T_3 (8.20 log cfu g^{-1}) and T_5 (8.20 log cfu g^{-1}).

The mean values of fungal population are furnished in Table 15. From Table 15 it was evident that the fungal population varied significantly among the composts. The highest value of fungal population was recorded for compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) with a mean value of 5.46 log cfu g^{-1}, which was found to be on par with T_{14} (5.45 log cfu g^{-1}), T_1 (5.45 log cfu g^{-1}) and T_7 (5.45 log cfu g^{-1}).

Data in Table 15 indicated that the actinomycetes population varied significantly among the composts. The mean values ranged from 5.32 log cfu g^{-1} and 5.61 log cfu g^{-1}. It was found from the data that the compost T_{12} which was the Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite recorded the highest value (5.61 log cfu g^{-1}) which was on par with T_{13} (5.51 log cfu g^{-1}). The lowest mean value of 5.32 log cfu g^{-1} was recorded by compost T_5.

Table 15. Biological properties of resultant biomineral enriched (Bokashi) composts

Treatments	Microbial load (viable count – log cfu g^{-1})			CO_2 emission(mg CO_2 g^{-1})
	Bacteria	Fungi	Actinomycetes	
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	8.22	5.45	5.33	4.04
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	8.39	5.42	5.52	4.19
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	8.20	5.36	5.42	4.09
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	8.23	5.41	5.43	4.13
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	8.20	5.37	5.32	4.11
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	8.36	5.43	5.53	4.25
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	8.38	5.45	5.49	5.02
T_8: Bokashi compost prepared from *L. flava* enriched with Epsom salt and sylvinite	8.27	5.42	5.47	4.11
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	8.25	5.41	5.52	4.15
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	8.41	5.43	5.57	5.02
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	8.50	5.43	5.58	4.97
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	8.44	5.41	5.61	5.04
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	8.54	5.46	5.59	5.09
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	8.52	5.45	5.54	5.12
SEm(±)	0.025	0.010	0.010	0.010
CD(0.05)	0.072	0.029	0.027	0.029

Table 16. Dehydrogenase and cellulase activity of resultant biomineral enriched (Bokashi) composts

Treatments	Dehydrogenase activity (µg TPF hydrolysed g^{-1} compost 24 h^{-1})	Cellulase activity (µg glucose hydrolysed g^{-1} compost h^{-1})
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	499.19	209.14
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	587.85	269.39
T_3: Bokashi compost prepared from *L. flava* enriched with sylvinite	483.16	217.14
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite	476.76	209.54
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt	478.97	202.34
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with sylvinite	481.29	198.78
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	512.41	215.84
T_8: Bokashi compost prepared from *L. flava* enriched with Epsom salt and sylvinite	500.56	210.53
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and sylvinite	506.79	210.09
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	575.17	299.28
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	523.14	324.37
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	596.91	276.68
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	598.01	328.96
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	576.87	307.54
SEm(±)	1.079	1.101
CD(0.05)	3.126	3.190

Table 17. C:N ratio, fertilizing index and clean index of resultant biomineral enriched (Bokashi) composts

Treatments	C:N ratio	Fertilizing index	Clean index
T_1: Bokashi compost prepared from *L. flava* enriched with calcium apatite	11.92	4.60	5
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	10.09	4.60	5
T_3: Bokashi compost prepared from *L. flava* enriched with Sylvinite	10.78	4.40	5
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite	10.49	4.60	5
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt	10.99	4.40	5
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Sylvinite	11.20	4.40	5
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	10.27	4.60	5
T_8: Bokashi compost prepared from *L. flava* enriched with Epsom salt and Sylvinite	11.00	4.40	5
T_9: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Sylvinite	10.90	4.60	5
T_{10}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	10.49	4.60	5
T_{11}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	10.45	4.60	5
T_{12}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	10.40	4.60	5
T_{13}: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	9.59	5.00	5
T_{14}: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	10.07	4.80	5
SEm(±)	0.234	0.027	
CD(0.05)	0.678	0.078	

4.1.5.2. CO_2 emission

The mean values of CO_2 emission from resultant biomineral enriched (Bokashi) composts are presented in Table 15. It was clear from the data that the composts varied significantly in their CO_2 emission. The mean values of CO_2 emission ranged from 4.04 mg CO_2 g^{-1} to 5.12 mg CO_2 g^{-1}. The highest mean value of 5.12 mg CO_2 g^{-1} was recorded for the compost T_{14} (Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite) which was on par with compost T_{13} (5.09 mg CO_2 g^{-1}). The lowest mean value of 4.04 mg CO_2 g^{-1}) was recorded for compost T_1 which was the Bokashi compost prepared from *L.flava* enriched with calcium apatite.

4.1.5.3. Dehydrogenase activity

Scrutiny of data (Table 16) revealed that dehydrogenase activity varied significantly among different biomineral enriched (Bokashi) composts. The highest value of dehydrogenase activity was recorded for compost T_{13} (Bokashi compost prepared from *L.flava* and was enriched with calcium apatite, epsom salt and sylvinite) with a value of 598.01 µg TPF hydrolysed g^{-1} compost 24 h^{-1} which was on par with T_{12} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite) with a value of 596.91 µg TPF hydrolysed g^{-1} compost 24 h^{-1}. The lowest mean value of 476.76 µg TPF hydrolysed g^{-1} compost 24 h^{-1} was registered for compost T_4 which was the Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite.

4.1.5.4. Cellulase activity

Table 16 presents the cellulase activity of the resultant biomineral enriched Bokashi composts and it was clear that the cellulase activity significantly varied among the composts. The values of cellulase activity ranged between 198.78 µg glucose hydrolysed g^{-1} compost h^{-1} and 328.96 µg glucose hydrolysed g^{-1} compost h^{-1}. The highest mean value of 328.96 µg glucose hydrolysed g^{-1} compost h^{-1} was recorded for the compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which was found to significantly higher than all the other composts. It was found from the data that compost T_6 (Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite) recorded the lowest value of cellulase activity with a mean value of 198.78 µg glucose hydrolysed g^{-1} compost h^{-1}.

4.1.6. C:N ratio

The C:N ratio of the prepared biomineral enriched (Bokashi) composts are presented in Table 17. The mean values of C:N ratio ranged from 9.59 to 11.92. The compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which was found to be on par with compost T_{14} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite) with a value of 10.07 and compost T_2 (Bokashi compost prepared from *L.flava* enriched with epsom salt). The highest value of C:N ratio was reported for compost T_1 (11.92) which was the Bokashi compost prepared from *L.flava* enriched with calcium apatite.

4.1.7. Fertilizing index and clean index

The calculated values of fertilizing index are presented in Table 17. The mean values of fertilizing index ranged from 4.40 to 5.00. The highest mean value of 5.00 was reported for compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite). The second highest value of 4.80 was recorded for T_{14} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite). The lowest mean value was reported for composts T_3 (4.40), T_5 (4.40), T_6 (4.40) and T_8 (4.40).

The calculated clean index values are presented in Table 17. All the composts recorded a value of 5 for clean index.

Based on the selection indices like fertilizing index, available major and minor nutrients, enzyme status and C:N ratio the best seven composts selected are T_2 (Bokashi compost prepared from *L.flava* enriched with epsom salt), T_7(Bokashi compost prepared from *L.flava* enriched with calcium apatite and epsom salt), T_{10}(Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt), T_{11}(Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt and sylvinite), T_{12} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite), T_{13}(Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) and T_{14} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite).

Table 18. Initial soil analysis

Sl no.	Parameters	Content
1	pH (1:2.5)	5.94
2	EC (1:2.5) dSm^{-1}	0.42
3	Available N (kg ha^{-1})	230.45
4	Available P (kg ha^{-1})	36.19
5	Available K (kg ha^{-1})	204.44
6	Exchangeable Ca (mg kg^{-1})	157.61
7	Exchangeable Mg (mg kg^{-1})	15.49
8	Available S (mg kg^{-1})	12.23
9	Micronutrients (mg kg^{-1}) Fe Mn Zn Cu	 19.81 18.64 2.29 0.97
10	Organic carbon	0.63
11	Dehydrogenase (µg of TPF hydrolysed g^{-1} of soil 24 h^{-1})	126.7
12	Cellulase (µg glucose hydrolysed g^{-1} soil h^{-1})	10.87
13	Microbial count Bacteria (log cfu g^{-1} soil) Fungi (log cfu g^{-1} soil) Actinomycetes (log cfu g^{-1} soil)	 6.97 4.62 4.00

4.2. SOIL INCUBATION STUDY FOR EVALUATING THE NUTRIENT RELEASE PATTERN

A soil incubation study was carried out to monitor the nutrient release pattern of best seven biomineral enriched (Bokashi) composts. The sampling was done at 1st, 4th, 8th, 12th and 16th week of incubation and the oganic carbon, available nutrients and enzyme activity were estimated and are presented in Table 19 to 31 and the initial soil analysis is presented in Table 18.

4.2.1. Available nitrogen

The available nitrogen content in soil of laboratory incubation study is presented in Table 19. 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 value of available nitrogen was observed for T_7 (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) for 1st to 8th week of incubation. During 8th week of incubation it was observed that treatment T_8 was on par with T_7. T_8 recorded the highest value during 12th and 16th week of incubation. T_1 (Absolute control) recorded the lowest value throughout the incubation period. The highest mean value was recorded by T_7 (339.70 kg ha^{-1}) during 4th week of incubation.

4.2.2. Available phosphorus

Table 20 presents the available phosphorus content in the soil during incubation study. The data indicated that the available phosphorus content increased up to 4th week of incubation and a drastic reduction can be observed during 8th week of incubation. The available phosphorus content was maximum for T_8 (Bokashi compost prepared from 1:1 mixture of *L.flava* enriched with calcium apatite, epsom salt and sylvinite) throughout the incubation period and the maximum value was recorded (68.77 kg ha^{-1}) during 4th week of incubation. During 8th week of incubation T_8 recorded a value of 57.53 kg ha^{-1} which was on par with T_7 (55.49 kg ha^{-1}). T_1 recorded the lowest value of phosphorus content throughout the incubation period.

Table 19. Changes in available nitrogen content of soil during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	232.89	242.99	229.87	226.75	225.85
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	269.21	307.49	294.07	309.78	303.87
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	265.76	293.72	277.29	274.80	277.41
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	255.08	284.67	277.62	262.41	274.66
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	255.66	277.33	265.97	268.70	261.69
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	259.60	287.74	275.19	285.73	290.45
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	274.37	339.70	319.44	321.74	313.60
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	270.14	327.77	317.53	328.56	340.77
SEm(±)	0.649	0.962	0.816	0.772	0.800
CD(0.05)	1.947	2.883	2.446	2.315	2.399

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

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	41.72	43.51	36.66	39.67	39.98
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	47.47	52.80	44.58	47.70	49.73
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	51.81	55.68	47.74	48.49	52.64
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	54.82	56.58	48.62	51.26	53.13
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	46.76	51.67	41.41	47.16	48.60
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	53.51	59.88	49.65	56.73	54.48
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	54.79	66.42	55.49	57.76	59.40
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	56.43	68.77	57.53	60.58	63.92
SEm(±)	0.451	0.457	0.731	0.412	0.148
CD(0.05)	1.352	1.369	2.193	1.236	0.445

Table 21. Changes in available potassium content (kg ha^{-1}) during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	262.04	282.88	270.78	290.59	278.98
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	278.36	324.56	312.71	328.48	316.25
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	286.59	339.57	312.25	331.37	332.10
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	299.56	358.67	333.36	342.96	338.23
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	322.44	373.47	355.50	366.60	363.20
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	325.51	387.92	359.74	386.99	390.54
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	307.50	370.48	351.76	375.33	382.63
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	319.73	393.08	374.36	399.96	390.21
SEm(±)	1.318	1.749	2.371	2.169	1.203
CD(0.05)	3.952	5.221	7.109	6.503	3.607

Table 22. Changes in exchangeable calcium content (mg kg^{-1}) of soil during incubation

Treatments	1^{st} week	4^{th} week	8^{th} week	12^{th} week	16^{th} week
T_1: Absolute control	168.35	170.51	164.49	151.86	157.53
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	182.46	190.68	180.90	170.54	176.62
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	192.50	207.04	199.36	198.56	193.38
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	196.28	209.89	207.54	198.79	196.95
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	188.44	194.81	185.36	180.58	173.61
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	209.65	238.70	236.28	232.48	226.35
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	196.52	218.67	213.54	202.40	202.19
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	202.66	229.72	224.59	210.68	207.86
SEm(±)	0.572	0.706	0.804	0.694	0.646
CD(0.05)	1.715	2.117	2.410	2.084	1.936

4.2.3. Available potassium

The changes in available potassium content during incubation study is presented in Table 21. During 1st week of incubation the highest value was reported by T_6 (325.51 kg ha^{-1}) with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite, which was on par with T_5 (322.44 kg ha^{-1}). During 4th week of incubation the highest value was recorded by T_8 (Bokashi compost prepared from 1:1 mixture of *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which was on par with T_6. During 8th and 12th week of incubation the highest value was reported by T_8 as 374.36 kg ha^{-1} and 399.96 kg ha^{-1} respectively. During 16th week of incubation the highest value was reported by T_6 (390.54 kg ha^{-1}) which was on par with T_8 (390.21 kg ha^{-1}). The lowest value of potassium content was recorded by T_1 throughout the incubation period. An increasing trend in potassium availability can be observed for all the treatments with maximum value recorded during 12th week of incubation.

4.2.4. Exchangeable calcium

Under laboratory condition the exchangeable calcium content (Table 22) increased up to 4th week of incubation and there after a decline can be observed. The highest value for calcium content was recorded by T_6 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite) throughout the incubation period with the maximum value recorded during 4th week of incubation (238.70 mg kg^{-1}). The lowest value was recorded by T_1 throughout the incubation period.

4.2.5. Exchangeable magnesium

Changes in exchangeable magnesium content due to treatment effects during the incubation period are presented in Table 23. There was a significant difference in magnesium content between treatments at different intervals. The highest value for available magnesium was recorded by T_7 (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) throughout the incubation period. T_2 and T_8 was on par with T_7 throughout the incubation period. The highest value for magnesium was recorded during 16th week of incubation, the maximum value was recorded by T_7 (46.48 mg kg^{-1}) which was on par with T_8 (44.03 mg kg^{-1}) and T_2 (45.64 mg kg^{-1}). The lowest value was recorded by T_1 throughout the incubation period. An increasing trend can be observed for magnesium availability during the incubation period.

4.2.6. Available sulphur

The mean values of available sulphur are presented in Table 24. During first week of incubation the highest value was recorded by T_8 (29.78 mg kg^{-1}) with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite, which was on par with T_3 (28.44 mg kg^{-1}) and T_7 (28.21 mg kg^{-1}). During 4th week of incubation the highest value was recorded by T_7 (38.80 mg kg^{-1}) which was on par with T_3 (37.52 mg kg^{-1}) and T_8 (38.31 mg kg^{-1}). During 8th week of incubation, the highest value was reported by T_8 (29.48 mg kg^{-}1) which was on par with T_3 (27.53 mg kg^{-1}), T_4 (27.03 mg kg^{-1}), T_5 (27.29 mg kg^{-}1) and T_7 (29.28 mg kg^{-1}). During 12th and 16th week of incubation the highest value was recorded by T_8 (35.89 mg kg^{-1} and 38.54 mg kg^{-1}). A sudden decrease in sulphur content could be observed during 8th week of incubation and an increasing trend in sulphur content could be observed thereafter.

4.2.7. Available iron

The mean values for available iron content are presented in Table 25. T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest value during 1st, 4th, 8th, 12th and 16th week of incubation having mean values of 48.39 mg kg^{-1}, 69.54 mg kg^{-1}, 56.96 mg kg^{-1}, 59.15 mg kg^{-1} and 61.65 mg kg^{-1} respectively. The maximum value of available iron content was recorded during 4th week of incubation while lowest value was recorded by T_1 throughout the incubation period.

Table 23. Changes in exchangeable magnesium content (mg kg^{-1}) of soil during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	21.71	23.46	21.27	25.33	29.32
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	33.87	41.53	39.53	44.12	45.64
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	29.00	34.35	32.17	37.66	37.75
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	29.95	36.52	37.59	40.36	40.37
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	28.47	33.58	30.18	35.65	37.53
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	24.80	29.32	27.19	30.27	32.14
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	33.95	43.44	41.74	44.38	46.48
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	33.38	40.54	39.36	42.75	44.03
SEm(±)	0.403	1.301	0.968	0.663	1.009
CD(0.05)	1.209	3.900	2.902	1.988	3.026

Table 24. Changes in available sulphur (mg kg^{-1}) in the soil during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	17.83	20.76	16.78	16.55	17.81
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	22.72	30.58	24.33	25.67	29.97
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	28.44	37.52	27.53	34.09	35.77
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	24.44	34.00	27.03	28.42	31.24
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	22.39	32.49	27.29	31.63	34.57
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	20.88	29.23	20.98	23.90	27.11
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	28.21	38.80	29.28	34.83	37.08
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	29.78	38.31	29.48	35.89	38.54
SEm(±)	0.679	0.902	0.886	0.604	0.811
CD(0.05)	2.035	2.703	2.655	1.810	2.431

4.2.8. Available manganese

The changes in mean values of manganese content during incubation period was presented in Table 26. The highest value of available manganese was recorded by T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite among all the treatments during the 1st (28.32 mg kg^{-1}) and 4th (39.04 mg kg^{-1}) week of incubation. During 8th and 12th week of incubation, T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest value (52.67 mg kg^{-1} and 48.79 mg kg^{-1} respectively). During 16th week of incubation, T_4 recorded the highest value (41.19 mg kg^{-1}) which was on par with T_2 (39.17 mg kg^{-1}), T_3 (37.70 mg kg^{-1}), T_6 (37.75 mg kg^{-1}) and T_8 (39.15 mg kg^{-1}). It was observed that the manganese content was found to be increasing up to 8th week of incubation and a decrease in manganese availability can be observed afterwards.

4.2.9. Available zinc

Table 27 prsents the changes in available zinc content during the incubation period. During the 1st week of incubation the highest value was recorded by T_7 (4.21 mg kg^{-1}) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite, which was on par with T_6 (4.09 mg kg^{-1}) and T_8 (4.13 mg kg^{-1}). During 4th week of incubation the highest value was recorded by T_7 (4.18 mg kg^{-1}) which was on par with T_8 (4.10 mg kg^{-1}). During 8th week of incubation highest value was recorded by T_7 (4.28 mg kg^{-1}) which was on par with T_8 (4.25 mg kg^{-1}). It was observed that T_8 recorded highest value during 12th (5.87 mg kg^{-1}) and 16th (5.63 mg kg^{-1}) week of incubation. A sudden increase in zinc content could be observed in available zinc content during 12th week of incubation.

Table 25. Changes in available iron content (mg kg^{-1}) of soil during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	25.60	26.12	21.17	22.76	20.09
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	38.20	55.17	47.17	42.48	44.77
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	41.47	55.00	48.06	50.65	48.88
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	43.74	55.76	45.94	42.29	47.94
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	45.78	56.31	46.01	48.37	50.19
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	45.89	56.93	50.76	54.17	51.71
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	48.39	69.54	56.96	59.15	61.65
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	45.98	61.94	51.17	52.33	54.35
SEm(±)	0.797	0.537	0.824	1.008	0.721
CD(0.05)	2.390	1.611	2.469	3.022	2.161

Table 26. Changes in available manganese content (mg kg^{-1}) of soil during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	18.47	20.09	22.17	18.16	16.59
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	21.46	34.45	42.29	40.64	39.17
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	24.57	36.19	45.80	41.12	37.70
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	22.49	29.16	44.94	43.65	41.19
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	22.16	29.46	44.16	45.54	37.09
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	23.55	33.50	48.59	41.10	37.75
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite	25.19	36.82	52.67	48.79	36.65
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite , epsom salt and sylvinite	28.32	39.04	52.19	47.72	39.15
SEm(±)	0.494	0.614	0.706	0.621	1.195
CD(0.05)	1.480	1.840	2.118	1.861	3.583

Table 27. Changes in available zinc content (mg kg^{-1}) of soil during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	2.79	2.65	2.71	2.96	2.84
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	3.37	3.31	3.46	4.67	4.58
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	3.87	3.95	4.05	4.78	4.71
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	3.58	3.41	3.60	4.45	4.36
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	3.42	3.37	3.51	4.31	4.25
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	4.09	3.98	4.18	5.25	5.18
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	4.21	4.18	4.28	5.66	5.51
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	4.13	4.10	4.25	5.87	5.63
SEm(±)	0.045	0.026	0.020	0.027	0.027
CD(0.05)	0.135	0.078	0.059	0.080	0.081

Table 28. Changes in available copper content (mg kg^{-1}) of the soil during incubation

Treatments	1^{st} week	4^{th} week	8^{th} week	12^{th} week	16^{th} week
T_1: Absolute control	1.22	1.36	1.19	1.28	1.16
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	1.24	1.66	1.57	1.60	1.54
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	1.28	1.75	1.64	1.68	1.59
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	1.25	1.62	1.53	1.59	1.50
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	1.27	1.71	1.61	1.65	1.63
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	1.28	1.77	1.64	1.68	1.61
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	1.31	1.82	1.69	1.75	1.63
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	1.33	1.85	1.71	1.77	1.74
SEm(±)	0.016	0.018	0.014	0.018	0.009
CD(0.05)	0.047	0.054	0.041	0.054	0.027

4.2.10. Available copper

The available copper content in soil during incubation study is presented in Table 28. The highest value for copper content was reported by T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite throughout the incubation period with values of 1.33 mg kg^{-1}, 1.85 mg kg^{-1}, 1.71 mg kg^{-1}, 1.77 mg $kg^{-1}$and 1.74 mg kg^{-1} during 1^{st}, 4^{th}, 8^{th}, 12^{th} and 16^{th} week of incubation respectively. T_7 was on par with T_8 during 1^{st}, 4^{th}, 8^{th} and 12^{th} week of incubation. An increase in copper content could be observed from 1^{st} to 4^{th} week of incubation for all the treatments while the lowest value was recorded by T_1 throughout incubation period.

4.2.11. Organic carbon

Table 29 shows the mean values of organic carbon content during the different period of incubation. During the first week of incubation, the highest mean value was reported by T_7 (0.92 %) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite, which was on par with T_3 (0.87%), T_6 (0.89%) and T_8 (0.86%). During the 4^{th} week of incubation, the highest value was reported by T_7 (1.15%) which was on par with T_3 (1.10%), T_5 (1.09%), T_6 (1.12%) and T_8 (1.14%). During the 8^{th} week of incubation T_6 (0.99%) and T_7 (0.99%) recorded the highest value for organic carbon content. It was observed that T_7 recorded highest value (1.13%) during 12^{th} week of incubation. During the 16^{th} week of incubation T_7 (1.10%) recorded the highest value which was on par with T_6 (1.07%) and T_8 (1.05%). The lowest value of organic carbon content was recorded by T_1 during the entire period of incubation. It was observed that organic carbon content increased during 4^{th} week of incubation, which decreased during 8^{th} week of incubation.

4.2.12. Dehydrogenase activity

Different treatments significantly influenced the dehydrogenase activity of the soil throughout the incubation study (Table 30). The highest value for dehydrogenase activity was recorded by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite, throughout the incubation period. It was found from the study that T_7 recorded a value of 200.55 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}, 229.67µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}, 198.86 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}, 197.50µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}, 197.90 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1} during 1^{st}, 4^{th}, 8^{th}, 12^{th}, and 16^{th} week of incubation respectively. The dehydrogenase activity was found to be maximum during 4^{th} week of incubation for all the treatments.

4.2.13. Cellulase activity

The cellulase activity of the soil during incubation study is presented in Table 31. During the 1^{st} week of incubation the highest value was reported by T_7 (17.54 µg glucose hydrolysed g^{-1} soil h^{-1}) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite, which was on par with T_8 (17.21µg glucose hydrolysed g^{-1} soil h^{-1}). During the 4^{th} week of incubation the highest value was reported by T_7 (22.49 µg glucose hydrolysed g^{-1} soil h^{-1}) which was on par with T_8 (21.12µg glucose hydrolysed g^{-1} soil h^{-1}) and T_6 (21.74 µg glucose hydrolysed g^{-1} soil h^{-1}). It was found that T_7 (16.98 µg glucose hydrolysed g^{-1} soil h^{-1}) recorded the highest value of cellulase activity during 8^{th} week of incubation which was on par with T_6 (16.48 µg glucose hydrolysed g^{-1} soil h^{-1}) and T_8 (16.53 µg glucose hydrolysed g^{-1} soil h^{-1}). During 12^{th} and 16^{th} week of incubation T_7 recorded the highest value of 17.42 µg glucose hydrolysed g^{-1} soil $h^{-1}$and 17.27 µg glucose hydrolysed g^{-1} soil h^{-1} respectively. It was found from the study that throughout the incubation period T_1 recorded the lowest value of cellulase activity. It was observed that the cellulase activity increased up to 4^{th} week of incubation and then decreased.

Table 29. Changes in organic carbon (%) of soil during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	0.70	0.80	0.68	0.77	0.71
T_2 Bokashi compost prepared from *L. flava* enriched with epsom salt	0.75	1.07	0.89	1.02	0.99
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and epsom salt	0.87	1.10	0.92	0.99	1.00
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and epsom salt	0.83	1.05	0.89	1.04	1.00
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with epsom salt and sylvinite	0.78	1.09	0.85	1.00	0.98
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with calcium apatite and sylvinite	0.89	1.12	0.99	1.09	1.07
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	0.92	1.15	0.99	1.13	1.10
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	0.86	1.14	0.87	1.00	1.05
SEm(±)	0.018	0.015	0.013	0.016	0.017
CD(0.05)	0.061	0.065	0.040	0.051	0.052

Table 30. Changes in dehydrogenase activity of the soil (µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}) during incubation

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	134.40	142.81	122.90	120.87	122.80
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	151.71	167.97	150.76	149.78	143.58
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	151.70	172.20	151.67	151.86	147.97
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	164.67	187.62	163.49	168.16	165.24
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	157.15	178.11	154.78	156.88	157.53
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	177.91	199.52	175.29	176.28	174.51
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	200.55	229.67	198.86	197.50	197.90
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	192.08	221.55	181.91	182.14	178.82
SEm(±)	1.181	1.497	1.377	0.855	0.929
CD(0.05)	3.540	4.489	4.127	2.562	2.784

Table 31. Changes in cellulase activity (µg glucose hydrolysed g^{-1} soil h^{-1}) of soil during incubation period

Treatments	1st week	4th week	8th week	12th week	16th week
T_1: Absolute control	12.42	14.33	12.50	12.56	12.75
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	14.70	16.82	14.59	15.38	16.46
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	15.80	18.57	15.48	15.79	15.67
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	15.55	19.29	15.67	16.46	15.76
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	14.83	17.41	14.74	15.63	15.20
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	16.59	21.74	16.48	16.67	16.50
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	17.54	22.49	16.98	17.42	17.27
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	17.21	21.12	16.53	16.64	16.52
SEm(±)	0.209	0.575	0.301	0.028	0.296
CD(0.05)	0.627	1.723	0.901	0.083	0.628

4.3. FIELD EXPERIMENT FOR EVALUATING THE PERFORMANCE OF BIOMINERAL ENRICHED (BOKASHI) COMPOSTS

Field experiment was carried out using Bhindi var. Anjitha as test crop followed by Amaranthus var. Arun as residual crop for evaluating the performance of biomineral enriched (Bokashi) composts.

4.3.1. Postharvest soil analysis

The postharvest soil was analysed for chemical, electro chemical and biological properties.

4.3.1.1. pH

Imposition of treatments had a significant effect on the pH of the soil (Table 32). The mean values ranged from 5.99 to 6.39. T_8 with the application of Bokashi compost prepared from 1:1 mixture of banana pseudostem and epsom salt enriched with calcium apatite, epsom salt and sylvinite registered the highest mean value of 6.39 which was on par with T_7 (6.36). The lowest mean value for pH was recorded by T_9.

4.3.1.2. Electrical conductivity

Critical appraisal of the data (Table 32) shows that treatment had influenced the electrical conductivity of the postharvest soil. The mean values ranged from 0.84 dSm^{-1} to 1.16 dSm^{-1}. Treatment T_9 (1.16 dSm^{-1}) with the application of KAU POP recommendation recorded the highest value of electrical conductivity, while the lowest value was recorded by T_1 (0.84 dSm^{-1}) which was significantly lower than all other treatments.

4.3.1.3. Organic carbon

The results revealed that the applied treatments had a significant influence on the organic carbon content of the postharvest soil (Table 33). The highest mean value for organic carbon was recorded by T_7 (1.14 %) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite and the lowest mean value was recorded by T_1 (0.75%) which was absolute control.

4.3.1.4. Available Nitrogen

Various treatments had significantly influenced the available nitrogen content in the postharvest soil as observed from Table 33. The highest mean value for nitrogen content was recorded by T_7 (319.86 kg ha^{-1}) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. The lowest value for available nitrogen was recorded by T_1 which was significantly inferior than all other treatments.

4.3.1.5. Available phosphorus

It was inferred from Table 33 the mean values of available phosphorus ranged from 34.58 kg ha^{-1} to 91.65 kg ha^{-1}. The highest value was recorded by T_8 (91.65 kg ha^{-1}) with the application of Bokashi compost prepared from 1:1 mixture of banana pseudostem and epsom salt enriched with calcium apatite, epsom salt and sylvinite and was found to be on par with T_7 (88.59 kg ha^{-1}) and T_6 (89.67 kg ha^{-1}). The lowest mean value for available phosphorus was recorded by T_1 (34.58 kg ha^{-1}).

4.3.1.6. Available potassium

Various treatments significantly influenced the available phosphorus content of the soil (Table 33). The mean values of available potassium content ranged from 197.66 kg $ha^{-1}$to 273.91 kg ha^{-1}. The highest value of 273.91 kg ha^{-1} was recorded by T_6 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite which was on par with T_8 (270.60 kg ha^{-1}). The lowest mean value of 197.66 kg ha^{-1} was recorded by T_1 (absolute control).

Table 32. Effect of treatments on electrochemical properties of postharvest soil

Treatments	pH	EC (dS m^{-1})
T_1: Absolute control	6.09	0.84
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	6.24	0.89
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	6.31	0.93
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	6.21	1.01
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	6.27	0.97
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	6.19	0.91
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	6.36	0.87
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	6.39	0.96
T_9: KAU POP recommendation	5.99	1.16
SEm(±)	0.012	0.023
CD(0.05)	0.035	0.070

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 33. Effects of treatments on available nutrient status in postharvest soil

Treatments	Organic carbon (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1: Absolute control	0.75	221.82	34.58	197.66
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	1.09	271.64	74.41	229.47
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	1.04	264.59	86.40	240.56
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	1.00	250.71	85.32	248.59
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	0.96	287.44	79.67	252.04
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	1.01	291.19	89.67	273.91
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	1.14	319.86	88.59	250.63
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	1.11	302.35	91.65	270.60
T_9: KAU POP recommendation	0.97	277.57	76.52	259.57
SEm(±)	0.018	3.078	0.723	3.457
CD(0.05)	0.054	9.228	2.168	10.365

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

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

Treatments	Calcium	Magnesium	Sulphur
T_1: Absolute control	218.59	20.50	11.69
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	280.56	42.54	17.32
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	305.39	40.63	16.38
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	316.69	37.46	16.94
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	277.09	33.61	20.48
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	342.48	32.44	15.46
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	314.55	33.47	21.29
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	321.66	45.83	19.61
T_9: KAU POP recommendation	287.79	36.45	16.45
SEm(±)	2.871	0.537	0.495
CD(0.05)	8.608	1.611	1.484

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 35. Effect of treatments on micronutrient and heavy metal status in postharvest soil (mg kg^{-1})

Treatments	Fe	Mn	Zn	Cu	B	Cd	Pb	Ni	Cr
T_1: Absolute control	20.40	15.32	2.97	1.20	0.368	BDL	BDL	BDL	BDL
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	39.08	20.46	3.92	1.56	0.528	BDL	BDL	BDL	BDL
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	41.76	22.02	3.87	1.36	0.664	BDL	BDL	BDL	BDL
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	41.17	19.05	3.68	1.51	0.656	BDL	BDL	BDL	BDL
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	43.85	19.22	2.97	1.28	0.576	BDL	BDL	BDL	BDL
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	46.17	23.05	3.21	1.29	0.744	BDL	BDL	BDL	BDL
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	48.54	23.40	4.79	1.88	0.832	BDL	BDL	BDL	BDL
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	46.86	25.62	4.24	1.76	0.472	BDL	BDL	BDL	BDL
T_9: KAU POP recommendation	33.32	22.62	3.71	1.61	0.592	BDL	BDL	BDL	BDL
SEm(±)	0.676	0.498	0.035	0.012	0.008				
CD(0.05)	2.026	1.493	0.106	0.035	0.024				

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

(BDL-Below Detectable Level).

4.3.1.7. Exchangeable calcium

Table 34 shows that there was a significant change in calcium content of postharvest soil due to different treatments. The mean values of exchangeable calcium ranged from 218.59 mg kg^{-1} to 342.48 mg kg^{-1}.The highest mean value was recorded by T_6 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite) with a value of 342.48 mg kg^{-1} which was significantly superior than all other treatments whilw the lowest mean value was reported by T_1 (218.59) absolute control.

4.3.1.8. Exchangeable magnesium

A perusal of the data revealed that there was a significant difference in magnesium content of postharvest soil (Table 34). The highest mean value of magnesium was recorded by T_8 with a mean value of 45.83 mg kg^{-1} and the lowest mean value was reported by T_1 with a mean value of 20.50 mg kg^{-1} which was significantly inferior than all other treatments.

4.3.1.9. Available sulphur

Various treatments significantly influenced the available sulphur content of the postharvest soil (Table 34). The highest mean value of available sulphur was reported by T_7 with a value of 21.29 mg kg^{-1}. T_5 recorded a value of 20.48 mg kg^{-1} which was on par with T_7. The lowest value of available sulphur was reported by T_1 (11.69 mg kg^{-1}) which was significantly lower than all other treatments.

4.3.1.10. Available iron

Table 35 reveals that there was significant difference due to treatments on iron content in postharvest soil. Mean values ranged from 20.40 mg kg^{-1} to 48.54 mg kg^{-1}. The highest value was recorded by T_7 (48.54 mg kg^{-1}) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was on par with T_8 with a value of 46.86 mg kg^{-1} while the lowest value was reported by T_1 (20.40 mg kg^{-1}).

4.3.1.11. Available manganese

Various treatments influenced manganese content of postharvest soil (Table 35). As per the data T_8 (25.62 mg kg^{-1}) with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was found to be highly significant than the rest of the treatments. The absolute control registered the lowest value for manganese content (15.32 mg kg^{-1}).

4.3.1.12. Available copper

Copper concentration in postharvest soil was significantly influenced by different treatments (Table 35). The mean values of copper content ranged from 1.88 mg kg^{-1} to 1.20 mg kg^{-1}. It was observed from the data that T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the value of 1.88 mg kg^{-1} which was significantly superior than all the other treatments. The lowest value was reported by T_1 (1.20 mg kg^{-1}) which was significantly lower than all the other treatments.

4.3.1.13. Available zinc

Table 35 represents the zinc concentration in the postharvest soil. The mean values of zinc ranged from 2.97 mg kg^{-1} to 4.79 mg kg^{-1}. The highest value of 4.79 mg kg^{-1} was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite and was significantly different from all other treatments. The lowest value of zinc content was reported by T_1 which was significantly lower than all the other treatments.

4.3.1.14. Available boron

A perusal of the data revealed that there was a significant difference in boron content of postharvest soil (Table 35). The highest mean value for boron content was registered by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite with a mean value of 0.832 mg kg^{-1} which was significantly higher than all the treatments. The lowest value was reported by T_1 with a mean value of 0.368 mg kg^{-1} which was significantly lower than all the treatments.

4.3.1.15. Heavy metal content

The heavy metal content of post harvest soil is presented in Table 35. The heavy metal content (Cd, Pb, Ni and Cr) were found to be below detectable level for all the treatments.

4.3.1.16. Dehydrogenase activity

It was observed from the Table 36 that all the treatments were found to impose significant effects with respect to dehydrogenase activity. The mean values of dehydrogenase activity ranged from 138.74 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1} to 302.68 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}. The highest value was recorded for treatment T_8 (302.68 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}) with application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The second highest value for dehydrogenase activity was registered by T_7 (296.58) which was on par with the highest value. However the absolute control plot recorded the lowest value for the dehydrogenase activity (138.74 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}) which was significantly lower than all other treatments.

4.3.1.17. Cellulase activity

The mean values of cellulase activity ranged from 25.67 µg glucose hydrolysed g^{-1} soil h^{-1} to 45.53 µg glucose hydrolysed g^{-1} soil h^{-1} (Table 36). The highest value for cellulase activity was noticed for T_7 (45.53 µg glucose hydrolysed g^{-1} soil h^{-1}) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which significantly higher than all other treatments. The lowest value was registered by T_1 (Absolute control) with 25.67 µg glucose hydrolysed g^{-1} soil h^{-1} which was significantly lower than all other treatments.

4.3.2. Rhizosphere soil analysis

The rhizosphere soil was analysed for properties like microbial load, soil respiratory activity, microbial biomass carbon, glomalin, humic acid and fulvic acid and the results are depicted in Table 37 and 38.

4.3.2.1. Microbial biomass carbon

The microbial biomass carbon expressed in rhizosphere soil showed significant difference due to treatments (Table 37). The highest value for microbial biomass carbon was registered by treatment T_7 with a value of 91.14 mg kg^{-1} soil. T_8 (89.75 mg kg^{-1} soil), T_6 (87.03 mg kg^{-1} soil) and T_5 (86.12 mg kg^{-1} soil) was found to be on par with T_7. It was found from the data that T_1 (73.64 mg kg^{-1} soil) reports the lowest value of microbial biomass carbon.

4.3.2.2. Glomalin

Application of different treatments significantly influenced the glomalin content of the rhizosphere soil (Table 37). The mean values of glomalin ranged from 6.52 mg g^{-1} to 14.27 mg g^{-1}. It was found from the data that highest value of glomlin content was registerd by T_7 (14.27 mg g^{-1}) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. The second highest value was reported by T_8 with a value of 14.08 mg g^{-1} and third highest value was reported by T_6 with a value of 13.88 mg g^{-1}. Both T_6 and T_8 were found to be on par with T_7. The lowest recorded value of 6.52 mg g^{-1} was registered by T_1 (Absolute control) which was significantly lower than all the other treatments.

4.3.2.3. Humic acid

Various treatments significantly influenced the humic acid content of rhizosphere soil (Table 37). The highest mean value for humic acid was reported by T_7 (9.21%) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was significantly

Table 36. Effect of treatments on the enzyme activity in postharvest soil

Treatments	Dehydrogenase (µg of TPF hydrolysed g^{-1} of soil 24 h^{-1})	Cellulase (µg glucose hydrolysed g^{-1} soil h^{-1})
T_1: Absolute control	138.74	25.67
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	230.45	35.37
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	236.59	33.18
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	246.09	37.33
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	234.23	36.54
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	279.43	40.76
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	296.58	45.53
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	302.68	42.77
T_9: KAU POP recommendation	206.35	29.33
SEm(±)	2.916	0.629
CD(0.05)	8.742	1.887

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 37. Effect of treatments on the microbial biomass carbon, glomalin, humic acid and fulvic acid content in rhizosphere soil

Treatments	Microbial biomass carbon (mg kg^{-1} soil)	Glomalin (mg g^{-1})	Humic acid (%)	Fulvic acid (%)
T_1: Absolute control	73.64	6.52	3.08	4.91
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	82.77	10.04	7.60	8.16
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	83.45	11.34	7.80	8.02
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	83.47	13.53	7.42	8.59
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	86.12	10.65	5.34	7.09
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	87.03	13.88	7.51	8.30
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	91.14	14.27	9.21	9.98
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	89.75	14.08	8.19	9.24
T_9: KAU POP recommendation	80.83	7.76	4.20	5.21
SEm(±)	2.443	0.238	0.079	0.386
CD(0.05)	7.324	0.715	0.236	1.156

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 38. Effect of treatments on the microbial load and respiratory activity in rhizosphere soil

Treatments	Bacteria (log cfu g^{-1} soil)	Fungi (log cfu g^{-1} soil)	Actinomycetes (log cfu g^{-1} soil)	Soil respiration (mg CO_2 g^{-1})
T_1: Absolute control	7.47	4.81	4.69	2.27
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	7.60	5.20	5.11	3.27
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	7.69	5.35	4.90	3.35
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	7.74	5.27	5.02	3.63
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	7.60	5.34	4.90	3.61
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	7.69	5.46	5.14	3.74
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	7.77	5.52	5.16	4.17
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	7.90	5.46	5.06	4.03
T_9: KAU POP recommendation	7.54	5.00	4.87	3.17
SEm(±)	0.002	0.009	0.011	0.021
CD(0.05)	0.006	0.028	0.034	0.062

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 39. Effect of treatments on microbial respiratory quotient of rhizosphere soil and V_{max} and K_m of dehydrogenase activity (µg of TPF hydrolysed g^{-1} of soil 24 h^{-1})

Treatments	Microbial respiratory quotient	V_{max}	K_m
T_1: Absolute control	30.8	2.57×10^{-3}	1.23×10^{-4}
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	39.5	4.59×10^{-3}	2.19×10^{-4}
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	40.1	4.61×10^{-3}	2.20×10^{-4}
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	43.4	6.43×10^{-3}	3.11×10^{-4}
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	41.9	5.61×10^{-3}	2.68×10^{-4}
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	42.9	6.12×10^{-3}	2.96×10^{-4}
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	46.4	7.92×10^{-3}	4.01×10^{-4}
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	44.0	7.23×10^{-3}	3.98×10^{-4}
T_9: KAU POP recommendation	39.2	3.81×10^{-3}	1.88×10^{-4}
SEm(±)	1.107	0.030	0.010
CD(0.05)	3.319	0.091	0.031

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

higher than all the other treatments while the lowest value of 3.08 % was recorded by T_1 (Absolute control).

4.3.2.4. Fulvic acid

It was clear from the Table 37 that the fulvic acid content was significantly influenced by different treatments. The mean values of fulvic acid content ranged from 4.91% to 9.98%. The highest mean value of 9.98% was recorded by the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (T_7) and this value was found to be on par with T_8 (9.24%) the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The lowest mean value was recorded for T_1 (absolute control) with a value of 4.91% which was found to be significantly different from all the other treatments.

4.3.2.5. Microbial load

Table 38 shows the microbial population of rhizosphere soil.

Bacterial population was found to be higher for T_8 (7.90 log cfu g^{-1} soil) which was significantly higher than all the other treatments. The lowest value of bacterial population was registered by T_1 (7.47 log cfu g^{-1} soil) which was absolute control.

In case of population of fungi in the rhizosphere, T_7 recorded the highest value (5.52 log cfu g^{-1} soil) which was significantly higher than all the other treatments and the lowest value was reported by T_1 with a value of 4.81 log cfu g^{-1} soil.

It was observed from the Table 38 that treatments have a significant effect on the actinomycetes population of rhizosphere. The mean values ranged from 4.69 log cfu g^{-1} soil to 5.16 log cfu g^{-1} soil. Highest mean value was recorded by T_8 (5.16 log cfu g^{-1} soil) with Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite application. It was also observed from the data that T_7 (5.14 log cfu g^{-1} soil) had the second highest value which was on par with T_8.

4.3.2.6. Soil respiratory activity

Soil respiratory activity of rhizosphere soil varied significantly from different treatments (Table 38). T_7 (4.17 mg CO_2 g^{-1}) with the application of Bokashi compost prepared from *L.flava* which was enriched with calcium apatite, epsom salt and sylvinite recorded the highest value which was found to be significantly higher than all the other treatments. It was noticed that T_1 (Absolute control) recorded the lowest value of 2.27 mg CO_2 g^{-1}.

4.3.3. Calculation of microbial respiratory quotient

Microbial respiratory quotient for treatments were calculated and are presented in Table 39. The mean values for microbial respiratory quotient ranged from 30.8 to 46.4. The highest value of microbial respiratory quotient was registered by T_7 (46.4) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was on par with T_8 with a value of 44 and T_4 with a value of 43.4 while the lowest mean value of 30.8 was registered by T_1 (Absolute control).

4.3.4. Calculation of enzyme kinetics (V_{max} and K_m) of dehydrogenase

It was observed from data presented in Table 39 the values of V_{max} with respect to dehydrogenase activity ranged from 2.57×10^{-3} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1} to 7.92×10^{-3} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}. The highest value of V_{max} was registered by T_7 (7.92×10^{-3} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was significantly higher than all the other treatments while the lowest value of V_{max} was registered by T_1(Absolute control) with a value of from 2.57×10^{-3} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}.

In case of K_m values for dehydrogenase as observed from Table 39, the values ranged from 1.23×10^{-4} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1} to 4.01 ×

10^{-4} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}. The highest value of 4.01 × 10^{-4} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1} was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. The second highest value was registered by T_8 (3.98 × 10^{-4} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}) which was on par with the highest value. The lowest value of K_m was reported for T_1 (1.23 × 10^{-4} µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}).

4.3.5. Biometric observations of bhindi

The biometric observations of bhindi var. Anjitha were recorded and presented in Table 40 to 42.

4.3.5.1. Root weight

The treatments were varied significantly with respect to root weight as inferred from Table 40. The highest value of root weight was recorded by T_8 (40.09g) with the application of Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. It was clear from the data that T_7 (37.67g) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite was on par with the T_8. The least value for root weight was observed in T_1 (19.85g) which was absolute control.

4.3.5.2. Root volume

The critical appraisal of the data revealed that the root volume varied significantly with the treatments (Table 40). The highest value of root volume was reported by T_7 (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) with a value of 44.61 cm^3 which was found to be on par with T_8 with a value of 40.88 cm^3. It was found from the data that T_1 (21.51cm^3) absolute control have the least value of root volume which significantly lower than all the other treatments.

4.3.5.3. Days to germination

A perusal of the data in Table 41 shows that treatments did not vary significantly with respect to days to germination. The mean values of days to germination varied from 4.00 days to 6.33 days.

4.3.5.4. Plant height at first harvest

Treatment application significantly influenced the plant height at first harvest (Table 41). The highest mean value was recorded by T_7 with a mean value of 74.43 cm followed by T_8 (70.37 cm), T_6 (68.57 cm), T_4 (65.73 cm) and T_9 (60.43 cm) which was found to be on par with each other. The lowest value was recorded by T_1 which was significantly lower than all the other treatments.

4.3.5.5. Internodal length at final harvest

After statistically analysing the data, the internodal length revealed that the treatments varied significantly (Table 41). The mean values ranged from 3.93 cm to 12.27 cm with the highest value recorded by T_7 (12.27 cm). It was observed that T_7 was followed by T_8 (10.72 cm), T_9 (9.45 cm) and T_6 (9.28 cm) which were on par with each other. The least value of internodal length was reported by T_1 (3.93 cm) which was significantly lower than all the other treatments.

4.3.5.6. Number of branches at final flowering

The number of branches at final flowering varied significantly with treatments (Table 42). It was found from the data that T_7 (3.33) recorded the highest value with the application of Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt and sylvinite which was significantly superior than all the other treatments and the lowest value of 1.33 branches was recorded by T_1 (Absolute control).

Table 40. Effect of treatments on the root weight and root volume of bhindi var. Anjitha

Treatments	Root weight (g)	Root volume (cm^3)
T_1: Absolute control	19.85	21.51
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	33.85	31.32
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	34.83	30.72
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	35.31	33.63
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	36.04	31.48
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	35.15	30.78
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	37.67	44.61
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	40.09	40.88
T_9: KAU POP recommendation	28.63	30.66
SEm(±)	1.338	2.326
CD(0.05)	4.011	6.973

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 41. Effect of treatments on days to germination, plant height at first harvest and intermodal length at final harvest of bhindi var. Anjitha

Treatments	Days to germination	Plant height at first harvest (cm)	Internodal length at final harvest (cm)
T_1: Absolute control	6.33	32.63	3.93
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	5.33	56.50	8.40
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	4.67	56.53	8.57
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	5.33	65.73	6.67
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	4.67	57.67	9.03
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	5.00	68.57	9.28
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	4.33	74.43	12.27
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	4.00	70.37	10.72
T_9: KAU POP recommendation	5.67	60.43	9.45
SEm(±)	1.321	4.676	1.011
CD(0.05)	NS	14.018	3.031

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

(NS – Not Significant)

Table 42. Effect of treatments on number of branches at final flowering and dry matter production of bhindi var. Anjitha

Treatments	Number of branches at final flowering	Dry matter production (t ha^{-1})
T_1: Absolute control	1.33	1536.60
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	2.33	2614.47
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	2.00	2779.74
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	2.66	3209.49
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	2.00	2871.49
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	2.33	3296.46
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	3.33	3547.80
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	3.00	3334.28
T_9: KAU POP recommendation	2.33	2644.67
SEm(±)	0.007	46.649
CD(0.05)	0.020	139.855

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 43. Effect of treatments on days to first flowering and days to 50% flowering of bhindi var. Anjitha

Treatments	Days to first flowering	Days to 50% flowering
T_1: Absolute control	38.00	43.33
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	34.00	38.00
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	35.67	36.67
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	36.00	38.00
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	37.33	39.67
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	36.67	38.00
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	30.67	37.00
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	31.00	38.33
T_9: KAU POP recommendation	35.33	40.33
SEm(±)	0.830	0.526
CD(0.05)	2.487	1.576

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

4.3.5.7. Dry matter production

There was significant difference among treatments with respect to dry matter production (Table 42). The mean values of dry matter prepared ranged from 1536.60 t ha^{-1} and 3547.80 t ha^{-1}. The highest value was registered by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was significantly higher than all the other treatments. The lowest recorded mean value of 1536.60 t ha^{-1} was recorded by T_1 (Absolute control).

4.3.6. Yield attributes of bhindi

The yield characters of bhindi var. Anjitha was recorded and presented in Table 43 to 45.

4.3.6.1. Number of days to first flowering

The treatment imposed significant difference in case of days to first flowering (Table 43). The mean values ranged from 30.67 days to 38.00 days. The highest mean value was reported by T_1 (38.00 days) which was on par with T_3 (35.67 days), T_4 (36.00 days), T_5 (37.33 days) and T_6 (36.67 days). It was noticed from the data that the lowest value for days to first flowering was reported by T_7 (30.67) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite.

4.3.6.2. Number of days to 50% flowering

Critical appraisal of the data (Table 43) revealed that the treatments had significantly influenced the days to 50% flowering. It was clear from the data that T_1 (Absolute control) had the highest value for days to 50% flowering and the lowest value was reported by T_3 (36.67 days) with the application of Bokashi compost prepared from *L.flava* enriched with epsom salt which was on par with T_2 (38 days), T_4(38 days), T_6(38 days), and T_7 (37 days).

4.3.6.3. Number of fruits per plant

The treatment imparted significant effect on the number of fruits per plant (Table 44). The mean values ranged from 15.33 to 30.67. The highest value was reported by T_7 (30.67) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite followed by T_8 (29.67), T_5 (28.33) and T_6 (27.33) which were on par with each other. The lowest value was recorded by T_1 (absolute control) with a mean value of 15.33.

4.3.6.4. Fruit length

Statistical analysis of the data showed that the fruit length was significantly influenced by different treatments (Table 44). The highest mean value of fruit length was registered by T_7 (23.81 cm) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was found to be significantly different than all the other treatments. The lowest mean value was recorded by T_1 (11.77 cm) which was the absolute control.

4.3.6.5. Fruit girth

Table 44 shows the effect of treatments on the fruit girth and it was inferred that treatments significantly influenced the fruit girth. The mean values ranged from 3.02 cm to 5.06 cm. The highest mean value of 5.06 cm was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was on par with T_8 (4.97 cm), T_6 (4.73 cm) and T_9 (4.67 cm). It was observed that treatment T_1 which was the absolute control, recorded the lowest value of 3.02 cm.

4.3.6.6. Yield per plant

Imposition of treatments had significant influence in the yield per plant (Table 45). The mean values ranged from 316.62 g to 570.42 g. The maximum mean value of 570.42 g was registered by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was found to be significantly superior than all the other treatments.

The lowest value for yield per plant was reported by T_1 (316.62g) which was the absolute control.

4.3.6.7. Yield

Statistical analysis of the data presented in Table 45 shows that treatments have a significant influence on the yield of bhindi var. Anjitha. The mean values of yield ranged from 11.22 t ha^{-1} to 21.05 t ha^{-1}. It was observed that T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite registered the highest value of yield and was significantly different from all the other treatments. The lowest yield of 11.22 t ha^{-1} was reported by T_1 which was the absolute control.

4.3.7. B:C ratio

B:C ratio was calculated for each treatments and are presented in Table 46, critical appraisal of which implied that treatments had a significant influence on the B:C ratio.It was noted that the mean values ranged from 1.01 to 2.26. The highest value was reported by T_7 while the lowest value was reported by T_1.

4.3.8. Scoring of pest and diseases

Occurrence of Bhindi Yellow Vein mosaic was noticed during the initial stages of cultivation which was effectively managed using nimbicidin (2%) and pseudomonas (2% solution).

4.3.9. Yield of residual crop

Perusal of data (Table 47) indicates that different treatments have a significant influence on the yield of residual crop amaranthus var. Arun. The maximum yield of 130.23 kg ha^{-1} was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was significantly higher than all the other treatments. The lowest mean value of 23.03 kg ha^{-1} was reported by T_1 absolute control which was significantly lower than all the other treatments.

Table 44. Effect of treatments on number of fruits per plant, fruit length and fruit girth of bhindi var. Anjitha

Treatments	Number of fruits per plant	Fruit length (cm)	Fruit girth (cm)
T_1: Absolute control	15.33	11.77	3.02
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	26.33	17.58	3.80
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	25.67	19.94	3.70
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	26.33	19.65	3.40
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	28.33	19.79	4.03
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	27.33	18.92	4.73
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	30.67	23.81	5.06
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	29.67	20.43	4.97
T_9: KAU POP recommendation	26.33	19.53	4.67
SEm(±)	0.871	1.001	0.259
CD(0.05)	2.612	3.002	0.776

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 45. Effect of treatments on yield per plant and total yield of bhindi var. Anjitha

Treatments	Yield per plant (g)	Yield (t ha^{-1})
T_1: Absolute control	316.62	11.22
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	451.45	16.51
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	486.42	17.78
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	459.07	16.84
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	475.51	17.65
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	462.69	17.11
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	570.42	21.05
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	524.78	18.91
T_9: KAU POP recommendation	472.46	17.59
SEm(±)	14.018	0.688
CD(0.05)	42.026	2.062

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 46. Effect of treatment on the BC ratio

Treatments	B:C ratio
T_1: Absolute control	1.01
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	1.78
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	1.92
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	1.65
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	1.73
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	1.68
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	2.26
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	2.21
T_9: KAU POP recommendation	1.69
SEm(±)	0.013
CD(0.05)	0.040

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

Table 47. Effect of treatments on the yield of residual crop amaranthus var. Arun

Treatments	Amaranthus yield ($kg\ ha^{-1}$)
T_1: Absolute control	23.03
T_2 Bokashi compost prepared from *L. flava* enriched with Epsom salt	53.17
T_3: Bokashi compost prepared from *L. flava* enriched with calcium apatite and Epsom salt	57.50
T_4: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Epsom salt	80.97
T_5: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Epsom salt and Sylvinite	51.00
T_6: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite and Sylvinite	85.93
T_7: Bokashi compost prepared from *L. flava* enriched with calcium apatite, Epsom salt and Sylvinite	130.23
T_8: Bokashi compost prepared from 1:1 mixture of *L. flava* and banana pseudostem enriched with Calcium apatite , Epsom salt and Sylvinite	127.11
T_9: KAU POP recommendation	57.93
SEm(±)	1.006
CD(0.05)	3.016

From treatment T_2 to T_9 FYM was applied at a rate of 20 t ha^{-1}. From treatment T_2 to T_8 Bokashi compost was supplemented on N equivalent basis supplementing KAU POP recommendation and the remaining doses of P&K is supplemented in the form of Single Super Phosphate and Muriate of Potash.

5. DISCUSSION

An experiment entitled “Biomineral enriched composts (Bokashi) – A tool for enhancing nutrient availability and enzyme activity in rhizosphere” was conducted during 2021-22 at College of Agriculture, Vellayani. The study involved in the production and characterization of biomineral enriched (Bokashi) composts, soil incubation study for evaluating the nutrient release pattern of selected composts and a field experiment using bhindi as main crop and amaranthus as test crop.

The results pertaining to the study are discussed in this chapter.

5.1. PRODUCTION AND CHARACTERIZATION OF BIOMINERAL ENRICHED (BOKASHI) COMPOSTS FROM DIFFERENT ORGANIC SOURCES

The nutrient analysis of substrates used for the production of Bokashi composts showed that aquatic weed *L.flava* had highest values for all the nutrients except potassium and boron content. Similar results of high nitrogen, phosphorus and organic carbon content of *L.flava* compared to banana pseudostem was observed by Anushma (2014). The highest nutrient content of aquatic weed *L.flava* might be due to the accumulation of nutrients from wet land ecosystems. Species of plant and time of year influence the nutrient content of the aquatic weeds like *L.flava* (Sutton and Portier, 1998). A high content of potassium in banana pseudostem was observed compared to *L.flava*. Similarly higher values of potassium in banana pseudostem was reported by Li *et al.* (2010), Saibaba *et al.* (2013) and Kinekar (2011).

The content of all the nutrients except potassium and boron of Bokashi compost produced from *L.flava* was found to be higher than the Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem. This might be due to the nutrient characteristics of the substrates. Kalemelawa *et al.* (2012) observed an increase in potassium content of the composts by the addition of banana peel. Mahalakshmi and Naveena (2016) observed that the fermented banana pseudostem liquid contains high amount of potassium which can be used as a liquid potassic biofertilizer.

It was observed that the total carbon content of organic waste decreased after composting through Bokashi Technology while total nitrogen content was found to be increased. This can be explained on the basis that decomposition of organic matter results in substantial amount of weight loss particularly of total carbon through loss of carbon in respiration as compared to lesser amount of weight loss of total nitrogen content (Goyal *et al*., 2005).

The increased nutrient content of Bokashi composts compared to the initial raw materials might be due to the decrease in overall biomass content during composting. Unlike conventional composting during Bokashi fermentation, most of the nutrients locked in the solid phase thus reducing its loss (Alattar *et al.,* 2016).

The prepared Bokashi composts were enriched with minerals at different combinations. The physical, electro chemical, chemical, proximate constituents and biological properties of the produced biomineral enriched (Bokashi) composts were analysed as per standard procedures.

5.1.1. Physical properties of the resultant biomineral enriched (Bokashi) compost

The physical properties of the produced biomineral enriched (Bokashi) composts like colour, water holding capacity, bulk density and moisture content were analysed.

All the produced biomineral enriched (Bokashi) composts were dark brown in colour (Table 8). Venugopal (2004) has also reported that a deep dark brown colour indicates the quality of the composts.

The water holding capacity was found to be higher for Bokashi compost prepared from *L.flava* and enriched with calcium apatite, epsom salt and sylvinite (T_{13}) which was found to be on par with T_8, T_3, T_9, T_2, T_1 and T_7 (Fig 4). The highest values of water holding capacity was observed for Bokashi composts prepared from

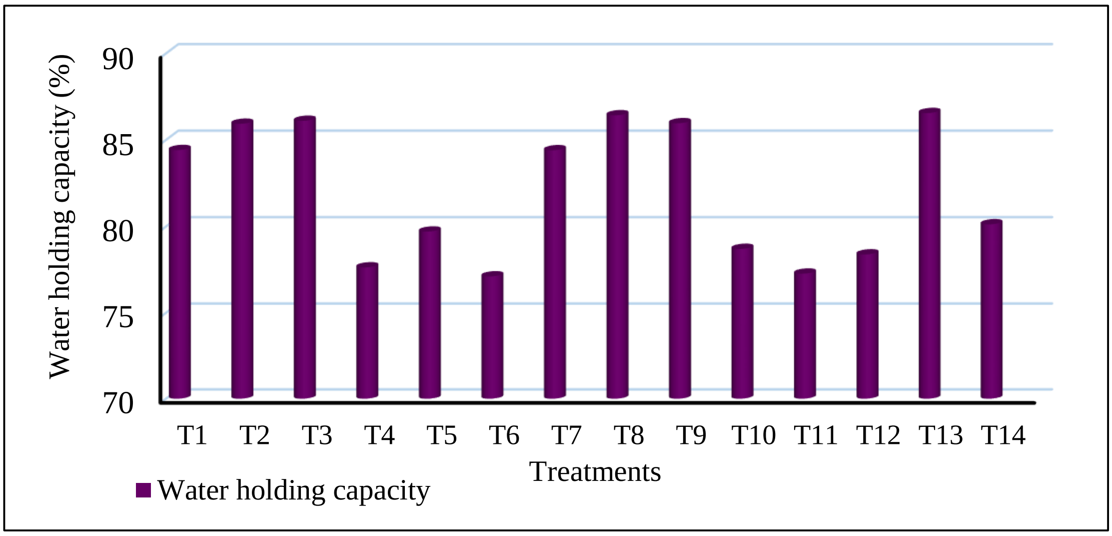


Fig 4. Water holding capacity (%) of the resultant bio mineral enriched

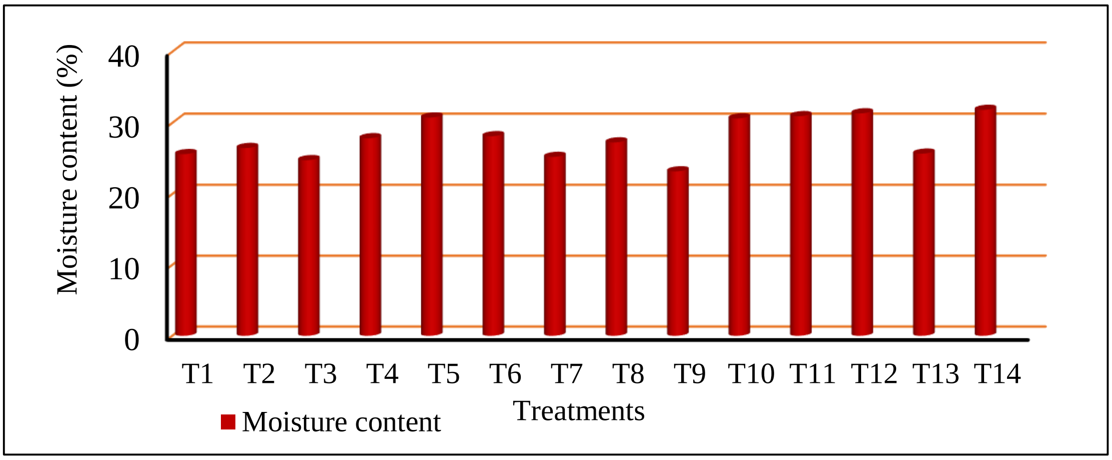


Fig 5. Moisture content (%) of the resultant bio mineral enriched (Bokashi) composts

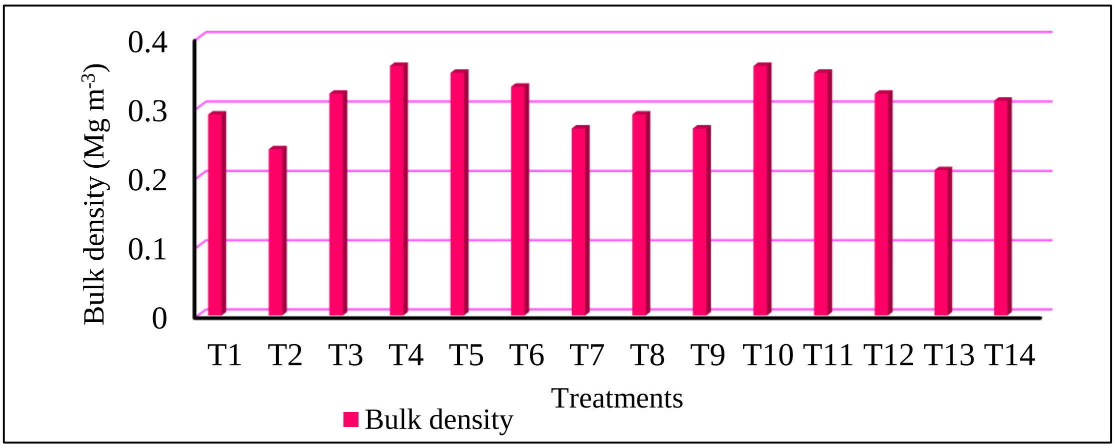


Fig 6. Bulk density (Mg m^{-3}) of the resultant bio mineral enriched (Bokashi) composts

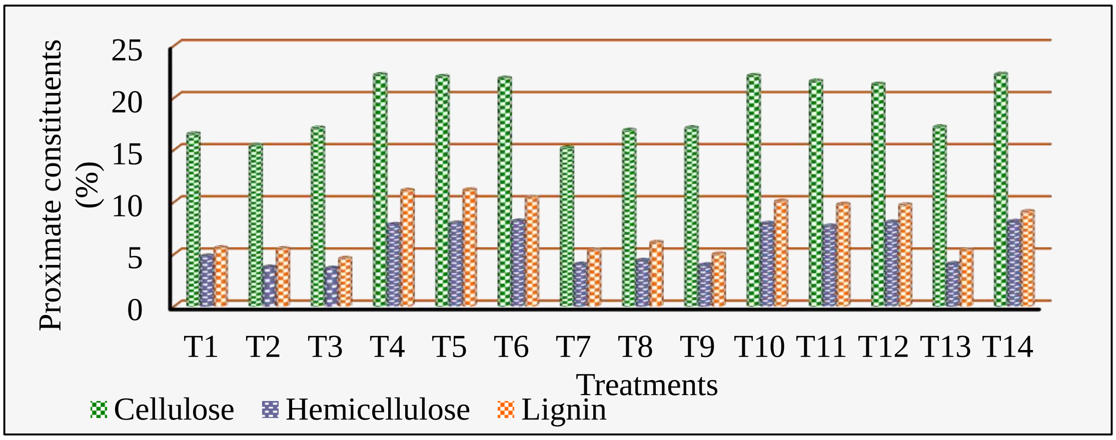


Fig 7. Proximate constituents lignin, cellulose and hemicellulose content (%) of resultant biomineral enriched (Bokashi) composts

L.flava. Although the particle size and the proportion of macro and micro pores was not analysed in the study, characteristics related to particle size directly might have influenced the water retention capacity of the composts (Werdin *et al.,* 2021).

The moisture content values of produced biomineral (Bokashi) composts ranged from 23.19 % to 31.83 % (Fig 5). Adhikari *et al.* (2009) observed that a moisture content less than 20% will slightly reduce the biological activities of the compost. Bokashi compost prepared from 1;1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite recorded the highest moisture content which might be due to the highest absorption capacity of the substrates (Bhattacharya, 2007).

The lowest bulk density was recorded for compost T_{13} (Bokashi compost prepared from *L.flava* and enriched with calcium apatite, epsom salt and sylvinite) (Fig 6) which might be due to the higher organic matter content of the compost (Khater, 2015). The EM Bokashi compost reported a lower apparent specific gravity indicating greater total porosity than other types of composts (Pereira *et al.,* 2022).

5.1.2. Electrochemical properties of the resultant biomineral enriched (Bokashi) compost

The pH values of the produced biomineral enriched (Bokashi) composts ranged from 6.66 to 7.39. Hogarh *et al.* (2008) reported that matured composts have a pH value between 6 and 8 while composts under maturation tend to be more acidic.

The values of electrical conductivity ranged from 3.21 dSm^{-1} to 3.38 dSm^{-1}. The EC values can be attributed by the enrichment materials or by high content of ammonium and mineral salts produced by the degradation of organic matter and that releases ammonium and phosphates (Sharma *et al.,* 2017).

5.1.3. Proximate constituents of the resultant biomineral enriched (Bokashi) compost

The amount of proximate constituents in the biomineral enriched Bokashi composts are depicted in Fig 7. Cellulose is a major component of plant cell walls and is almost never found in pure conditions in nature but binds to lignin and hemicellulose to form lignocellulose. The highest value of cellulose was reported by T_{14}, Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was on par with T_{10} and T_4. Cellulose is composed of glucose polymers with β-1, 4 glucoside bonds in a straight chain. Bonds of β-1,4 glucosides in cellulose fibres can be broken down in to glucose monomers by acidic or enzymatic hydrolysis (Lynd *et al*., 2002).

The highest value of hemicellulose content was reported for compost T_6 which was prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite which was on par with. In plants hemicellulose acts as a matrix of cellulose. Hemicellulose is relatively easier to hydrolyze with acids in to monomers containing glucose, mannose, galactose, xylose and arabinose (Sunarya *et al*., 2020).

Lignin is a polymer with an aromatic structure that is formed through propillating units that are interconnected by several types of bonds (Perez *et al*., 2002). The highest mean value of lignin content was recorded for compost T_5 which was the Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt which was found to be on par with compost T_4. Lignin is difficult to degrade by hydrolysis enzymes because the structure is complex and heterogeneous (Hofrichter, 2002). Therefore high lignin content may cause the degradation process of organic matter in composting process to become incomplete, contributing to high carbon content in the resulted compost or Bokashi fertilizer (Sunarya *et al.*, 2020).

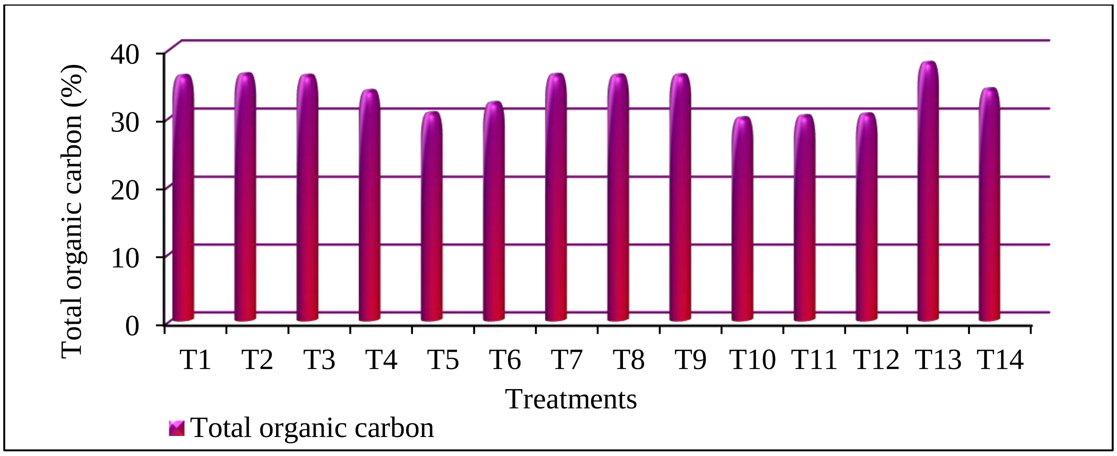


Fig 8. Total organic carbon (%) of resultant biomineral enriched (Bokashi) composts

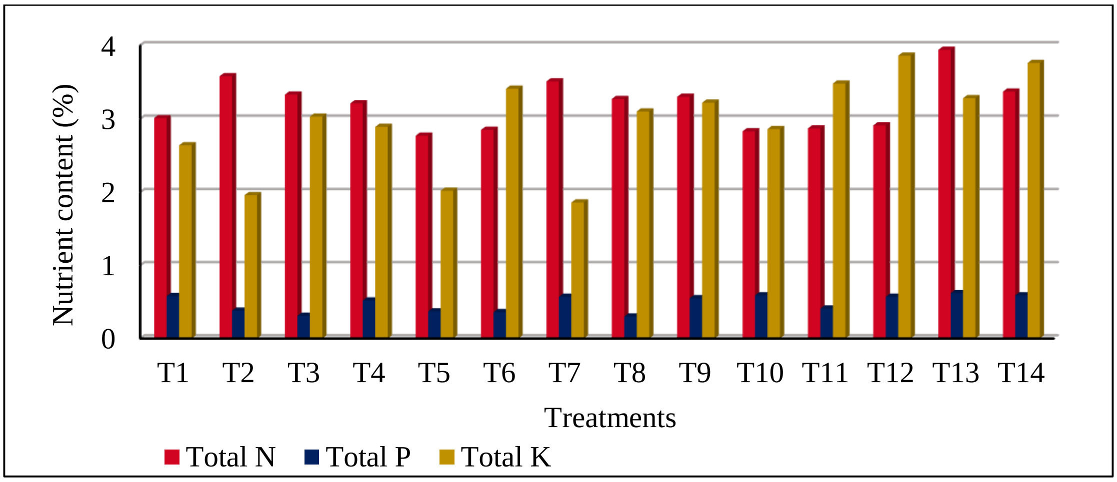


Fig 9. Total nitrogen, phosphorus and potassium content (%) of resultant biomineral enriched (Bokashi) composts

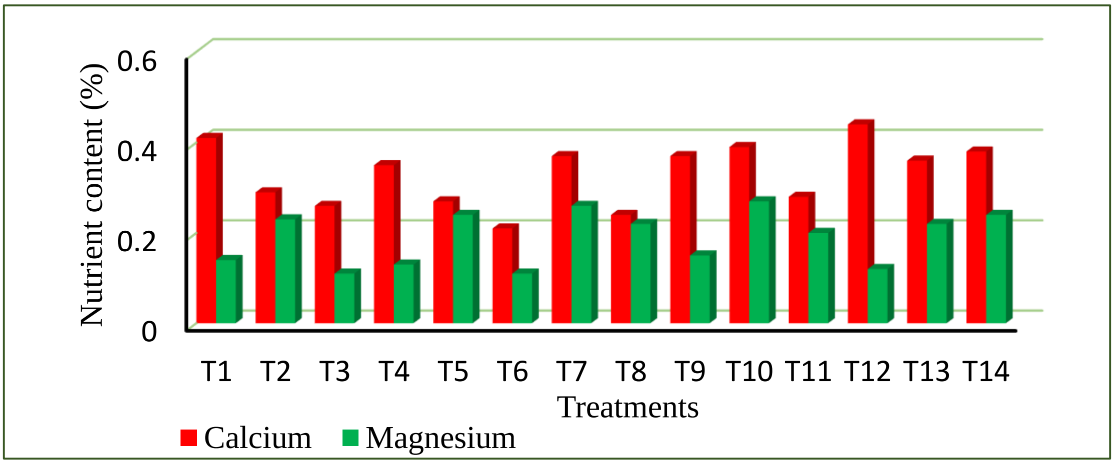


Fig 10. Calcium and magnesium content (%) of the resultant biomineral enriched (Bokashi) composts.

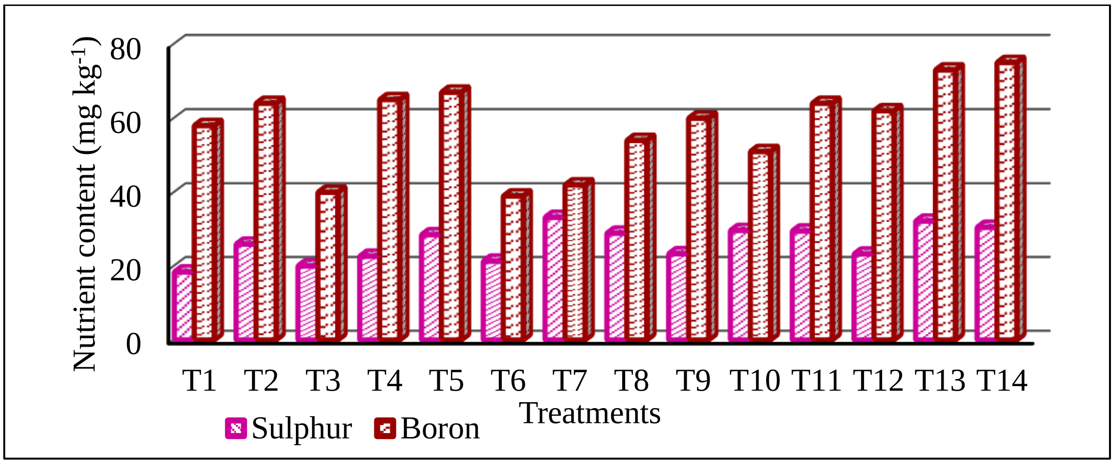


Fig 11. Boron and sulphur content (mg kg^{-1}) of the produced biomineral enriched (Bokashi) composts

5.1.4. Chemical properties of the resultant biomineral enriched (Bokashi) compost

According to Quiroz and Cespedes (2019), the characteristics of Bokashi compost are related to the raw materials used in the preparation, with direct reflection mainly on the availability of nutrients. Bokashi compost has a high content of organic matter and nutrients required for plants, presents high porosity and water holding capacity.

The highest mean value of total organic carbon was registered by Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (Fig 8). Similar results were reported by Anushma (2014) who observed that compost produced from substrate *L.flava* in combination with *Trichoderma reesei* contributed to high quality compost with high organic matter. The relatively high organic matter content in the Bokashi compost indicates that Bokashi will still be gradually decomposing during use in the field (Mylavarapu and Zinati, 2009). Footer (2013) reported that the loss of carbon and nutrients to ground or atmosphere is minimum during anaerobic fermentation of organic matter thus producing the Bokashi composts with high nutritional values.

The NPK content of the resultant biomineral enriched Bokashi composts are presented in Fig 9. Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest total nitrogen content. This might be due to the high nitrogen content of the substrate (*L.flava*) used for the production of the composts. Lee *et al.* (2009) observed that addition of magnesium and phosphate salts to organic matter while composting reduced the ammonia emission thus nitrogen losses.

The highest mean value of total phosphorus was recorded for compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite). It is evident from Table 6 that *L.flava* has reported a higher phosphorus content than banana pseudostem. The addition of all the three minerals, especially rock phosphate might have increased the phosphorus content of the above compost. The addition of calcium apatite as a phosphorus source increased the phosphorus content of the composts (Biswas and Narayanasamy, 2006). The microorganisms inoculated in the compost supplemented with rock phosphate have allowed the increase of phosphorus concentration from 205 ppm for uninoculated compost up to 1000 ppm for inoculated compost (Zayed and Abdel-Motaal, 2005).

Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite recorded the highest mean value for total potassium which was found to be on par with the potassium content of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The addition of sylvinite as a source of potassium might be the reason for increased potassium content in these composts (Nishanth and Biswas, 2008). It is evident from Table 6 that banana pseudostem contains higher potassium content than *L.flava* which might also be the reason for the increased potassium content in these composts.

Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite (T_{12}) recorded the highest value for total calcium content which was found to be on par with T_1 (Fig 10). The high calcium content in these composts may be due to presence of calcium apatite as the calcium source. Maass *et al.* (2020) observed that the calcium content of Bokashi compost enriched with rock phosphate had reported almost twice calcium content compared to that of Bokashi without the addition of rock phosphate.

Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt registered the highest mean value for total magnesium which was found to be on par with composts T_7, T_5, T_{14} and T_2 (Fig 10) while Bokashi compost prepared from *L.flava* enriched with calcium apatite and epsom salt recorded the highest sulphur content (Fig 11). Magnesium sulphate (epsom salt) is an excellent source of magnesium and sulphur with 9.8% of magnesium and 13% of sulphur present in it (Vrataric *et al*., 2006).

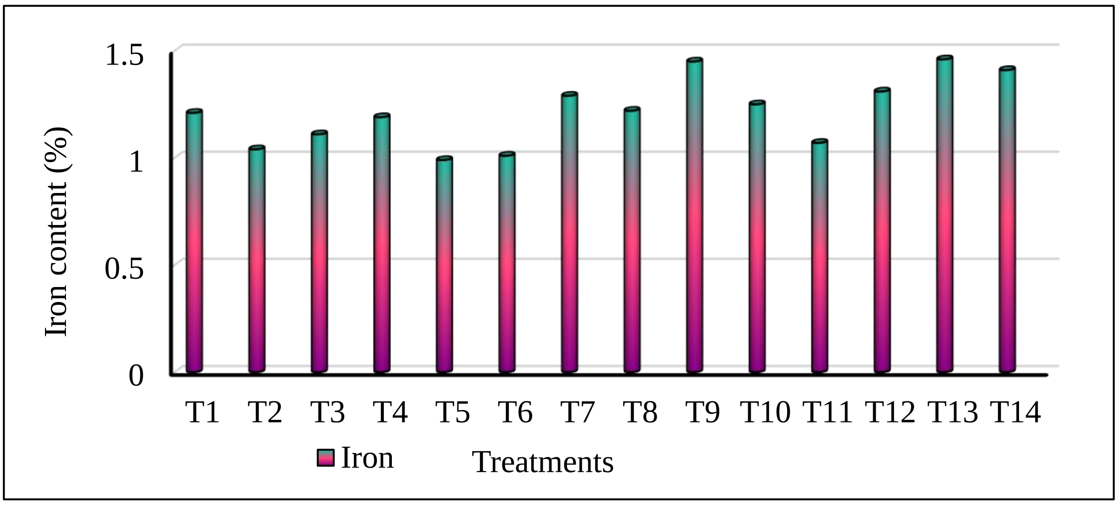


Fig 12. Iron content (%) of the resultant biomineral enriched (Bokashi) composts

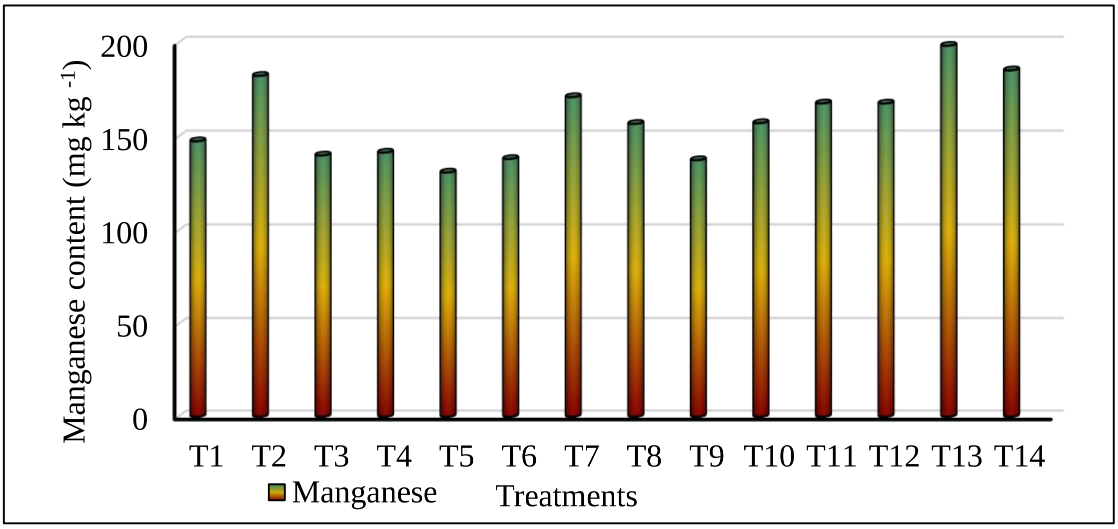


Fig 13. Manganese content (mg kg^{-1}) of the resultant biomineral enriched (Bokashi) composts

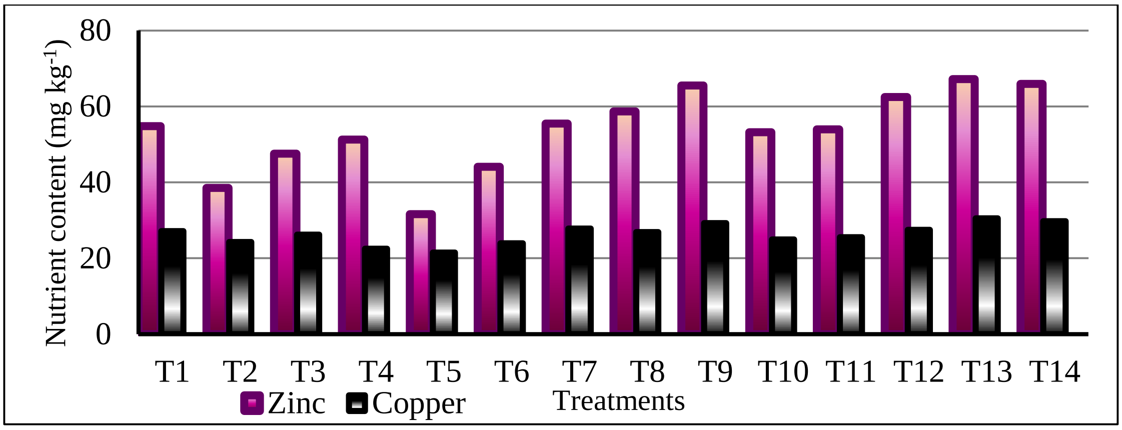


Fig 14. Zinc and copper content (mg kg^{-1}) of the resultant biomineral enriched (Bokashi) composts

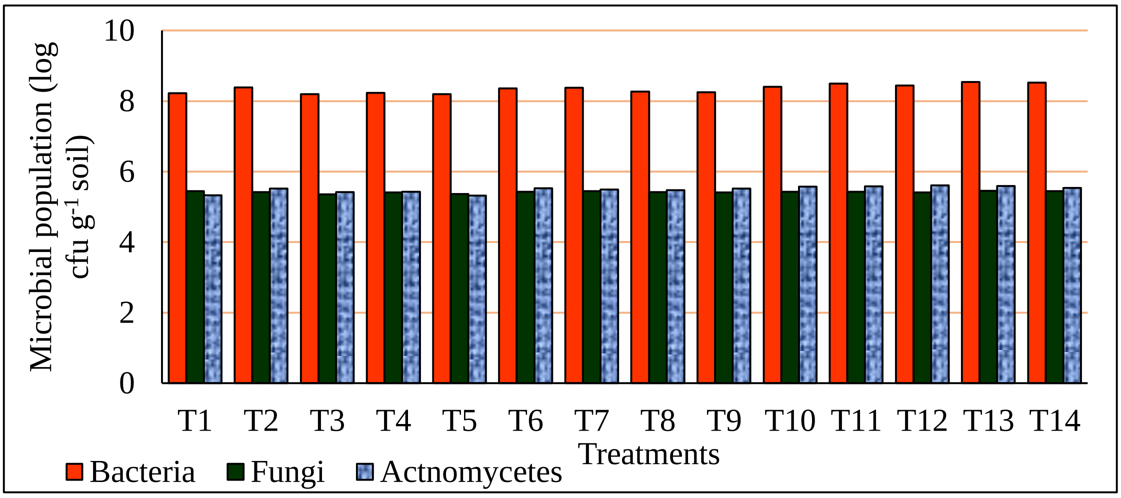


Fig 15. Microbial population (log cfu g^{-1}soil) of the resultant biomineral enriched (Bokashi composts)

Boron content was found to be the highest for Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was on par with compost T_{13} (Fig 11). The highest boron content in banana pseudostem (Table 6) and the presence of all the three minerals (viz. calcium apatite, epsom salt, sylvinite) in the compost might be the reason for the higher boron content in this compost.

The micronutrient content of prepared biomineral enriched Bokashi composts are presented Fig 12, Fig 13 and Fig 14. The micro nutrient like Fe, Mn, Zn and Cu content were found to be higher for T_{13} (Bokashi compost prepared) from *L.flava* enriched with calcium apatite, epsom salt and sylvinite). The composts enriched with all the three minerals have higher amount of micronutrients because of the contribution of these cations due to addition of rock phosphate, sylvinite and epsom salt (Meena and Biswas, 2014). It was also evident from Table 6 that substrate *L.flava* contains more micronutrients than banana pseudostem. Enrichment of compost with minerals (viz. calcium apatite, epsom salt, sylvinite) increased the availability of micronutrients present in composting material due to organically chelated micronutrients (Dakshinamurthy and Upendra, 2008). The heavy metal content was found to be below detectable level for all the prepared composts. Anushma (2014) recorded similar results for the composts prepared from *L.flava* and banana pseudostem. It might be due to the complexation of heavy metals during the process of composting (Wong and Selvam, 2006).

5.1.5. Biological properties of the resultant biomineral enriched (Bokashi) compost

The EM solution used for the preparation of Bokashi is a rich source of various, bacteria, fungi and actinomycetes (Xu, 2001). It has been reported that during Bokashi preparation these microorganisms can coexist with LAB populations, yeasts, photosynthetic bacteria, filamentous fungi and actinomycetes

(Higa and Parr, 1994). The microbial population of resultant biomineral enriched Bokashi composts are depicted in Fig 15.

The bacterial population was the highest in compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which was on par with composts T_{14} and T_{11}. The lactic acid bacteria present in the Bokashi compost enhance the breakdown of organic matter inclusive of lignin and cellulose and ferment these materials rapidly (Nayak *et al.*, 2020).

The highest value of fungal population was recorded for compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, Epsom salt and sylvinite) which was found to be on par with T_{14}, T_1 and $T_{7.}$

It was found from the data that the compost T_{12} which is the Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite recorded the highest actinomycetes population which was on par with T_{13}. Actinomycetes play important role in the rotation of organic matter and inhibit several plant pathogens in the rhizosphere. They produce lot of extracellular enzymes which can be conducive of crop production (Nayak *et al.*, 2020).

The addition of mineral additives to the Bokashi compost has a positive effect on decomposition by increased availability of N, P and essential nutrients for microorganisms which in turn increases their population (Chari and Ravi, 2013).

The mean values of CO_2 emission from the biomineral enriched (Bokashi) composts ranged from 4.04 mg CO_2 g^{-1} to 5.12 mg CO_2 g^{-1}. Carbon dioxide production is due to the degradation of the total organic carbon and mineralization of organic matter by microbes (Santos *et al.*, 2014). The highest mean value of CO_2 emission was recorded for the compost T_{14} (Bokashi compost prepared from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite) which was on par with compost T_{13} (5.09 mg CO_2 g^{-1}). A higher carbon dioxide emission is an indicator of stronger microbial activity (Jia *et al.*, 2016).

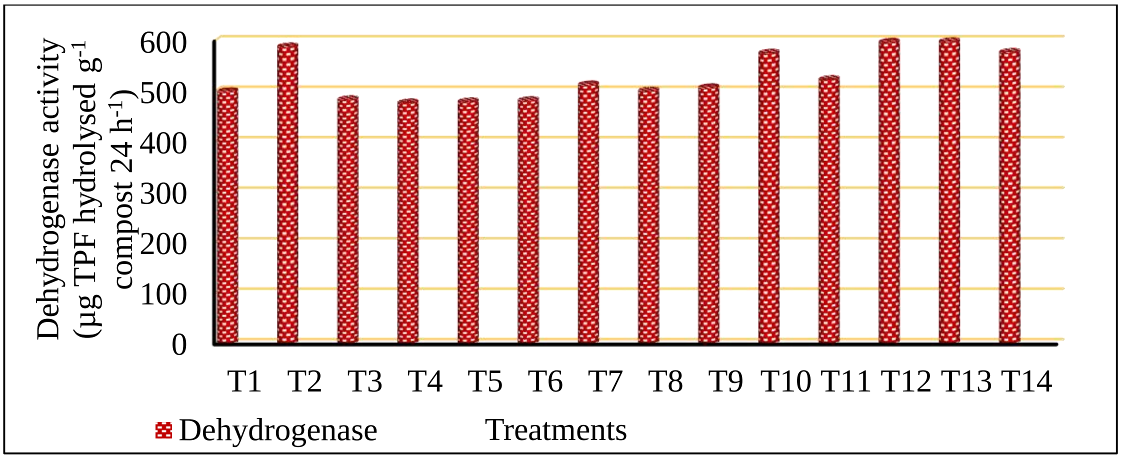


Fig 16. Dehydrogenase activity of the resultant biomineral enriched (Bokashi) composts (µg TPF hydrolysed g^{-1} compost 24 h^{-1})

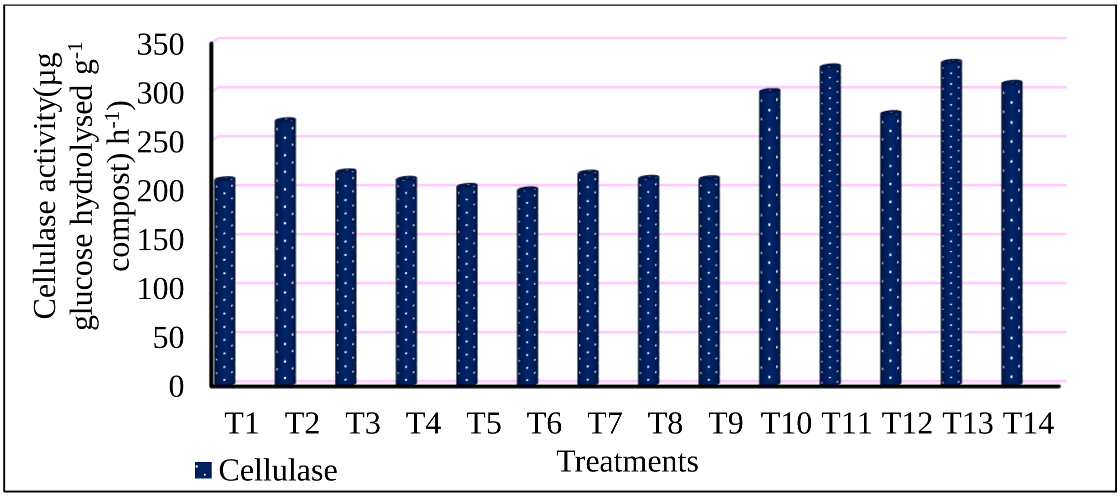


Fig 17. Cellulase activity (µg glucose hydrolysed g^{-1} compost h^{-1}) of the resultant biomineral enriched (Bokashi) composts

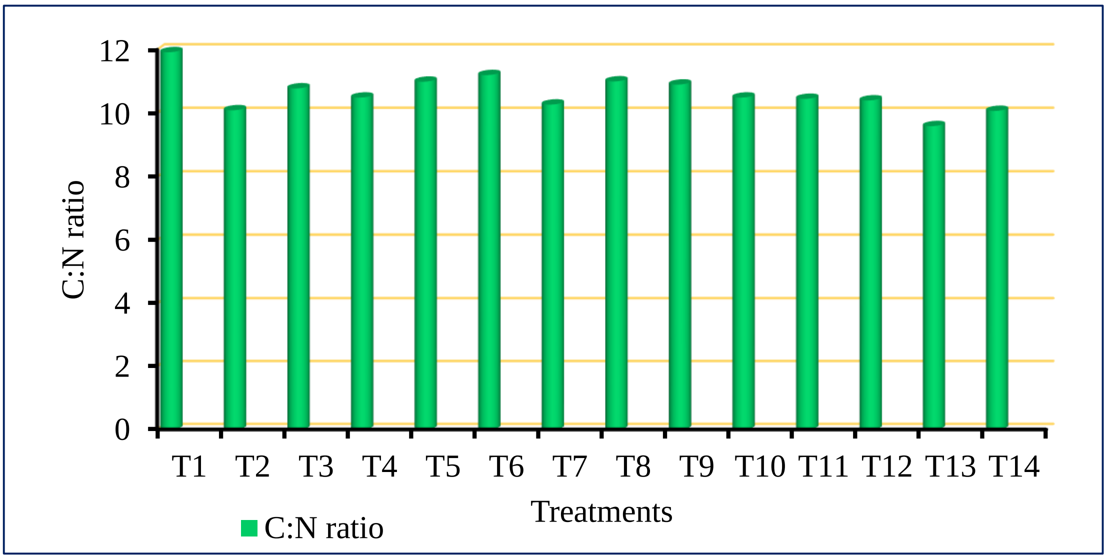


Fig 18. C:N ratio of the resultant biomineral enriched (Bokashi) composts

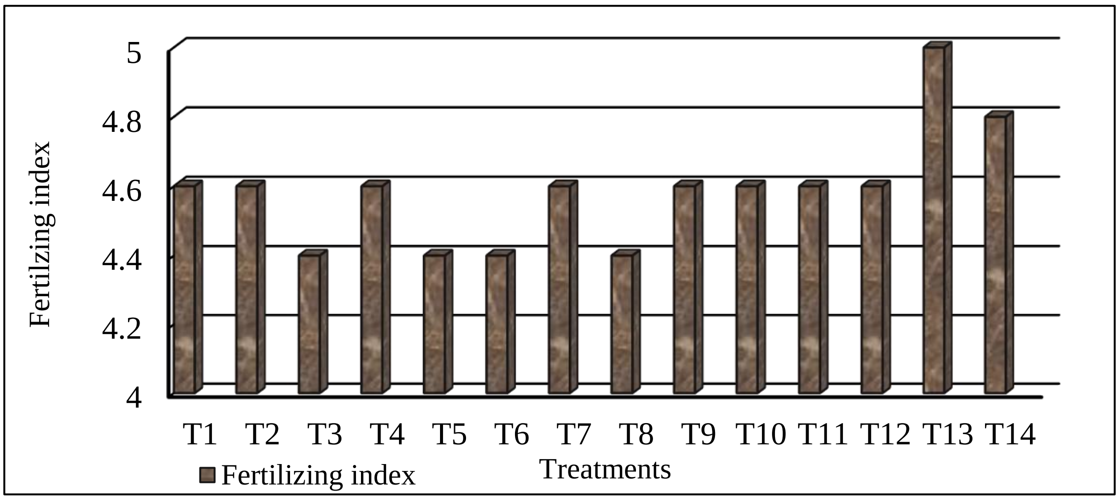


Fig 19. Fertilizing index of resultant biomineral enriched (Bokashi) composts

The dehydrogenase and cellulase enzyme activity of the composts are represented in Fig16 and Fig 17 respectively. Microbes in the composting pile cannot directly metabolize the insoluble particles of organic matter. Rather they produce enzymes to depolymerize the larger compounds to smaller fragments that are water soluble (Hankin *et al.*, 1976).The highest value of dehydrogenase activity was recorded for the Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which might be due to the high microbial population in the compost. The highest mean value of cellulase activity was recorded for the compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite). Cellulase activity was found to be higher when aquatic weed (water hyacinth) was used for composting compared to other substrates like press mud, sugarcane trash or poultry waste (Goyal *et al.*, 2005).

5.1.6. C:N ratio of the resultant biomineral enriched (Bokashi) compost

Composts or other organic fertilizers with C:N ratio greater than 20 leads to a temporary immobilization of nitrogen through microorganisms and thus cause nitrogen deficiency in plants (Akhtar, 2000; Lloyed *et al*., 2002). Formowitz *et al.* (2007) observed that Bokashi compost produced using EM had a C:N ratio less than 20. The mean values of C:N ratios of the prepared biomineral enriched Bokashi composts ranged from 9.59 to 11.92 (Fig 18). Some studies report a similarly low C:N ratio of 10-11 for the Bokashi composts with ammonium as the dominant inorganic form of nitrogen (Yamada and Xu, 2001; Daiss *et al.*, 2008 and Gomez-Velasco *et al.,* 2014). Decrease in C:N ratio by the decrease of organic carbon and increase of total nitrogen was observed during the decomposition of organic matter (Goyal *et al*., 2005; Nishanth and Biswas, 2008). The lowest C:N ratio was reported by T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which might be due to high nitrogen content of the compost (Table 11).

5.1.7. Fertilizing index and clean index of resultant biomineral enriched (Bokashi) compost

The mean values of fertilizing index ranged from 4.40 to 5.00 (Fig 19). Fertilizing index indicates the fertilizing potential of organic fertilizers and it is usually greater than 4 for organic fertilizers (Jalal and Shekha., 2019). The highest mean value of 5.00 was reported for compost T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite). The second highest value of 4.80 was recorded for T_{14} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite).

Based on the selection indices like fertilizing index, available major and minor nutrients, enzyme status and C:N ratio the best seven composts selected are T_2 (Bokashi compost prepared from *L.flava* enriched with epsom salt), T_7 (Bokashi compost prepared from *L.flava* enriched with calcium apatite and epsom salt), T_{10} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt), T_{11} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt and sylvinite), T_{12} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite), T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) and T_{14} (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite).

The value of clean index was found to be 5 for all the prepared compost. By maintaining a higher clean index for organic fertilizers, the entry of heavy metals in to sensitive environments such as agricultural land and water bodies are restricted (Mandal *et al.*, 2014).

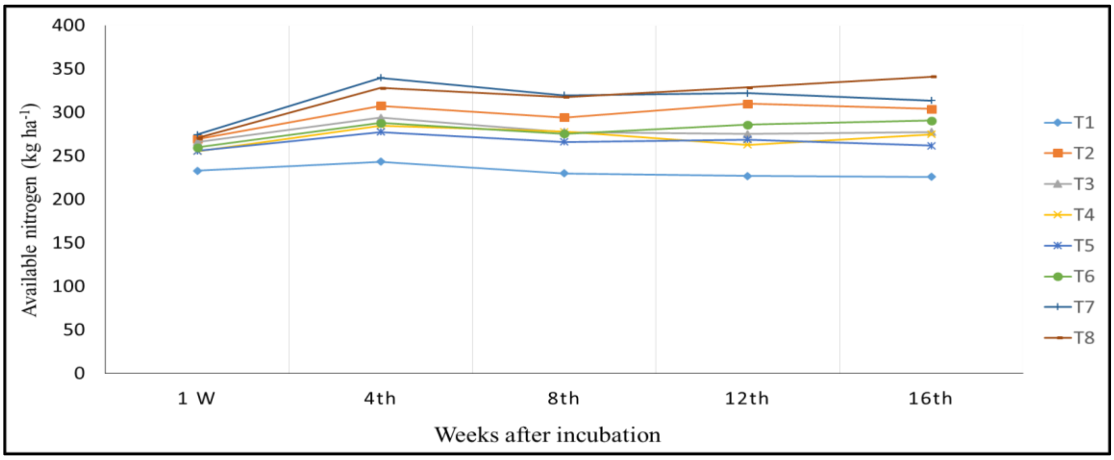


Fig 20. Effect of treatments on available nitrogen (kg ha^{-1}) during incubation

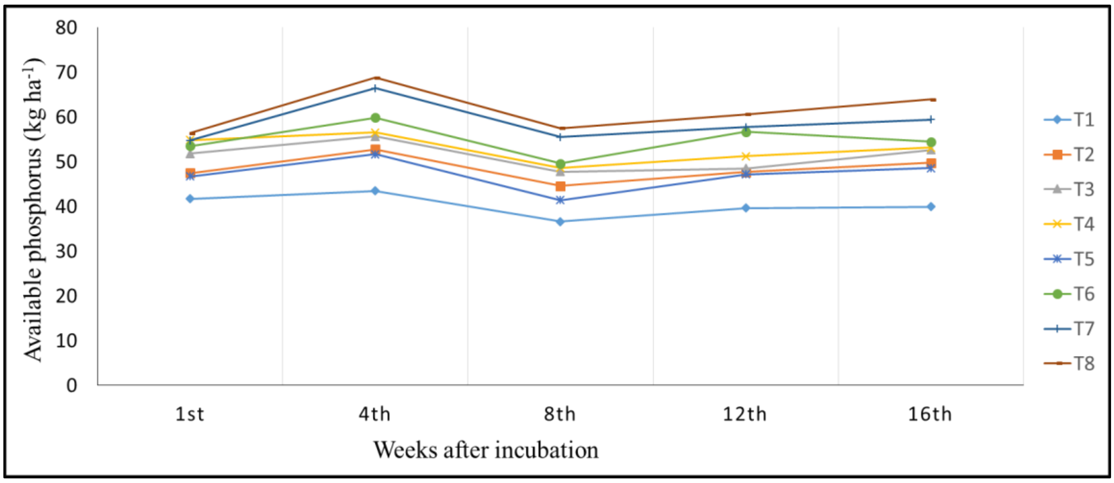


Fig 21. Effect of treatments on available phosphorus (kg ha^{-1}) during incubation

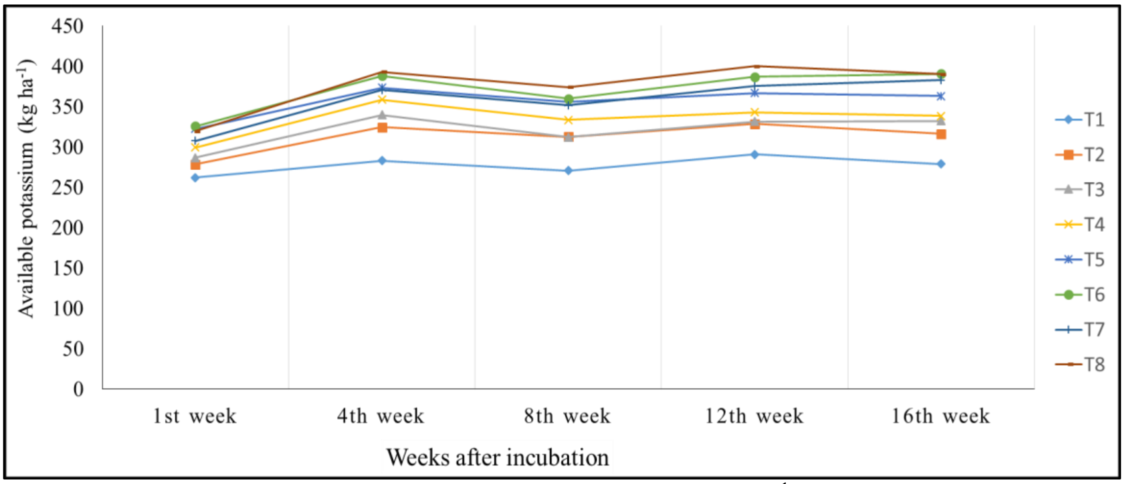


Fig 22. Effect of treatments on available potassium (kg ha^{-1}) during incubation

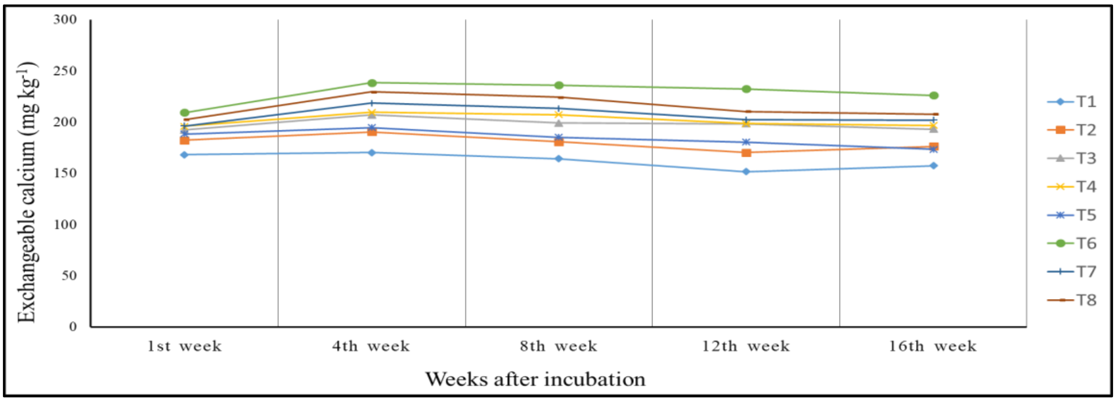


Fig 23. Changes in exchangeable calcium content (mg kg^{-1}) of soil during the incubation period

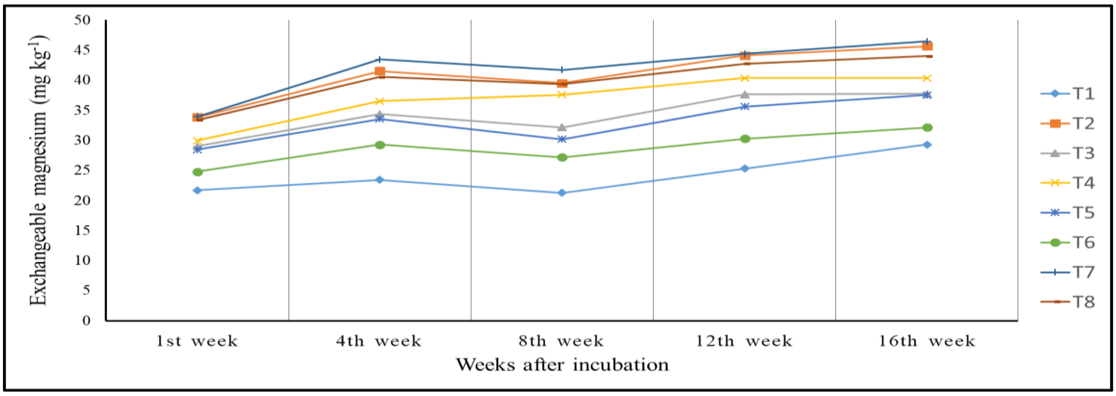


Fig 24 . Changes in exchangeable magnesium content (mg kg^{-1}) of soil during the incubation period

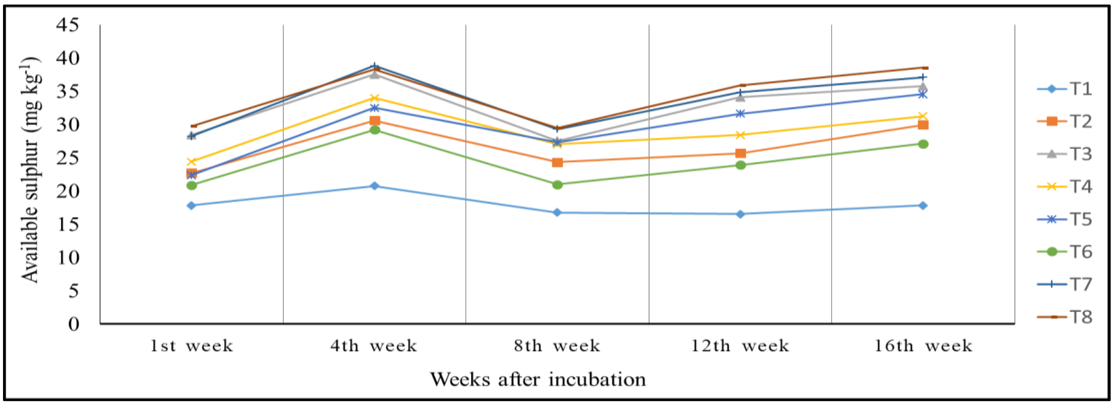


Fig 25. Changes in available sulphur content (mg kg^{-1}) of soil during the incubation period

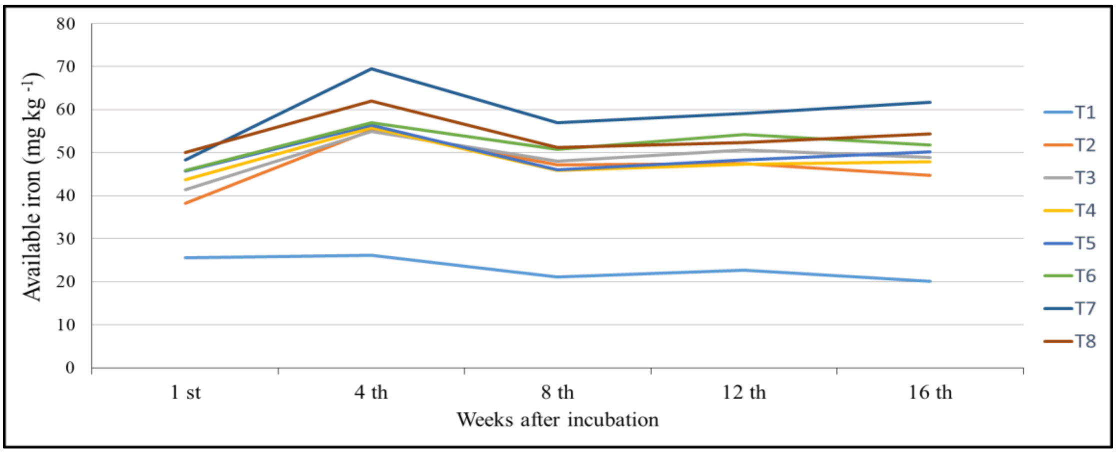


Fig 26. Changes in available iron content (mg kg^{-1}) of soil during incubation period

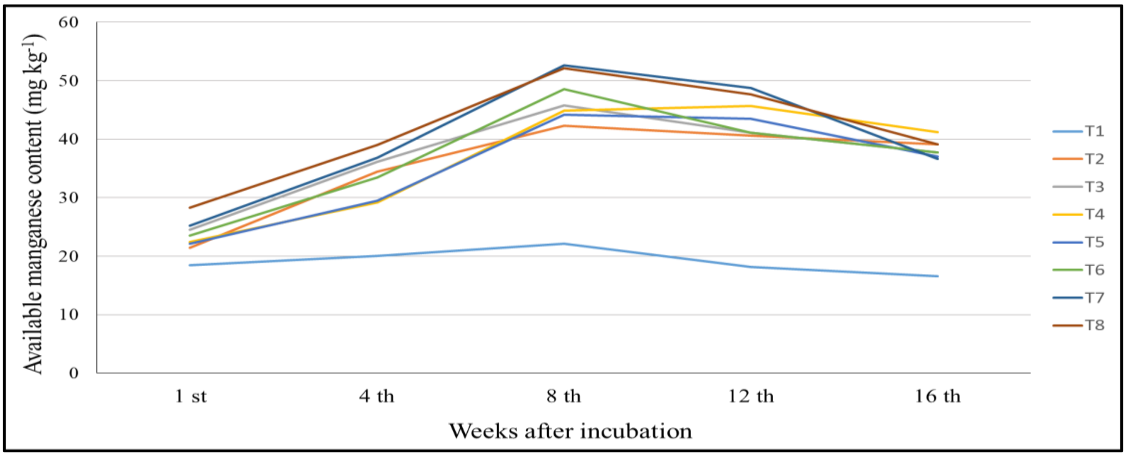


Fig 27. Changes in available manganese content (mg kg^{-1}) during incubation period

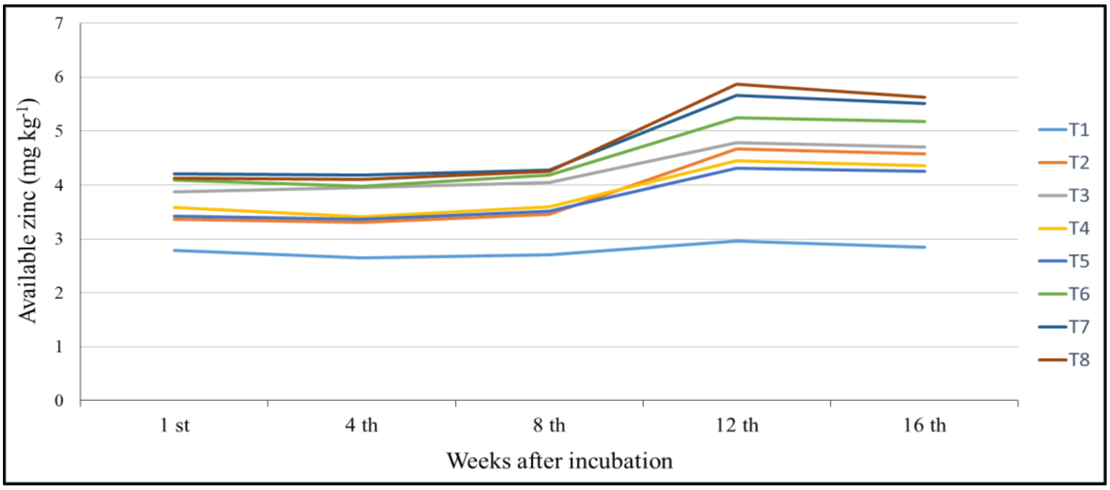


Fig 28. . Changes in available zinc content (mg kg^{-1}) during incubation period

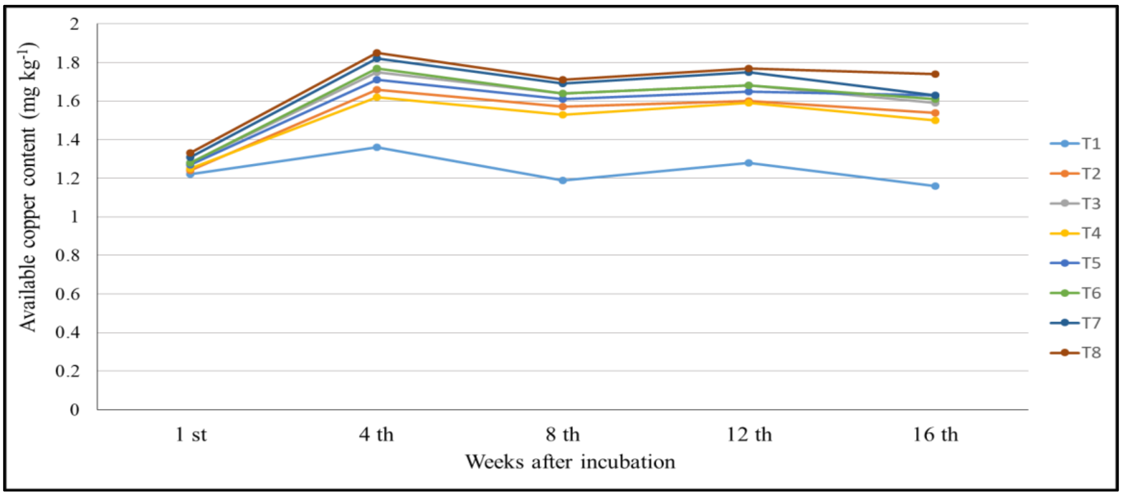


Fig 29. Changes in available copper content (mg kg^{-1}) during incubation period

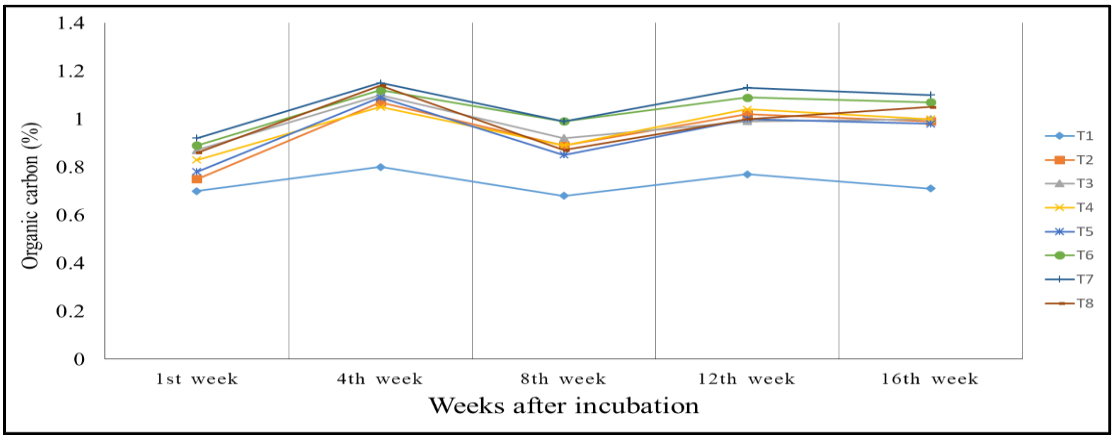


Fig 30. Changes in organic carbon (%) of soil during the incubation period

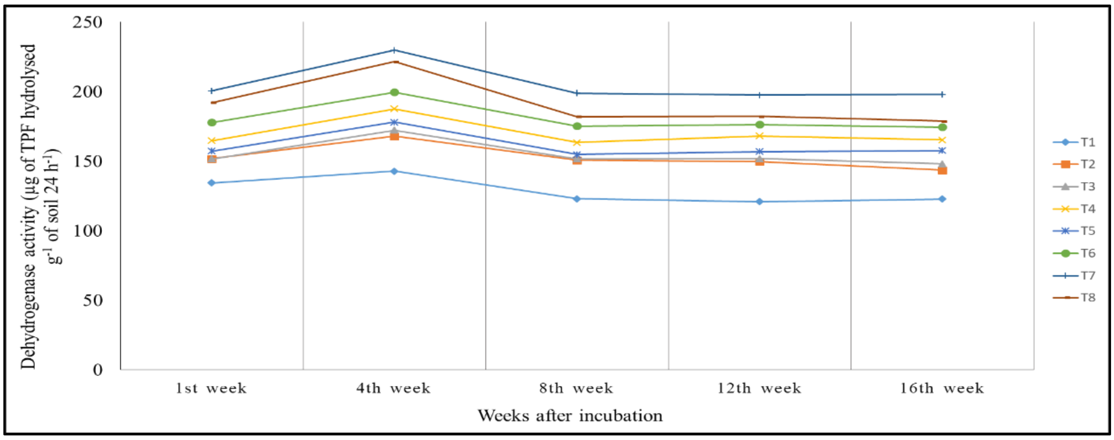


Fig 31. Changes in dehydrogenase activity (µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}) of soil during the incubation period

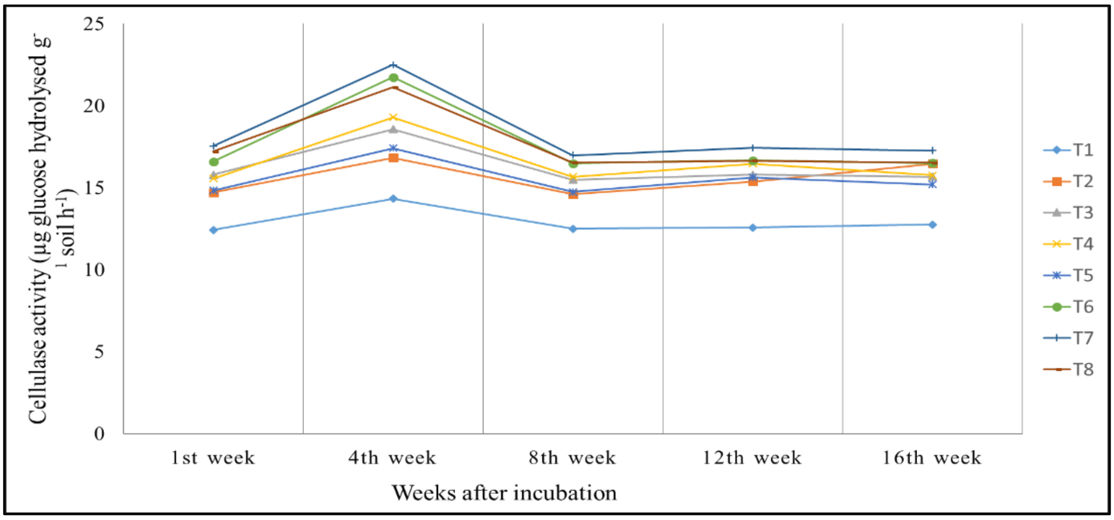


Fig 32. Changes in cellulase activity (µg glucose hydrolysed g^{-1} soil h^{-1}) of soil during the incubation period

5.2. SOIL INCUBATION STUDY FOR EVALUATING THE NUTRIENT RELEASE PATTERN

The laboratory incubation study was carried out to monitor the nutrient release pattern of biomineral enriched (Bokashi) compost.

5.2.1. Changes in primary and secondary nutrients

An increasing trend in available nitrogen during incubation study could be observed (Fig 20) which might be due to the mineralisation of organic matter through high microbial activity. The highest nitrogen content was observed in T_7 (Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite) which reported higher nitrogen content than other biomineral (Bokashi) composts. An increase in available nitrogen up to 45 days of incubation for soil treated with vermicompost enriched with bone meal (2%) was also reported by Sheeba (2004). Soil treated with biomineral enriched vermicompost showed an increase in nitrogen content which may be due the PGPR Mix – I which is a consortium of microorganisms which actively solubilize and fixes the nitrogen (Sreeja, 2015). Boechat *et al.* (2013) also observed that in the presence of Bokashi net nitrogen mineralised was higher after a week of incubation compared to the treatment were Bokashi was not added hence can be said that presence of Bokashi accelerate nitrogen availability.

In case of available phosphorus T_8 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite) recorded the highest value for available phosphorus throughout the incubation period (Fig 21). Maass *et al.* (2020) observed an increase in phosphorus content of soil with the application of Bokashi compost enriched with rock phosphate. Available phosphorus content increased upto 4th week of incubation and a drastic decrease can be observed during 8th week of incubation. An increase of available phosphorus up to 30th day of incubation and a drastic decrease later on was also reported by Kavya (2019) during incubation study using organic liquid fertilizers. Initial increase in phosphorus content of soil may be attributed to the increase in microbial activity which releases the P nutrient by the decomposition of organic materials which is related to organic acids which helps in solubility of native insoluble phosphates (Thite *et al*., 2022). The carbonic acid and organic acid produced during the decomposition of organic matter solubilized the insoluble phosphate in the rock phosphate resulting in the release of phosphate in to the solution (Singh *et al.,* 1982). Bijulal (1997) reported that significant addition of phosphorus through organic matter improved the solubility of phosphorus due to microbial activity. A positive relation exists between the effect of organic matter and humus on phosphorus availability (Vyas and Mothiramani, 1971).

The potassium release pattern of the biomineral enriched Bokashi composts are depicted in Fig 22. The highest potassium content was recorded by T_6 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite) during the first week of incubation which might be due to highest potassium content of the compost. It is found from the study that T_8 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite) recorded higher value for available potassium during the rest of the incubation period which might be due to the high microbial activity of the compost. According to Tan (1982), the interaction with organic matter and clay accelerated the mineralisation which enhanced the release of potassium during incubation. Samuel and Ebenezer (2014) reported from their incubation study that organo-mineral fertilizer increased the soil forms of N,P and K to sufficient levels that can boost the plant growth. The available potassium content increased due to the dissolution of insoluble potassium minerals by weak organic acids produced from the added organic manures (Hue and Silva, 2000). The higher availability of potassium in soil might be due to the beneficial effect of organic manure on reduction of potassium fixation. The organic manure added interacts with K-clay complex to release potassium from non-exchangeable fractions to the available pool (Bhanwaria and Yadav, 2016).

Fig 23 depicts the variation in calcium content during incubation period. The exchangeable calcium content increased up to 4^{th} week of incubation and there after a decrease can be observed. An increase in calcium release by bio mineral compost during 30th day of incubation was also reported by Sreeja (2015). The highest value for calcium content was recorded by T_6 throughout the incubation period. This might be due to the highest calcium content in the Bokashi compost prepared from1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite which have supplement calcium.

Fig 24 shows the changes in magnesium content during the incubation period. The highest value for exchangeable magnesium was recorded by T_7 (application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) throughout the incubation period. The highest value magnesium was recorded during 16th week of incubation. An increasing trend in magnesium release was also observed by Sreeja (2015) during the incubation of biomineral enriched compost.

Changes in available sulphur content during the incubation period was depicted in Fig 25. A sudden decrease in sulphur content can be observed during 8th week of incubation and an increasing trend in sulphur content can be observed thereafter. Kavya (2019) also observed a much lower sulphur content during 60th day of incubation compared to 30th day of incubation when organic liquid fertilizer was subjected to an incubation study.

5.2.3. Changes in available micronutrients

Application of Bokashi compost prepared from *L.flava* enriched with calcium apatite epsom salt and sylvinite recorded the highest value of iron content throughout the incubation period (Fig 26) which might be due to the high iron content present in the compost. The maximum value of available iron content was recorded during 4th week of incubation which might be due to high microbial activity during 4th week of incubation. Higher organic matter changes iron from crystalline iron oxide to amorphous iron oxide forms. When organic matter undergoes biological degradation in soils, electrons or other reducing agents are reduced to the surrounding soil which decreases the redox potential and significantly increase the solubility of Fe^{2+} (Lindsay, 1991).

It is observed that the manganese content was found to be increasing up to 8th week of incubation and a decrease in manganese availability can be observed afterwards (Fig 27). Addition of organic matter changes manganese in to the more available forms. The manganese was most likely to reduce due to the organic matter additions and changed into more soluble forms since organic matter decomposition produces electrons, which increased the redox activity (Lindsay, 1979).

A sudden increase in zinc content could be also observed in available zinc content during 12th week of incubation (Fig 28). Movement of zinc from the exchangeable fraction might be from the zinc utilization by microbes (Shuman, 1988).

The highest value for copper content was reported by T_8 (Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite) throughout the incubation period. An increase in copper content could be observed from 1st to 4th week of incubation for all the treatments (Fig 29). The decreased availability of micronutrients during later stages of incubation might be due to sorption of micro nutrients by solid form of organic matter by sorbing micronutrients on to the surface functional groups (Boguta and Sokolowka, 2016).

Rose (2008) reported the pattern of solubilisation of micronutrients like Fe, Mn, Zn and Cu for soil treated with different doses of rock dust and farm yard manure through incubation study and revealed that there was a gradual increase in the concentration of these nutrients during the early period of incubation and the maximum values were observed during the later stages of incubation.

5.2.4. Changes in organic carbon

Changes in organic carbon content of the soil during incubation study is depicted in Fig 30. It is observed that treatment T_7 (Bokashi compost prepared from

L.flava enriched with calcium apatite, epsom salt and sylvinite) recorded the highest value of organic carbon throughout the incubation study which might be due to the high total organic carbon present in the initial compost. It is observed that organic carbon content increased during 4th week of incubation, which decreases during 8th week of incubation. The highest amount of soil organic carbon at the start of the incubation might be due to the availability of the a larger pool of less resistant fractions that were broken down and recycled thus resulting lower contents remaining at the end of incubation (Thite *et al.*, 2022). Six *et al.* (2002) also reported that stabilization of soil organic matter is a consequence of a series of factors or processes such as the recalcitrance of organic molecule, the link to the surface of clay minerals or the in accessibility of soil organic matter to the microorganisms when protected in stable soil aggregates.

5.2.5. Changes in enzyme activity

The dynamic of the nutrients in the soils is mainly influenced by the biological activity in the soil. The dynamics of different nutrients and enzyme activity in the soil are directly affected by the composition of organic amendments added to the soil (Kwabiah *et al*., 2003). The changes in dehydrogenase and cellulase activity in the soil during the incubation study is depicted in Fig 31 and Fig 32 respectively.

It was observed from Fig 31 and Fig 32 that the enzyme activity increased up to 4th week of incubation then decreased and became stable. A similar trend in enzyme activity during incubation was observed by Zhao and Zhang (2018) and El-Shinawi *et al*. (1982). The highest value for dehydrogenase and cellulase activity was recorded by T_7 which is the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite, throughout the incubation period. This might be due to the high organic carbon content in T_7. The dehydrogenase activity in soil was affected by different factors including incubation time, temperature, soil aeration, soil organic carbon and moisture (Kumar *et al.*, 2013). The higher dehydrogenase activity after addition of organic manure could be due to increased microbial population, which is known to stimulate the dehydrogenase activity in the soil (Watts *et al*., 2010). Cellulase activity in soil was highly correlated to the humus content (Schinner and von Mersi, 1990).

5.3. FIELD EXPERIMENT FOR EVALUATING THE PERFORMANCE OF BIOMINERAL ENRICHED (BOKASHI) COMPOSTS

A field experiment was carried out using bhindi var. Anjitha as the test crop and amaranthus var. Arun as residual crop.

5.3.1. Effect of biomineral enriched (Bokashi) compost on postharvest soil

5.3.1.1. pH and Electrical Conductivity

The pH of the soil varied significantly with the treatments. It was observed that pH increased after the experiment and pH ranges from moderately acidic to slightly acidic. The highest mean value of pH was recorded by the application of Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. Application of lime might have 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 (Dahia *et al*., 2003). Lal *et al*. (2000), Vemaraju (2014), Krishnan (2014), Rameeza (2016) and Kavya (2019) reported an increase in pH of the soil after addition of organic manures to the soil.

The electrical conductivity of the soil increased after the experiment. An increase in EC was the indication of increased total soluble salt content. Addition of organic manure with beneficial microorganisms facilitated the mineralization of nutrients and faster release of bases (Thompson *et al*., 1989). Treatment T_9 (application of KAU POP recommendation) records the highest value of electrical conductivity. Addition of salts through inorganic fertilizers might have increased the electrical conductivity (Ozlu and Kumar, 2018).

5.3.1.2. Organic carbon and NPK content

The results revealed that the treatments had a significant influence on the organic carbon content of the postharvest soil (Table 32). The organic carbon content was higher in the biomineral (Bokashi) applied plots compared to control (Fig 33). The highest mean value for organic carbon in the postharvest soil was recorded by treatment T_7 (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) which might be due to the high organic matter content of the compost (Table 11). Hernandez *et al.* (2014) observed a 40% increase in soil organic carbon with the addition of Bokashi compared to the control. Addition of organic manure might have increased the root biomass production and thus the organic carbon content (Halvorson *et al*., 1999). Ravisankar *et al.* (2008) also observed an 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). Similar results was observed by Prayogo and Ihsan (2018) .

Addition of biomineral enriched (Bokashi) composts improved the nitrogen content of the soil compared to the absolute control (Fig 34). The effective microorganisms in the Bokashi facilitates to enhance soil quality with the aid of fixing atmospheric nitrogen and thus increasing soil nitrogen content (Nayak *et al.*, 2020). Boechat (2013) observed a positive effect of Bokashi on net nitrogen mineralisation and soil fertility evolution. The highest mean value for nitrogen content was recorded by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which might be due to the lowest C:N ratio of the compost (Table 16) and higher nitrogen releasing ability of the compost as evident from the incubation study.

The highest value for phosphorus was reported by T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_7 (Fig 34). From the incubation study it was clear that the release of P from Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite was higher than that of other treatments. 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 P fixation. It was observed that the phosphorus content of the Bokashi applied plots were significantly higher than the control. Prayogo and Ihsan (2018) observed that with the application of Bokashi compost the available phosphorus content in the postharvest soil was 5-7 times higher than the initial condition. Bokashi compost fermented with EM solution can dissolve phosphate compounds present in the minerals that were not available to plants (Wididana, 1998). Compost amendments significantly enhances the microbial biomass phosphorus and population density of phosphorus solubilizing microbes which showed a positive correlation with available phosphorus in soil (Wickramatilake *et al*., 2011).

Increase in potassium content could be observed with the addition of biomineral enriched Bokashi composts compared to the control (Fig 34). The increase in available potassium may be attributed to the increased release of non-exchangeable potassium from the soils as the enriched composts increased soil cation exchange capacity, which might have resulted in increased available potassium (Blake *et al*., 1999).

5.3.1.3. Secondary nutrient content

The highest value for calcium content was reported for T_6 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite (Fig 35). This might be due to the high calcium content in the compost as indicated in the characterization study. The highest nutrient release pattern of calcium from Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite could be observed in incubation study as well (Table 21). The carbonic acid and organic acid produced during the decomposition of organic matter solubilized the insoluble phosphate in the rock phosphate resulting in the release of calcium in to the solution (Singh *et al*., 1982).

The highest magnesium content was reported by T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite (Fig 35) which might be due to the highest magnesium content in this compost as evident from characterization study (Table 12). The sulphur content was found to be higher for T_7 (Fig 35) with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. The higher availability of Mg and S in the postharvest soil with the application of these composts might be due to their higher content of magnesium and sulphur as evident from the characterization study.

5.3.1.3. Micronutrient content

An increase in micronutrient content compared to control was observed with the addition of biomineral enriched Bokashi composts (Fig 36). The highest value for iron content was recorded for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was on par with T_8. The manganese content was found to be higher for T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The copper, zinc and boron content was recorded to be highest for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. Increase in micro nutrient content of postharvest soil with the application of biomimeral enriched compost was also observed by Sreeja (2015). The increased availability of micronutrients with the addition of mineral enriched Bokashi composts may be due to the presence of organically chelated micronutrients (Dakshinamurthy and Upendra, 2008). The heavy metal content was found to be below detectable level for all the treatments which might be due to below detectable level of heavy metals in the composts.

5.3.1.4. Enzyme activity

The highest dehydrogenase activity was recorded by T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was on par with T_7 (Fig 37). This indicates the highest microbial activity of these treatments. Dehydrogenase activity is considered as an indicator of overall microbial activity because it occurs intra-cellularly in all living microbial cells, and it is linked with microbial respiratory processes (Bolton *et al.*, 1985; Nannipieri *et al*., 1990). Koper *et al*. (2008) observed a positive correlation between dehydrogenase activity and organic carbon content of the soil.

The highest cellulase activity was recorded for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (Fig 37). High microbial content in the soil (Table 37) might be the reason for high cellulase activity. Microorganisms are the major factors affecting cellulase activity in the soil (Deng, 1994). Fungi was reported to be the major contributors of soil cellulases (Hayano, 1986). So high microbial especially fungal population of this treatment might be the reason for the increased cellulase activity in the soil (Table 37).

5.3.2. Effect of biomineral enriched (Bokashi) compost on rhizosphere soil

An increase in microbial biomass carbon could be observed with the addition of biomineral enriched Bokashi composts compared to the control (Fig 38). Hata *et al.* (2020) observed a similar increase in microbial biomass carbon in soil with the addition of Bokashi, suggesting the conditioner provides a stimulus to soil micro biota. Application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (T_7) had recorded the highest microbial biomass carbon value which was on par with T_8, T_6 and T_5. The high organic carbon content in these composts might be the reason for their high microbial biomass carbon since microorganisms consumes soil organic matter for maintenance and multiplication. The higher microbial biomass carbon suggests soil quality because many nutrients may remain incorporated in microbial biomass carbon rather than immobilized in its matrix or free for lixiviation which may be easily released to the plants after microorganisms decease (Gama-Rodrigues and Gama-Rodrigues, 2008).

Glomalin is a soil protein produced by arbuscular mycorrhizal fungi hyphal walls and can remain in soil for years and is resistant to microbial attack (Wright and Upadhyaya, 1996). Application of different treatments significantly influenced the glomalin content of the rhizosphere soil (Fig 39). It was found from the data that the highest value of glomalin content was registered by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was on par with T_6 and T_8. Increase in glomalin content might also be due to the increase in soil organic carbon, available phosphorus, total nitrogen and potassium which was opined by (Sarapatka *et al.,* 2019).

The highest value of humic acid was reported for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (T_7). The fulvic acid content was also found to be the highest for T_7 which was on par with T_8 and T_4. The high microbial activity and organic carbon content might be the reason for high humic substances since microbes are responsible for the continued development of humus in soil as it continues to break down the not fully decomposed organic matter. Extractable humic substances which include humic acid and fulvic acids improve soil fertility, permeability, aeration and aggregation when applied to the soil (Salman *et al*., 2005).

Bokashi composts contributes to the soil with different types of microorganisms including bacteria, fungi and actinomycetes, which can improve the health of the soil (Silva *et al.,* 2014; Restrepo and Hensel 2015). Adding organic matter supports the growth of naturally occurring microbial populations (Lazcano *et al.,* 2013). It was observed that the biomineral enriched Bokashi application increased the microbial population of rhizosphere soil (Fig 40). Lasmini *et al*. (2018) observed that soil application of Bokashi fertilizer of cow manure increased the population of beneficial microbes such as N-fixing bacteria and phosphate solubilizing bacteria, since the organic material serves as a source of nutrients and energy for soil organisms.

Bacterial population was found to be higher for T_8 with the application of Bokashi prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. While the highest fungal population was recorded for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. The actinomycetes population was found to be higher for T_8 with the application of Bokashi prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_7. Sanchez *et al*. (2017) also reported that the addition of microbial and mineral enriched composts to the soil increase the rhizosphere microorganisms. Application of composts having highest microbial activity to the agricultural soils could stimulate microbial processes such as nutrient cycling (Epelde *et al*., 2018).

Addition of Bokashi increased the organic carbon content of the soil, which leads to an increase in fertility because the increase in microorganism activity using carbon as energy source (Vargas and Suarez, 2007). In addition organic fertilizers play a role in changing soil biological properties by increasing the diversity and population of soil organisms (microbial and soil microbes) and increasing soil fertility characterised by increased microbial activity (Lee, 2010).

Treatment T_7 with the application of Bokashi compost prepared from *L.flava* which is enriched with calcium apatite, epsom salt and sylvinite recorded the highest value of soil respiration (Fig 41). The high soil respiration might be due to the higher microbial population. The increase in soil respiration as of the addition of biomineral (Bokashi) compost had been anticipated as it is a source of nutrients for the microorganisms, which in turn favours microbial activity (Scotton *et al*., 2017). A similar result was reported by Pocas *et al*. (2009) who, up on adding different organic materials to the soil, verified an increase in basal respiration. Variation in carbon dioxide emission may be related to soil nutrient content and microbial biomass carbon cycling (Emmerling *et al*., 2000). High basal soil respiration values may indicated a perturbated or even highly productive environment (Islan and Weil, 2000).

5.3.3. Effect of biomineral enriched (Bokashi) compost on microbial respiratory quotient

The microbial respiratory quotient expresses the efficiency of substrate usage by the soil microorganisms (Anderson and Domsch, 1993). The highest microbial respiratory quotient was recorded by T_7 with the application of Bokashi compost prepared from *L.flava* which was enriched with calcium apatite, epsom salt and sylvinite. The higher the value of microbial respiratory quotient, the greater input of carbon in to the system (Scotton *et al.,* 2017).

5.3.4. Effect of biomineral enriched (Bokashi) compost on enzyme kinetics (V_{max} and K_m) of dehydrogenase

Knowledge concerning the dynamics and kinetics of soil enzymes is necessary for understanding their role in biogeochemical analysis. Knowledge of V_{max} and K_m values provide useful information regarding the interaction of enzyme with substrate (Gianfreda *et al*., 1995).

The highest V_{max} value was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. It was observed that highest value for K_m was also recorded by T_7 which was found to be on par with T_8.

Kujur and Patel (2014) observed a positive correlation between V_{max} value of dehydrogenase and organic matter content of the soil. The variation in K_m value with respect to soils from different treatments can be explained on the basis of capability of the enzyme catalysing the same reaction can have different sources in soil and thus different K_m values (Nannipieri *et al.,* 1990). Value of K_m reflects the apparent affinity of the enzyme for the substrate (Masciandaro *et al.,* 2000).

5.3.5. Effect of biomineral enriched (Bokashi) compost on biometric observations of bhindi var. Anjitha

The biometric characters such as root weight, root volume, plant height at first harvest, internodal length at final harvest, number of branches at flowering and dry matter production were significantly influenced by different treatments.

The root weight and root volume of plants treated with Bokashi composts were significantly higher than control and those treated with KAU POP recommendation (Fig 42 and Fig 43). Positive effects of Bokashi composts on root growth by increasing root length and root dry weight of shallot plants with Bokashi application was observed by Lasmini *et al.* (2018). The presence of 3- phenyl lactic acid (PLA), a metabolite of lactic acid bacteria was identified as the root promoting substance in Bokashi compost which may be the reason for increased root weight and root volume in Bokashi compost applied plants (Maki *et al*., 2021). Prisa (2020) also observed an increase in root volume with the application of Bokashi compost. Chen *et al*. (2021) observed that organic amendments enriched with minerals increased the root growth of rice.

The highest value of root weight was recorded with the application of Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was on par with T_7. The highest value of root volume was reported by Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_8. As observed from the incubation study, these composts have highest phosphorus availability in soil (Table 19). Williamson *et al.* (2001) observed that increased phosphorus availability increased the primary root growth in Arabidopsis.

The application of biomineral enriched Bokashi composts significantly increased the vegetative characteristics of plant. Lasmini *et al.* (2018) and Alvarez – Solis *et al.* (2016) observed similar results. The highest value of plant height and internodal length was observed with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_8, T_6, T_4 and T_9 (Fig 44).The number of branches and dry matter production were also found to be higher for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (Fig 45 and Fig 46). The sustained availability of higher levels of nitrogen from Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite might have resulted in higher vegetative growth and dry matter production in plants. Bokashi compost prepared from aqauatic weed contains high nitrogen element that function to optimize plant growth (Managanta *et al.*, 2023). The organic nitrogen present in the applied composts readily converted to ammoniacal and nitrate nitrogen through bacterial action and they become available for a longer period (Neff *et al.*, 2003).

Biomineral enriched Bokashi compost application increased the growth attributes and these observations are in conformity with the report of Prayogo and Ihsan (2018) and Prisa (2020).

5.3.6. Effect of biomineral enriched (Bokashi) compost on yield characters of bhindi var. Anjitha

Application of biomineral enriched (Bokashi) compost resulted in advancement of flowering in the test crop compared to control (Fig 47). The highest availability of nutrients in these treatments might have induced early flowering. Sreeja (2015) also observed an earlier flowering in plants treated with biomineral enriched composts.

The highest number of fruits was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_8, T_5 and T_6 (Fig 48). The highest value of fruit girth was recorded by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_8, T_6 and T_9 (Fig 49). Application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite registered the highest value for fruit length (Fig 50).

Yield per plant and total yield were found to be higher with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (Fig 51 and Fig 52).

Nutrients nitrogen, phosphorus and potassium contained in the biomineral enriched Bokashi compost can play a role in the growth and yield. Phosphorus serves as an energy source in various plant metabolic reactions, plays an important role increasing yields and provides lots of photosynthates which are distributed to the seeds. Fruit size and fruit quality can be influenced by the availability of potassium (Erner *et al.,* 1992). Better root development widens the area of nutrient uptake which in turn increases the yield (Shaheen *et al.,* 2007). Root system is the main nutrient uptake portal for crop, root exudates could improve the availability of soil nutrients and thus increase crop yield (Burton *et al*., 2013). Surawijaya *et al.* (2019) observed increased yield of red onion with the application of Bokashi produced from aquatic weed (*Eichornia crassipes*). Managanta *et al*. (2023) observed an increased yield in sweet corn when water hyacinth Bokashi was applied at a rate of 20 t ha^{-1}. Application of biomineral enriched compost increased the yield characters of yard long bean (Sreeja, 2015). The combined application of organic material, effective microorganism and minerals will improve soil structure, soil fertility, soil humus and stimulate the life of microorganisms in the soil. These microorganisms will improve the growth and yield of plants because of their role in fixing nitrogen from the air and converting ammonium to nitrate.

The efficacy of Bokashi application on the yield was reported by Mohan (2008), Roldi *et al.* (2013), Goulart *et al*. (2018), Amalia *et al.* (2020) and Soares *et al*. (2020).

5.3.7. B:C ratio

The mean values of B:C ratio ranged from 1.01 to 2.26. The B:C ratio was found to be higher with the application of bio mineral (Bokashi) composts compared to the control (Fig 53). Mohan (2008) observed a higher B:C ratio when Bokashi was applied for the cultivation of brinjal than control and other growth promoters like Amrit pani and Panchagavya.

5.3.8. Scoring of pest and diseases

Occurence of Bhindi yellow vein mosaic was there during the initial stages of growth which was effectively managed using nimbicidin (2%) and pseudomonas (2% solution). No major incidence of pests and diseases could be observed. Decreased incidence of pest and diseases with the application of Bokashi was observed by Khaeruni *et al.* (2020), Al-Jarah *et al.* (2016) and Roldi *et al.* (2013). Lactic acid bacteria and actinomycetes present in the EM used for the preparation of Bokashi composts acts to sterilize soils and suppress harmful microorganisms (Condor *et al*., 2007).

5.3.9. Effect of biomineral enriched (Bokashi) compost on yield of residual crop

The yield of residual crop was very poor which indicates the poor residual effect of composts. The highest yield was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt an sylvinite.

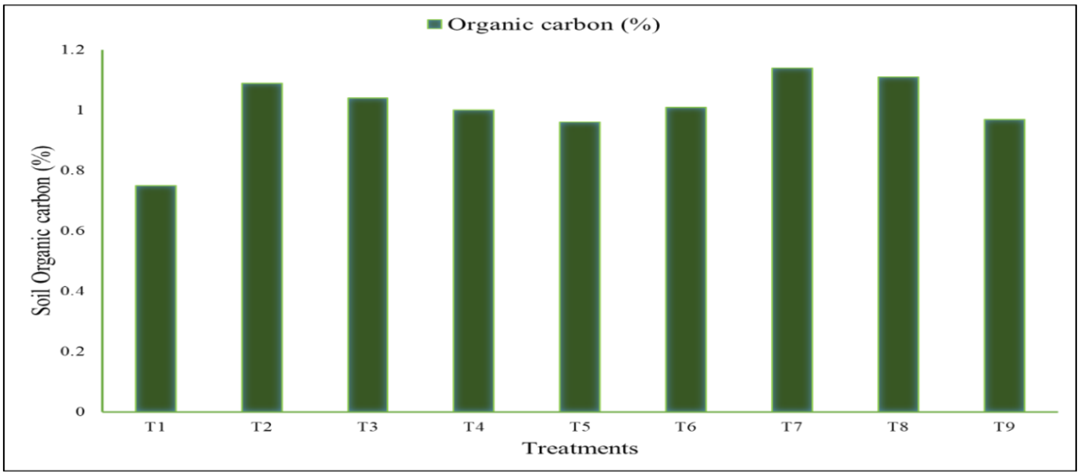


Fig 33. Effect of treatments on organic carbon content (%) of postharvest soil.

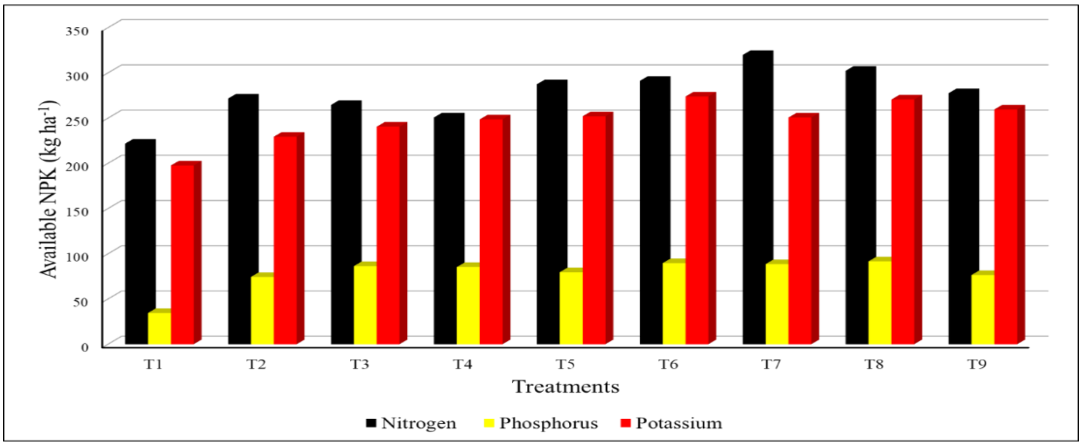


Fig 34. Effect of treatments on available NPK content (kg ha^{-1}) of postharvest soil

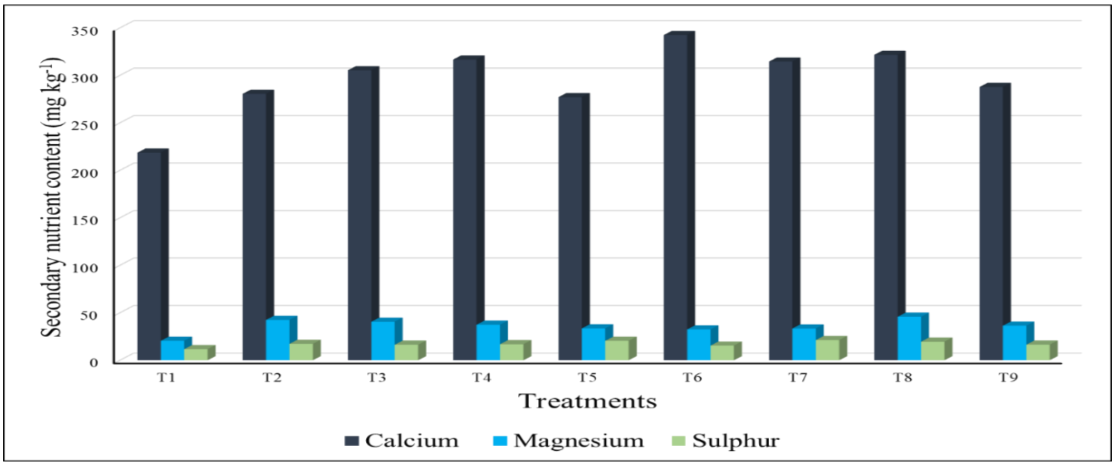


Fig 35. Effect of treatments on secondary nutrients (mg kg^{-1}) in postharvest soil

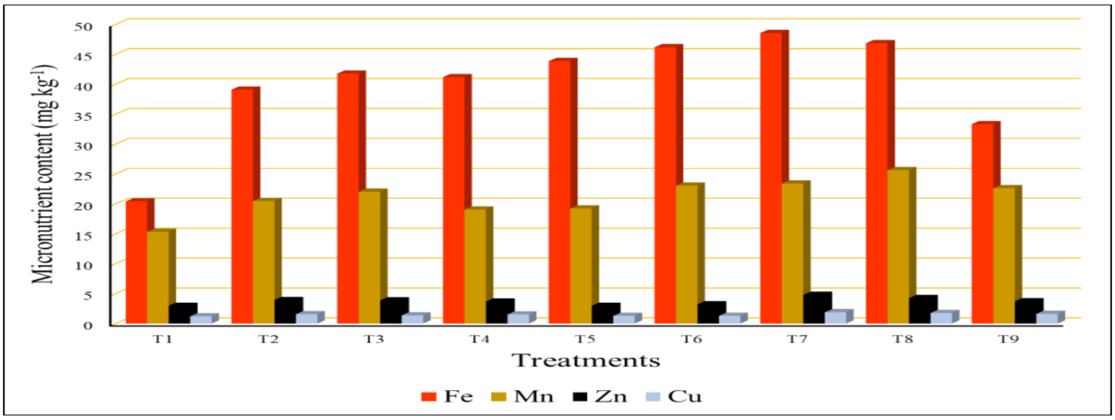


Fig 36. Effect of treatments on micronutrient content (mg kg^{-1}) of postharvest soil

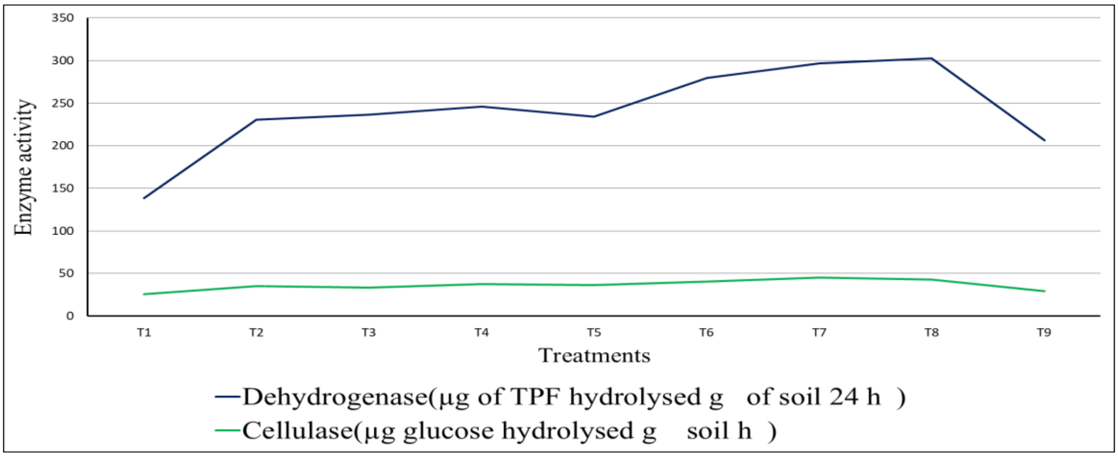


Fig 37. Effect of treatments on the enzyme activity of pot harvest soil

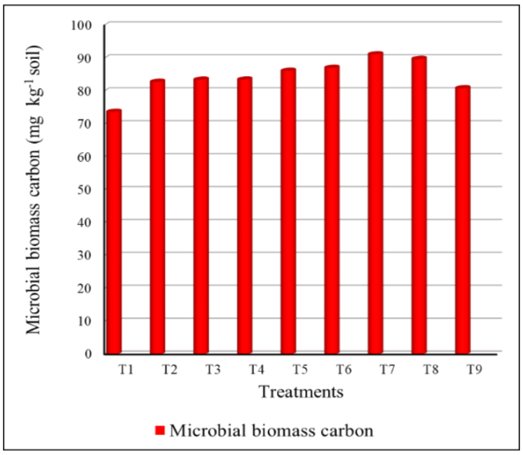


Fig 38. Effect of treatments on the microbial biomass carbon (mg kg^{-1}soil) of rhizosphere

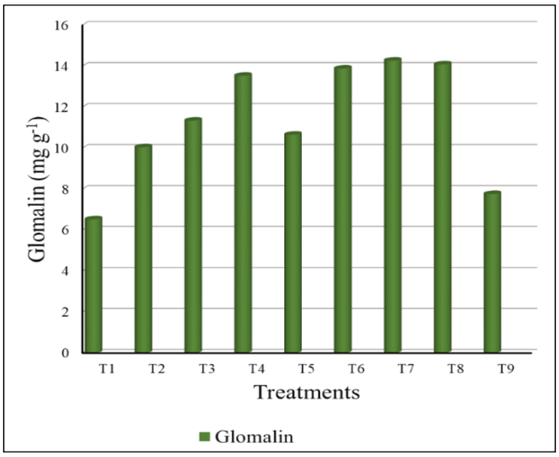


Fig 39. Effect of treatments on the glomalin content (mg g^{-1}) of rhizosphere soil

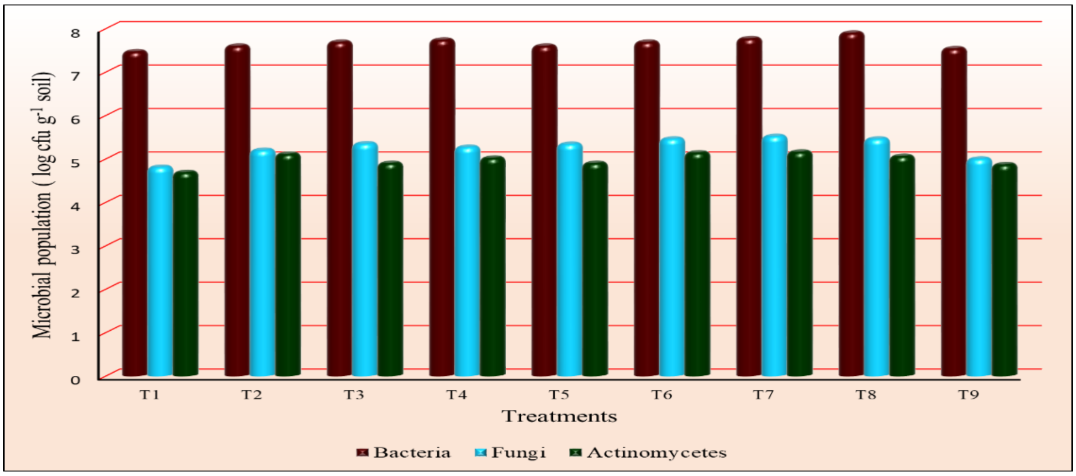


Fig 40. Effect of treatments on population of microorganisms (log cfu g^{-1} soil) in rhizosphere soil

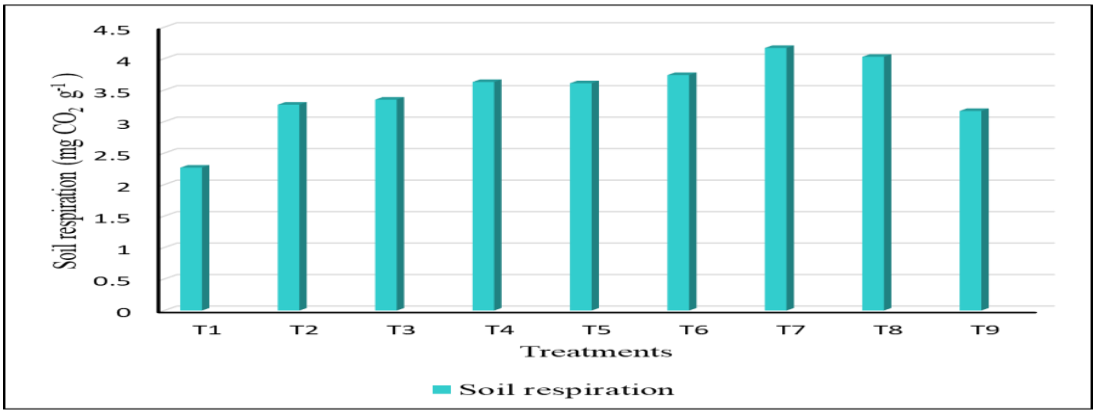
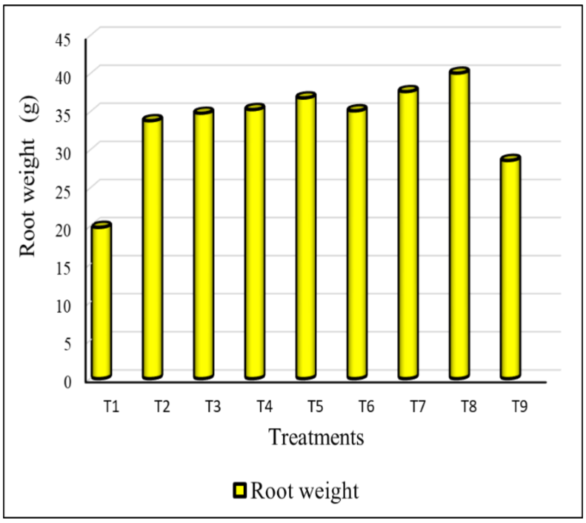


Fig 41. Effect of treatments on soil respiration (mg CO_2 g^{-1}) in rhizosphere soil



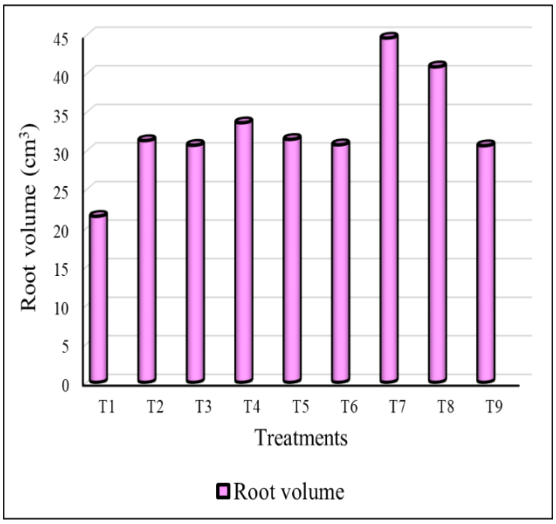


Fig 42. Effect of treatments on the root length volume (cm) of the bhindi var.Anjitha

Fig 43. Effect of treatments on the root of the bhindi var. Anjitha

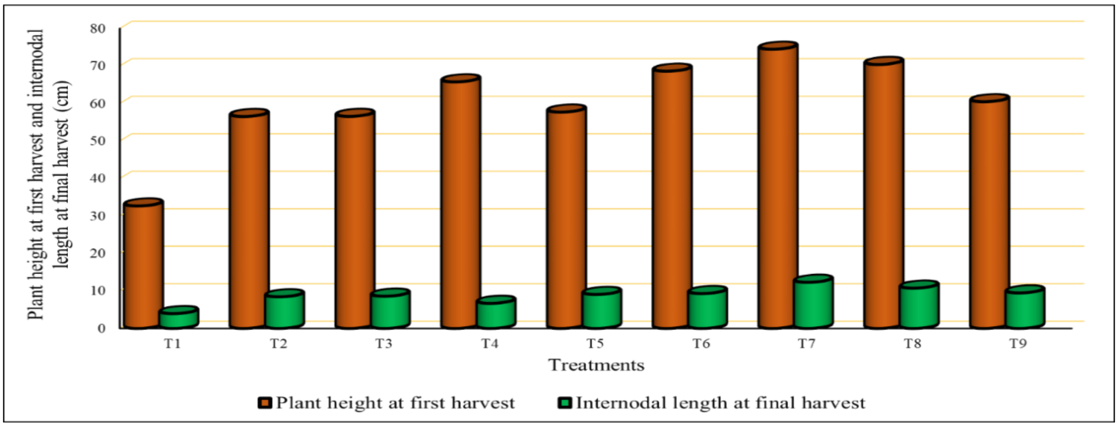


Fig 44. Effect of treatments on the plant height at first harvest (cm) and intermodal length at final harvest of bhindi var. Anjitha

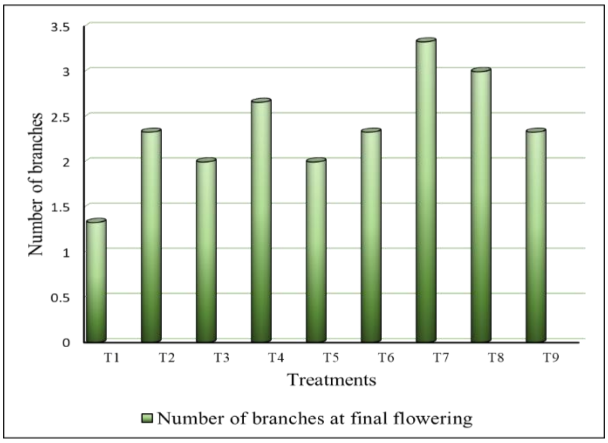


Fig 45. Effect of treatments on number of branches at final flowering of bhindi var. Anjitha

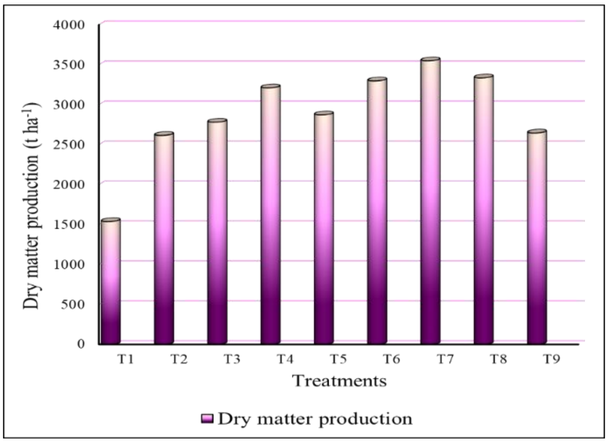


Fig 46. Effect of treatments on dry matter production (t ha^{-1}) of bhindi var. Anjitha

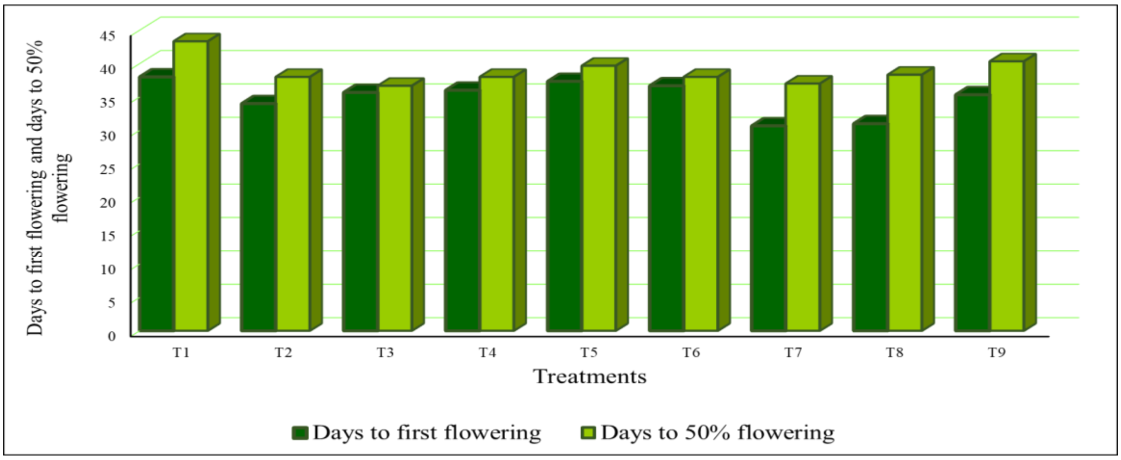


Fig 47. Effect of treatments on days to first flowering and days to 50% flowering of bhindi var. Anjitha

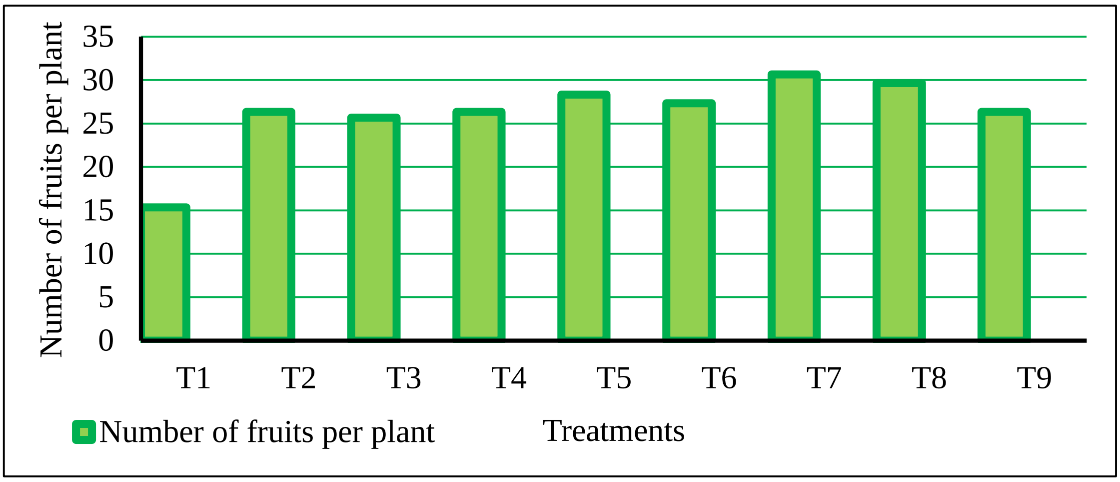


Fig 48. Effect of treatments on number of fruits per plant of bhindi var. Anjitha

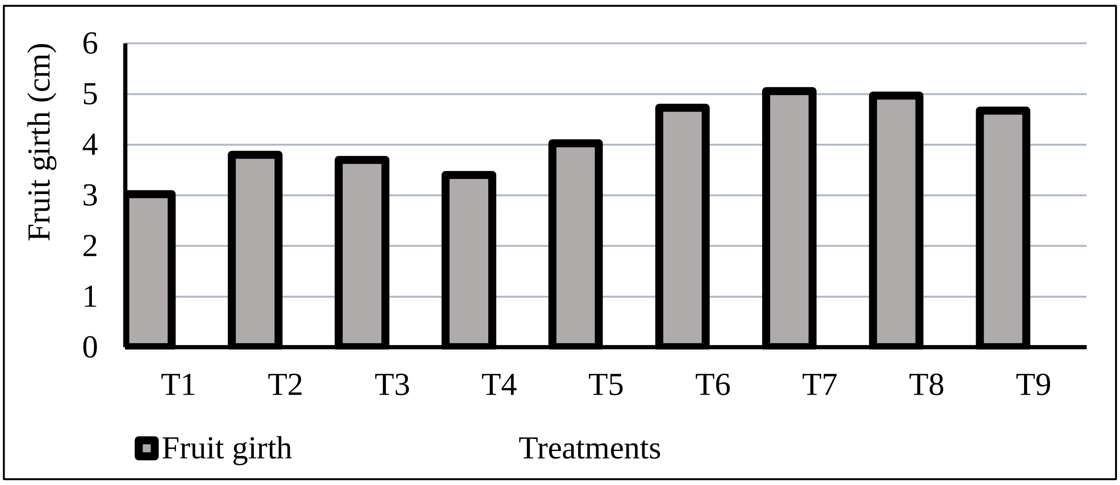


Fig 49. Effect of treatments on fruit girth (cm) of bhindi var. Anjitha

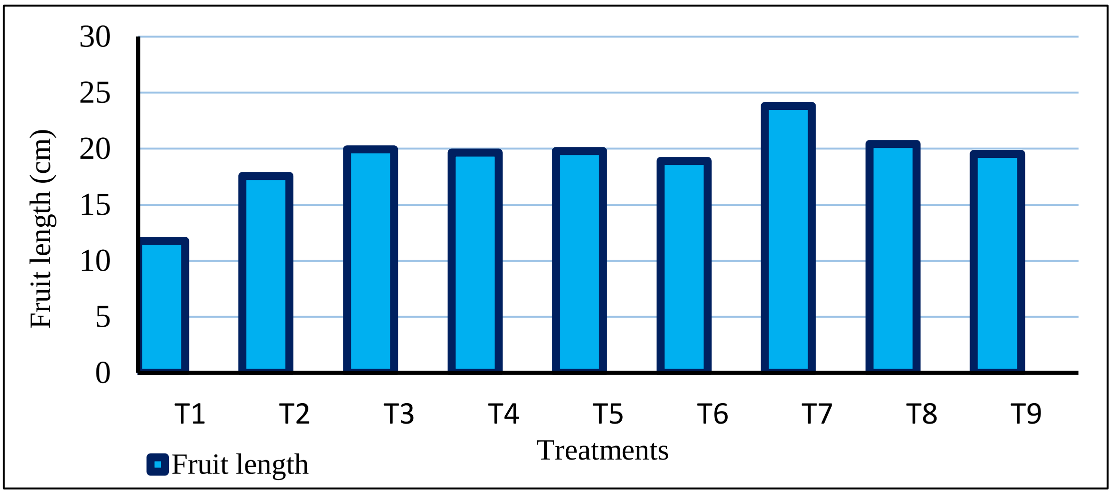


Fig 50. Effect of treatments on fruit length (cm) of bhindi var. Anjitha

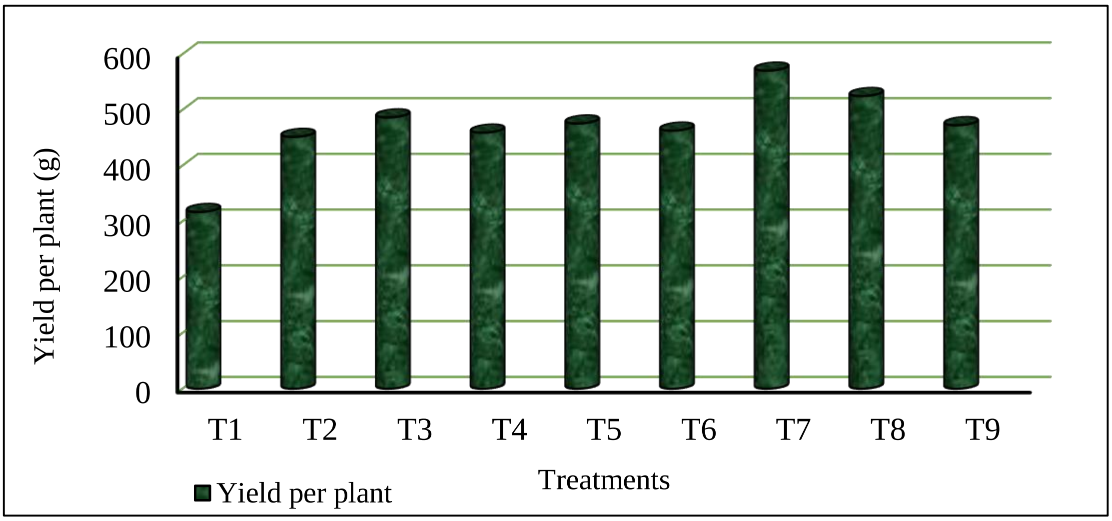


Fig 51. Effect of treatments on the yield per plant (g) of bhindi var. Anjitha

Treatments

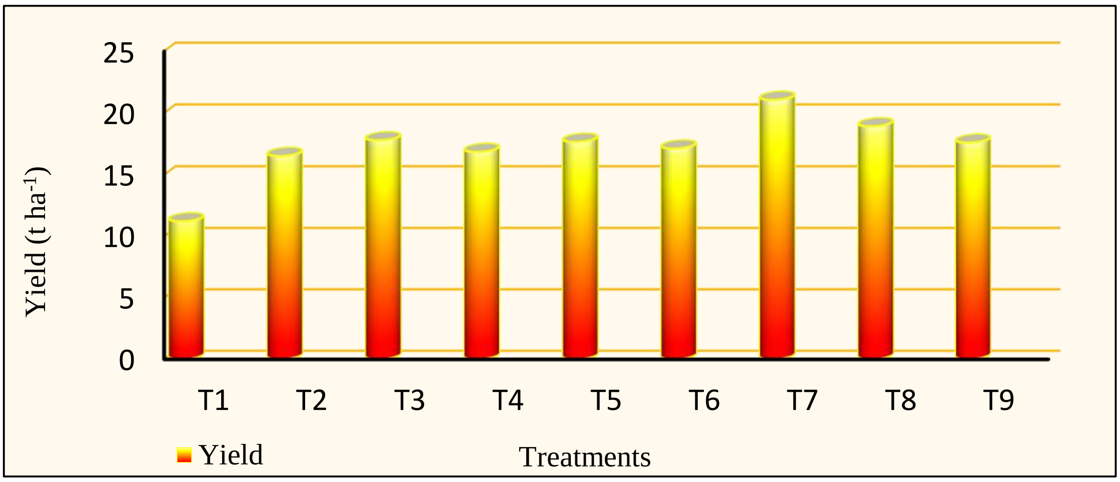


Fig 52. Effect of treatments on the yield (t ha^{-1}) of bhindi var. Anjitha

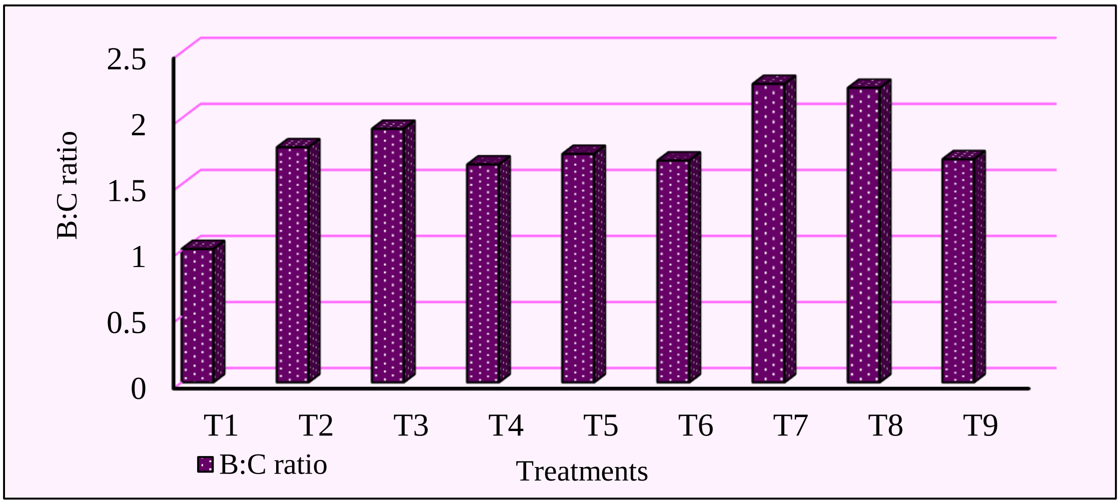


Fig 53. Effect of treatments on the B:C ratio

6. SUMMARY

The study entitled " Biomineral enriched composts (Bokashi) - A tool for enhancing nutrient availability and enzyme activity in rhizosphere" was carried out in the Department of Soil Science and Agricultural Chemistry, Vellayani, Thiruvananthapuram with the objectives to prepare and characterize biomineral enriched (Bokashi) composts from different organic sources, evaluate the nutrient release pattern under laboratory conditions and to evaluate the performance of biomineral enriched (Bokashi) compost in field conditions using bhindi as a test crop and amaranthus as a residual crop. The study comprised of three parts and the summary of salient findings is presented below.

6.1. Production and characterization of biomineral enriched (Bokashi) composts from different organic sources

Bokashi composts were prepared by the anaerobic fermentation of two substrates S_1 (*L.flava*) and S_2 (1:1 mixture of *L.flava* and banana pseudostem) using EM solution 1. The matured composts were enriched with three minerals calcium apatite (M_1), epsom salt (M_2) and sylvinite (M_3) in different combinations.

- The colour of all the composts were dark brown. The Bokashi compost produced from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest water holding capacity and the lowest bulk density. The moisture content of the produced biomineral enriched Bokashi composts ranged from 23.19 % to 31.83 %.
- The pH values of the produced biomineral enriched (Bokashi) composts ranged from 6.66 to 7.39 while the electrical conductivity values ranged from 3.21 dSm^{-1} to 3.38 dSm^{-1}.
- The biomineral enriched (Bokashi) composts produced from S_2 (1:1 mixture of *L.flava* and banana pseudostem) registered comparatively higher values of cellulose, hemicellulose and lignin than S_1 (*L.flava*). The cellulose content was found to be higher than Bokashi compost prepared

from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite registered the highest value for hemicellulose and Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt registered the highest value for lignin.

- ❖ Bokashi compost produced from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest values of organic carbon, nitrogen and phosphorus content while potassium content was found to be highest for Bokashi compost produced from a 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite.
- ❖ Bokashi compost produced from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite recorded the highest value for total calcium content. The highest value of total magnesium content was recorded by the Bokashi compost produced from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt.
- ❖ Bokashi compost produced from *L.flava* enriched with calcium apatite and epsom salt recorded the highest sulphur content while the boron content was recorded highest for Bokashi compost produced from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite.
- ❖ The micronutrient content (Fe, Mn, Zn and Cu) was found to be higher for Bokashi compost produced from *L.flava* enriched with calcium apatite, epsom salt and sylvinite.
- ❖ The biological properties like bacterial and fungal population and enzyme activity (dehydrogenase and cellulase) was found to be higher for Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite.
- ❖ The C:N ratio of produced biomineral enriched Bokashi composts ranged from 9.59 to 11.92. The lowest C:N ratio (9.59) was recorded by Bokashi

compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite followed by Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite.

- ❖ The values of fertilizing index ranged from 4.40 to 5.00. The highest value of fertilizing index (5.00) was recorded by Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite recorded the second highest value of fertilizing index (4.80).
- ❖ Based on the selection indices like fertilizing index, available major and minor nutrients, enzyme status and C:N ratio the best seven composts selected are Bokashi compost prepared from *L.flava* enriched with epsom salt, Bokashi compost prepared from *L.flava* enriched with calcium apatite and epsom salt, Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt, Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt and sylvinite, Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite, Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite and Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite.
- ❖ Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite was concluded as the best compost with highest values of nitrogen, phosphorus, micro nutrients and enzyme activity. T_{13} also have the lowest C:N ratio.

5.2. Soil incubation study for evaluating the nutrient release pattern

To monitor the nutrient release pattern the selected seven biomineral (Bokashi) composts an incubation study was conducted. The soil was collected from the Model Organic Farm under the Department of Organic Agriculture. Inubation was conducted for a period of four months at field capacity.

- An increasing trend in nitrogen release was observed from the composts. Available phosphorus content increased up to 4th week of incubation and then a drastic decrease can be observed during 8th week of incubation. The highest value of release of available potassium was observed during the 12th week of incubation. The highest value of nitrogen was noticed in Bokashi compost prepared from *L.flava* enriched with calcium apatite epsom salt and sylvinite recorded the highest value while phosphorus and potassium released from soil treated with Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite recorded the highest value.
- The exchangeable calcium content increased up to 4th week of incubation and there after a decrease can be observed. The highest value of exchangeable magnesium content was observed during the 16th week of incubation by the application of Bokashi compost produced from *L.flava* enriched with calcium apatite, epsom salt and sylvinite. A drastic decrease in sulphur content can be observed during 8th week of incubation and an increasing trend in sulphur content can be observed thereafter.
- Application Bokashi compost produced from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest value of iron content throughout the incubation period with maximum value recorded at 4th week of incubation. Manganese content was found to be increasing up to 8th week of incubation. The highest value of manganese release was observed for Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite during the 1st and 4th week of incubation.
- An increase in copper content can be observed from 1st to 4th week of incubation for all the treatments. The highest value of zinc content was recorded during 12th week of incubation.

- Application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, Epsom salt and sylvinite recorded highest value of organic carbon throughout the incubation study. Organic carbon content increased up to 4th week of incubation, which decreased during 8th week of incubation.
- It observed that the dehydrogenase and cellulase activity increased up to 4th week of incubation then decreased and then became stable. The highest value for dehydrogenase and cellulase activity was recorded by the application of Bokashi compost produced from *L.flava* enriched with calcium apatite, Epsom salt and sylvinite, throughout the incubation period.
- Application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite and Bokashi compost preapaed from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite recorded high values for most of the nutrients during incubation period like nitrogen, phosphorus, magnesium, sulphur, manganese, zinc, copper, organic carbon and enzyme activity.

5.3. Field experiment for evaluating the performance of biomineral enriched (Bokashi) composts

A field experiment was conducted using bhindi var. Anjitha as the test crop and amaranthus var. Arun as the residual crop for evaluating the performance of biomineral enriched (Bokashi) composts. The design followed is RBD with 9 treatments replicated thrice.

Salient findings of the field experiment are summarized below

- Analysis of postharvest and rhizosphere soil showed that the chemical and biological properties of the soil varied significantly with the treatments. The highest pH was recorded by the application of Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. The EC was highest with the application of KAU POP recommendation.

- The highest mean value for organic carbon and nitrogen in the postharvest soil was recorded by treatment T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite.
- The highest value for phosphorus in the postharvest soil was reported by T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_7. The highest value of potassium content in the postharvest soil was recorded by T_6 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite which was on par with T_8.
- The highest calcium content was recorded by T_6 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite. It was observed that T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite recorded the highest value of magnesium while sulphur content was found to be higher for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite.
- The iron, copper and zinc content of postharvest soil was recorded highest with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite while T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite recorded the highest value for manganese.
- The highest dehydrogenase activity of the soil was recorded by T_8 with the application of Bokashi compost prepared from 1:1 mixture of *L.flava*

and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite which was on par with T_7. The highest cellulase activity of the soil was recorded for T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite.

- ❖ T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest values of microbial biomass carbon, glomalin, humic acid and fulvic acid content of rhizosphere soil.
- ❖ The bacterial population was highest for T_8 with the application of Bokashi prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite while T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite recorded the highest fungal population, actinomycetes population, soil respiration and V_{max} and K_m values. T_7 also recorded the highest value of microbial respiratory quotient which was found to be on par with T_8 and T_4.
- ❖ The highest value of root weight was recorded with the application of Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, Epsom salt and sylvinite which was on par with T_7. The highest value of root volume was reported by Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite which was found to be on par with T_8.
- ❖ The highest value of plant height and internodal length was observed with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite (T_7) which was found to be on par with T_8, T_6, T_4 and T_9. The number of branches and dry matter production were also found to be higher for T_7.
- ❖ Application of biomineral enriched Bokashi compost resulted in the advancement of flowering.

- The highest number of fruits was reported by T_7 which was found to be on par with T_8, T_5 and T_6. The highest value of fruit girth was recorded by T_7 which was found to be on par with T_8, T_6 and T_9.
- The highest yield per plant, total yield and the highest B:C ratio was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite.
- No major incidence of pests and diseases could be observed except the minor incidence of Bhindi Yellow Vein Mosaic during the initial stages of crop growth.
- The yield from residual crop amaranthus was very poor. The highest yield of amaranthus was reported by T_7 with the application of Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt an sylvinite.
- T_7 (Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite) recorded as the best treatment with high values of most of the nutrient content on the postharvest soil like nitrogen, sulphur, iron, zinc, copper and boron high biological properties, high yield and B:C ratio.

CONCLUSION

Thus it was inferred from the study that Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite (T_{13}) was concluded as the best compost. Application of Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite (T_7) and application Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite (T_8) recorded highest values for most of the nutrients during incubation period. Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite (T_7) recorded as the best treatment during the field study showing significantly highest yield and B:C ratio. From the present study for the crop Bhindi (var Anjitha), the nutrient recommendation suggested is 20 t ha^{-1} of FYM, 2.8 t ha^{-1} of Bokashi compost, 110.6 kg ha^{-1} of SSP and 19.9 kg ha^{-1} of MOP.

FUTURE LINE OF WORK

- Not much work had done in Kerala with respect to Bokashi composts. More works has to be done and dose application of Bokashi compost should be standardised for different crops.
- Efforts should be taken to popularise this method of composting among the farming community of Kerala since it is comparatively cheap and easy method compared to conventional methods of composting.
- Enrichment of compost improved the nutrient content of the Bokashi composts. More works has to be done to standardize the rate of application of minerals to the Bokashi composts.

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APPENDIX I

COMPOSITION OF MEDIA FOR MICROBIAL ENUMERATION

1. Enumeration of Bacteria

Media: Nutrient Agar

Composition

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

2. Enumeration of Fungi

Media: Martin's Rose Bengal Agar

Composition

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

3. Enumeration of Actinomycetes

Ken Knight's agar medium

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

APPENDIX II

Weather data during field experiment

(February, 2022 to June, 2022) – Weekly averages of temperature, rainfall, relative humidity and evaporation

Standard weeks	Temperature (°C)		Average rainfall (mm)	Relative humidity (%)		Evaporation (mm)
	Maximum	Minimum		maximum	minimum	
7	31.85	21.46	9.74	93.86	79.57	2.97
8	32.24	21.48	0.8	91.28	77.14	3.86
9	32.74	22.14	0	91.57	74.71	3.87
10	32.84	24.1	0.114	90.14	78.14	4.07
11	33.44	24.36	0	89.28	75.71	4.3
12	33.93	25.28	0	87.71	76.43	4.63
13	33.76	25.16	0	87.71	75.71	4.61
14	33.46	23.36	5.71	89.14	83.71	3.61
15	32.51	21.33	5.14	91.85	89.28	2.27
16	32.72	21.58	0.84	90.28	80.71	3.65
17	33.43	23.26	3.714	87.43	76.57	3.85
18	33.91	23.87	3.04	89.71	75.43	3.84
19	33.61	23.84	5.74	89.28	81.28	3.68
20	30.97	22.91	33.57	96.57	88.57	0.68
21	31.17	23.26	10.66	91.42	85.71	2.56
22	31.35	23.35	13.88	91.71	85.14	3.06
23	31.4	23.48	2.57	91.28	88.14	3.48

BIOMINERAL ENRICHED COMPOSTS (BOKASHI) – A TOOL FOR ENHANCING NUTRIENT AVAILABILITY AND ENZYME ACTIVITY IN RHIZOSPHERE

by

SHILPA S

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ABSTRACT OF THE THESIS

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ABSTRACT

Biomineral enriched composts (Bokashi) – A tool for enhancing nutrient availability and enzyme activity in rhizosphere

The study entitled "Biomineral enriched composts (Bokashi) – A tool for enhancing nutrient availability and enzyme activity in rhizosphere" was carried out during 2020-22 in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. The objective of the study was the production and evaluation of biomineral enriched composts for enhanced nutrient availability, yield of test crop (Bhindi) and enzyme activity in the rhizosphere. The study comprised of three parts *viz.*, production and characterization of biomineral (Bokashi) composts from different organic sources, soil incubation study for evaluating the nutrient release pattern and field experiment for evaluating the performance of the biomineral enriched (Bokashi) compost.

Bokashi composts were prepared from two substrates S_1 (Aquatic weed *Limnocharis flava*) and S_2 (Aquatic weed *Limnocharis flava* and banana pseudostem in 1:1 ratio). The substrates were allowed to ferment anaerobically using EM solution and the matured composts were enriched with three minerals like M_1 (Calcium apatite), M_2 (Epsom salt) and M_3 (Sylvinite) at 2% rate in different combinations. The design followed was Completely Randomized Design with 14 treatments replicated thrice. The treatment combinations were T_1 – Bokashi compost prepared from *L.flava* enriched with calcium apatite, T_2 - Bokashi compost prepared from *L.flava* enriched with epsom salt, T_{3}- Bokashi compost prepared from *L.flava* enriched with sylvinite, T_4 –Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, T_5 - Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt, T_6 - Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with sylvinite, T_7- Bokashi compost prepared from *L.flava* enriched with calcium apatite and epsom salt, T_8 - Bokashi

compost prepared from *L.flava* enriched with epsom salt and sylvinite, T_9 - Bokashi compost prepared from *L.flava* enriched with calcium apatite and sylvinite, T_{10} - Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and epsom salt, T_{11} - Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with epsom salt and sylvinite, T_{12} - Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite and sylvinite , T_{13} – Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite and T_{14} - Bokashi compost prepared from 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite. To all the treatments (T_1 – T_4) zeolite was added at a rate of 0.5%.

The physico-chemical and biological properties of the produced composts were subjected to analysis. Based on the analysed parameters like major and minor nutrient, enzyme activity, C:N ratio, fertilizing index the best seven composts selected for incubation study and field experiment were T_2, T_7 , T_{10}, T_{11}, T_{12}, T_{13} and T_{14}. Among these T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) was selected as the best compost with the highest values of nitrogen, phosphorous, micro nutrients and enzyme activity while the lowest value of C:N ratio was also reported by T_{13}.

In part 2 of the study a soil incubation was carried out to investigate the nutrient release pattern of selected composts. The design followed is CRD with 8 treatments which was replicated thrice. One kg soil was incubated at field capacity for four months. The treatments were T_1 - Absolute control, T_2 to T_8 - selected best seven composts. The treatments were imposed at surface of the soil at 20 g kg^{-1} and thoroughly mixed. Soil sample was drawn at 1^{st}, 4^{th}, 8^{th}, 12^{th} and 16^{th} week of incubation and analysed for organic carbon, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, dehydrogenase and cellulase activity. From the study, it was observed that nitrogen, phosphorous, potassium, calcium, sulphur, iron, copper, organic carbon and enzyme activity were found to be maximum at the 4^{th} week of incubation. Zinc content was observed to be maximum during 12^{th} week of incubation while magnesium content was highest during 16th week of incubation. Manganese availability was maximum during 8th week of incubation.

In part 3 of the study a field experiment was conducted from February – May 2022 with Bhindi (var. Anjitha) as the main crop and Amaranthus (var. Arun) as the residual crop. In the field experiment 9 treatments were imposed viz. T_1 - Absolute control, T_2 to T_8 – selected best seven composts and T_9 - KAU POP recommendation.

Analysis of postharvest soil for chemical properties revealed that the highest value of organic carbon (1.14 %) and nitrogen (319.86 kg ha^{-1}) was recorded for T_7. The highest value for available phosphorous (91.65 kg ha^{-1}) was recorded for T_8 which was on par with T_6 (89.67 kg ha^{-1}) and T_7 (88.59 kg ha^{-1}). The potassium content was found to be the highest for T_6 (273.91 kg ha^{-1}) which was on par with T_8 (270.60 kg ha^{-1}). T_7 recorded the highest values of iron (48.54 mg kg^{-1}), zinc (4.79 mg kg^{-1}), copper (1.88 mg kg^{-1}) and boron (0.832 mg kg^{-1}). While manganese (25.62 mg kg^{-1}) was reported to be the highest with regard to T_8. The highest value of cellulase activity was recorded by T_7 (45.53 µg glucose hydrolysed g^{-1} soil h^{-1}) while T_8 recorded the highest value of dehydrogenase activity (302.68 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}).

Analysis of rhizosphere soil showed the highest value of microbial biomass carbon (91.14 mg kg^{-1} soil), glomalin (14.27 mg g^{-1}), humic acid (9.21 %), fulvic acid (9.98), fungi (5.52 log cfu g^{-1}), actinomycetes (5.16 log cfu g^{-1}) and soil respiration (4.17 mg CO_2 g^{-1}) for T_7 while T_8 recorded highest value for bacteria (7.90 log cfu g^{-1}).

T_7 recorded the highest value for number of fruits per plant (30.67) which was on par with T_5, T_6, and T_8. Fruit girth was found to be the highest for T_7 (5.06 cm) which was on par with T_6, T_8 and T_9. T_7 also recorded the highest value for fruit length (23.81 cm), yield per plant (570.42 g) and total yield (21.05 t ha^{-1}). The highest B: C ratio (2.26) was reported by T_7. The highest yield of amaranthus (130.23 kg ha^{-1}) was recorded for T_7.

From the study, T_{13} (Bokashi compost prepared from *L.flava* enriched with calcium apatite, epsom salt and sylvinite) was concluded as the best compost. T_7 (Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite) and T_8 (Bokashi compost prepared from the 1:1 mixture of *L.flava* and banana pseudostem enriched with calcium apatite, epsom salt and sylvinite) recorded the highest values for the available nutrient status during incubation period like nitrogen, phosphorous, magnesium, sulphur, iron, manganese, zinc, copper, organic carbon and enzyme activity. Considering both the soil parameters and yield parameters T_7 (Bokashi compost prepared from *L. flava* enriched with calcium apatite, epsom salt and sylvinite) was recorded as the best treatment.

സംഗ്രഹം

“ജൈവ-ധാതു സമ്പുഷ്ടമായ കമ്പോസ്റ്റ് (ബൊകാശി) -റൈയ്സോസ്സ്ഫിയറിലെ പോഷക ലഭ്യതയും എൻസൈം പ്രവർത്തനവും വർധിപ്പിക്കുന്നതിനുള്ള ഒരു ഉപാധി” എന്ന തലക്കെട്ടിലുള്ള പഠനം 2020-22 കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിലെ സോയിൽ സയൻസ് ആൻഡ് അഗ്രിക്കൾച്ചറൽ കെമിസ്ട്രി വിഭാഗത്തിൽ നടത്തി. മണ്ണിലെ മെച്ചപ്പെട്ട പോഷക ലഭ്യതക്കും പരീക്ഷണ വിളയുടെ (വെണ്ട) മെച്ചപ്പെട്ട വിളവിനും , റൈസോസ്പിയറിലെ മെച്ചപ്പെട്ട എൻസൈം പ്രവർത്തനത്തിനുമായി ജൈവ - ധാതു സമ്പുഷ്ടമായ ബൊകാശി കമ്പോസ്റ്റിന്റെ ഉല്പാദനവും വിലയിരുത്തലും എന്നതായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യം. വിവിധ ജൈവ സ്രോതസ്സുകളിൽ നിന്നും ബൊകാശി കമ്പോസ്റ്റിന്റെ ഉല്പാദനവും വിലയിരുത്തലും, പോഷക മോചനത്തിന്റെ മാതൃക വിലയിരുത്തുന്നതിനുള്ള മണ്ണ് ഇൻക്യൂബേഷൻ പഠനം, പ്രകടനം വിലയിരുത്തുന്നതിനുള്ള കൃഷിയിട പഠനം എന്നിങ്ങനെ മൂന്ന് ഭാഗങ്ങളായാണ് പഠനം നടത്തിയത്.

S_1 (ജല കളയായ ലിംനോക്കാരിസ് ഫ്ലാവ), S_2 (1:1 അനുപാതത്തിലുള്ള ജല കളയായ ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതം) എന്നിവയാണ് ബൊകാശി കമ്പോസ്റ്റിൻറെ ഉല്പാദനത്തിനു വേണ്ടിയുള്ള രണ്ട് അടിസ്ഥാന പദാർത്ഥങ്ങളായി ഉപയോഗിച്ചത്. ഇവയെ EM ലായനി ഉപയോഗിച്ചു വായുരഹിതമായി പുളിപ്പിക്കുകയും, അപ്രകാരം തയ്യാറാക്കിയ കമ്പോസ്റ്റിനെ, M_1 (കാൽസിയം അപ്പറ്റയിറ്റ്), M_2(ഇപ്സം സാൾട്), M_3(സിൽവിനൈറ്റ്) തുടങ്ങിയ മൂന്ന് ധാതുക്കൾ ഉപയോഗിച് സമ്പുഷ്ടീകരിക്കുകയും ചെയ്തു. ഇപ്രകാരം മൂന്നു തവണ ആവർത്തിക്കുന്ന രീതിയിൽ പതിന്നാല് തരം കമ്പോസ്റ്റുകളാണ് CRD മാതൃകയിൽ ഉത്പാദിപ്പിച്ചത്. T_1 (ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ് ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_2(ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു ഇപ്സം സാൾട് ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_3(ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു സിൽവിനൈറ്റ് ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_4(1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ് ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_5(1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും

മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചു ഇപ്സം സാൾട് ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_6 (1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചു സിൽവിനൈറ്റ് ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_7(ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_8(ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_9(ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_{10}(1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചുകാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_{11}(1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചു ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_{12}(1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_{13} (ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്), T_{14} (1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്) എന്നിവയായിരുന്നു പതിന്നാലു തരം കമ്പോസ്റ്റുകൾ. ഉത്പ്പാദിപ്പിച്ച എല്ലാ കമ്പോസ്റ്റുകളിലും 0.5% അളവിൽ സിയോലൈറ്റ് ചേർത്തു യോജിപ്പിക്കുകയും ചെയ്തു.

ഉത്പാദിപ്പിച്ച കമ്പോസ്റ്റ്കളുടെ ബാഹ്യ-രാസ-ജൈവിക പ്രത്യേകതകൾ പരിശോധനക്കു വിധേയമാക്കുകയും, കമ്പോസ്റ്റിലെ പോഷകങ്ങളുടെ അളവ്, എൻസൈമിൻറെ പ്രവർത്തനം, കാർബൺ - നൈട്രജൻ അനുപാതം, ഫെർട്ടിലൈസഷൻ ഇൻഡക്സ് എന്നിവയുടെ അടിസ്ഥാനത്തിൽ ഏഴു മികച്ച കമ്പോസ്റ്റുകളെ ഇൻക്യൂബേഷൻ പഠനത്തിനും, കൃഷിയിട പഠനത്തിനും വേണ്ടി തിരഞ്ഞെടുത്തു. T_2, T_7, T_{10}, T_{11}, T_{12}, T_{13}, T_{14} തുടങ്ങിയവയാണിവ. ഇവയിലെ T_{13}

(ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്) നെ നൈട്രജൻ, ഫോസ്ഫറസ്, ലഘു പോഷണങ്ങൾ, എൻസൈം അളവ് എന്നിവ കൂടുതൽ ആയി കാണപ്പെടുകയും, കാർബൺ നൈട്രജൻ അനുപാതം കുറഞ്ഞു കാണപ്പെടുകയും ചെയ്തതിനാൽ മികച്ച കമ്പോസ്റ്റായി തിരഞ്ഞെടുത്തു.

പഠനത്തിന്റെ രണ്ടാം ഭാഗത്തിൽ പോഷക മോചനത്തിന്റെ മാതൃക വിലയിരുത്തുന്നതിനായി തിരഞ്ഞെടുത്ത കമ്പോസ്റ്റുകളെ ഇൻക്യൂബേഷൻ പഠനത്തിനു വിദേയമാക്കി. CRD മാതൃകയിൽ മൂന്നു തവണ ആവർത്തിക്കുന്ന എട്ട് ട്രീട്മെന്റുകളായാണ് കമ്പോസ്റ്റിനെ ഇൻക്യൂബേഷൻ പഠനത്തിനു വിദേയമാക്കിയത്. ഒരു കിലോഗ്രാം മണ്ണ് നാല് മാസക്കാലം ഫീൽഡ് കാപ്പാസിറ്റിയിൽ ഇൻക്യൂബേഷൻ നടത്തി. T_1- മണ്ണ് മാത്രം, T_2-T_8 - തിരഞ്ഞെടുത്ത ഏഴു കമ്പോസ്റ്റുകൾ എന്നിവയായിരുന്നു ട്രീട്മെന്റുകൾ. ഒരു കിലോഗ്രാം മണ്ണിൽ ഇരുപത് ഗ്രാം കമ്പോസ്റ്റ് എന്ന അളവിൽ നിക്ഷേപിക്കുകയും നല്ലതുപോലെ ഇളക്കി കൊടുക്കുകയും ചെയ്തു. ഇൻക്യൂബേറ്റ് ചെയ്ത മണ്ണിലെ ഓർഗാനിക് കാർബൺ, നൈട്രജൻ, ഫോസ്ഫറസ്, പൊട്ടാസിയം, കാൽസ്യം, മഗ്നീഷ്യം, സൾഫർ, ലഘു പോഷണങ്ങൾ, എൻസൈമിൻറെ അളവ് എന്നിവ ഇൻക്യൂബേഷനു ശേഷമുള്ള 1,4,8,12,16 ആഴ്ചകളിൽ പരിശോധിച്ചു. പഠനത്തിന്റെ അടിസ്ഥാനത്തിൽ മണ്ണിലെ നൈട്രജൻ, ഫോസ്ഫറസ്, പൊട്ടാസിയം, കാൽസ്യം, സൾഫർ, അയൺ, കോപ്പർ, ഓർഗാനിക് കാർബൺ, എൻസൈം എന്നിവയുടെ അളവ് നാലാമത്തെ ആഴ്ച കൂടുതലായി കാണപ്പെട്ടു. സിങ്ക്, മഗ്നീഷ്യം, മാംഗനീസ് എന്നിവയുടെ അളവ് യഥാക്രമം ഇൻക്യൂബേഷനു ശേഷമുള്ള 12,16,8 ആഴ്ചകളിൽ കൂടുതലായി കാണപ്പെട്ടു.

പഠനത്തിന്റെ മൂന്നാം ഭാഗത്തിൽ 2022 ഫെബ്രുവരി-മെയ് മാസത്തിൽ ഒരു കൃഷിയിട പരീക്ഷണം നടത്തി. അഞ്ചിത വെണ്ട ഇനം ഉപയോഗിച്ചു മൂന്നു തവണ ആവർത്തിക്കുന്ന ഒൻപത് വള പ്രയോഗരീതി എന്ന രീതിയിലാണ് പരീക്ഷണം രൂപകൽപന ചെയ്തത്. T_1 - മണ്ണ് മാത്രം, T_2-T_8 - തിരഞ്ഞെടുത്ത ഏഴു കമ്പോസ്റ്റുകൾ, T_9 - കേരള കാർഷിക സർവകലാശാല ശുപാർശ അനുസരിച്ചുള്ള രാസവളങ്ങളുടെയും ജൈവവളങ്ങളുടെയും പ്രയോഗം എന്നിവയായിരുന്നു വളപ്രയോഗങ്ങൾ.

വിളവെടുപ്പിനു ശേഷമുള്ള മണ്ണിന്റെ രാസപരിശോധനയുടെ അടിസ്ഥാനത്തിൽ T_7 ൽ ഓർഗാനിക് കാർബൺ(1.14%), നൈട്രജൻ (319.86 kg ha^{-1})

എന്നിവയുടെ അളവും, T_8 ൽ ഫോസ്ഫോറിസിന്റെ അളവും (91.65 kg ha^{-1}) കൂടുതൽ ആയി കാണപ്പെട്ടു. പൊട്ടാസിയത്തിന്റെ അളവ് കൂടുതൽ ആയി കാണപ്പെട്ടത് T_6 (273.91 kg ha^{-1}) ൽ ആണ് . T_8 (270.60 kg ha^{-1}) ലെ പൊട്ടാസിയത്തിന്റെ അളവ് T_6 ലേതിന് തുല്യമായി കാണപ്പെട്ടു. അയൺ (48.54 mg kg^{-1}) , സിങ്ക് (4.79 mg kg^{-1}), കോപ്പർ(1.88 mg kg^{-1}) , ബോറോൺ (0.832 mg kg^{-1}) തുടങ്ങിയവയുടെ അളവ് കൂടുതൽ ആയി കാണപ്പെട്ടത് T_7 ലും എന്നാൽ മാംഗനീസിന്റെ അളവ് (25.62 mg kg^{-1}) കൂടുതൽ ആയി കാണപ്പെട്ടത് T_8 ലും ആണ്. സെല്ലുലേസ് എൻസൈമിന്റെ അളവ് T_7(45.53 µg glucose hydrolysed g^{-1} soil h^{-1}) ലും ഡീഹൈഡ്രോജിനാസ് എൻസൈമിന്റെ അളവ് T_8 ലും (302.68 µg of TPF hydrolysed g^{-1} of soil 24 h^{-1}) കൂടുതൽ ആയി കാണപ്പെട്ടു.

റൈസോസ്ഫീയറിലെ മണ്ണിന്റെ പരിശോധനയുടെ അടിസ്ഥാനത്തിൽ മൈക്രോബിയൽ ബയോമാസ്സ് കാർബൺ (91.14 mg kg^{-1}) , ഗ്ലോമാലിൻ (14.27 mg g^{-1}) , ഹ്യൂമിക് ആസിഡ്(9.21 %) , ഫൾവിക്ക് ആസിഡ്(9.98%), ഫംഗസ്സുകൾ (5.52 log cfu g^{-1}), ആക്റ്റിനോമൈസീറ്റുകൾ(5.16 log cfu g^{-1}) , സോയിൽ റെസ്പിറേഷൻ (4.17 mg CO_2 g^{-1}) എന്നിവ T_7 ൽ കൂടുതലായി കാണപ്പെടുകയും, എന്നാൽ ബാക്റ്റീരിയയുടെ അളവ് T_8 ൽ കൂടുതൽ ആയി കാണപ്പെടുകയും ചെയ്തു.

കായ് പിടുത്തത്തിന്റെ നിരക്ക് T_7 ൽ(30.67) കൂടുതൽ ആയി കാണപ്പെട്ടു. T_5, T_6, T_8, എന്നിവയിലെ കായ് പിടുത്തതിന്റെ നിരക്ക് T_7 നു തുല്യമായി കാണപ്പെട്ടു. ഫലങ്ങളുടെ വണ്ണം കൂടുതലായി കാണപ്പെട്ടത് T_7 ൽ(5.06 cm) ആണ്. T_6, T_8, T_9 എന്നിവയുടെ ഫലങ്ങളുടെ വണ്ണം T_7 നു തുല്യമായി കാണപ്പെട്ടു. ഫലങ്ങളുടെ നീളം (23.81cm), വിളവ് നിരക്ക്(570.42g), ആകെ വിളവ്(21.05 t ha^{-1}) എന്നിവ T_7 ൽ ആണ് കൂടുതൽ ആയി കാണപ്പെട്ടത്. വരവ് ചിലവ് അനുപാതവും, ശേഷ വിളയായ ചീരയുടെ വിളവും കൂടുതലായി കാണപ്പെട്ടത് T_7 ൽ തന്നെയാണ്.

പഠനത്തിൽ നിന്നും, T_{13} (ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്) മികച്ചതാണെന്നുള്ള നിഗമനത്തിലെത്തി. ഇൻക്യൂബേഷൻ കാലയളവിൽ നൈട്രജൻ, ഫോസ്ഫറസ് മഗ്നീഷ്യം, സൾഫർ, അയൺ, മാംഗനീസ്, സിങ്ക്, കോപ്പർ, ഓർഗാനിക് കാർബൺ, എൻസൈം പ്രവർത്തനം ഇവ കൂടുതലായി കാണപ്പെട്ടത് T_7 (ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്,

ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്) നും T_8 (1:1 അനുപാതത്തിലുള്ള ലിംനോക്കാരിസ് ഫ്ലാവയുടെയും വാഴ തണ്ടിൻറെയും മിശ്രിതത്തിൽ നിന്നും ഉത്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്) നുമാണ്. മണ്ണിൻറെ ഫലപുഷ്ടിയുടെയും വിളവിന്റെയും അടിസ്ഥാനത്തിൽ T_7 (ലിംനോക്കാരിസ് ഫ്ലാവയിൽ നിന്നും ഉത്പ്പാദിപ്പിച്ചു കാൽസിയം അപ്പറ്റയിറ്റ്, ഇപ്സം സാൾട്, സിൽവിനൈറ്റ് എന്നിവ ഉപയോഗിച് സമ്പുഷ്ടമാക്കിയ ബൊകാശി കമ്പോസ്റ്റ്) മികച്ചതായി തിരഞ്ഞെടുത്തു.