BIO RECYCLING OF PADDY STRAW FOR QUALITY MANURE PRODUCTION

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"BIO RECYCLING OF PADDY STRAW FOR QUALITY MANURE PRODUCTION"** 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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Certified that this thesis entitled **"BIO RECYCLING OF PADDY STRAW FOR QUALITY MANURE PRODUCTION"** is a record of research work done independently by Ms. Amala Mary George (2017-11-055) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

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Amala Mary George

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LIST OF ABBREVIATIONS

B	Boron
$BaCl_2$	Barium Chloride
BCR	Benefit Cost Ratio
C	Carbon
CEC	Cation Exchange Capacity
cfu g^{-1}	Colony forming unit per gram
cm	Centimetre
cm^2	Square centimetre
c mol kg^{-1}	Centimol per kilogram
C: N ratio	Carbon: Nitrogen ratio
Cu	Copper
DAP	Days after planting
DAS	Days after sowing
DMP	Dry matter production
dS m^{-1}	deci Siemens per metre
EC	Electrical Conductivity
et al	Co- authors/ Co- workers
Fe	Iron
FYM	Farm Yard Manure
g	Gram
g kg^{-1}	Gram per kilogram
g^{-1}	Per gram
IFSRS	Integrated Farming System Research Station
K	Potassium
K_2O	Potassium Oxide
KAU	Kerala Agricultural University
m	Metre
m^3	Cubic metre
mS cm^{-1}	milli Siemens per centimetre

µg TPF hr^{-1} g^{-1}	Microgram TPF per hour per gram
MAP	Month after planting
mg	Milligram
mg kg^{-1}	Milligram per kilogram
Mn	Manganese
N	Nitrogen
ppm	Parts per million
P	Phosphorus
PM	Potting media
pH	Negative logarithm of H^+ ion concentration
P_2O_5	Phosphorus Pentoxide
RDF	Recommended dose of fertilizers
RDN	Recommended dose of nitrogen
Si	Silicon
t	Tonnes
t ha^{-1}	Tonnes per hectare
TPF	2,3,5- triphenyl formazan
Zn	Zinc

LIST OF SYMBOLS

%	Per cent
^{0}C	Degree Celsius
@	At the rate of
<	Less than
₹	Rupees

INTRODUCTION

1. INTRODUCTION

Crop residues are untapped sources of nutrients and are generated in substantial quantities in most agricultural systems after harvesting and processing of crops. These residues at times have been regarded as unuseful waste that require disposal, but are being increasingly realized as important natural resources and not mere wastes. India generates around 500 to 550 million tonnes of crop residues annually (GOI, 2016). Of this, Kerala contributes around 9.74 million tonnes (MOSPI, 2014). Among different residues, cereals contribute almost 70 per cent of the total residue generated in India. Among cereal residues, rice crop generates most of the residue (53 %) followed by wheat (33 %) (Jain *et al.*, 2014).

In Kerala, rice is the major cereal crop. Rice farming is essentially associated with generation of two residues *viz.*, paddy straw and husk. From an area of 1.98 lakh ha (FIB, 2017), 5.62 lakh t of grain and 8 lakh t of straw are produced annually in Kerala. Rice based cropping systems are thus characterized with the production of large quantities of residues. Paddy straw, though finds use as fodder for milch animals and as base material for mushroom production, largely goes as waste as a result of improper storage and drying. Mostly in double cropped conditions, at least one harvest is during wet season which limits the chances of spreading and drying of straw resulting in mouldy growth considerably reducing the feed value of straw. The straw which is not suitable as feed material is often left discarded as biowaste in fields.

With the increasing trend towards organic farming, recycling of all possible resources assumes greater importance. However, there are limitations in recycling rice straw as such to soil due to its bulky volume, slow degradation and short term negative effect of nitrogen immobilization (Buresh and Sayre, 2007). Composting of paddy straw is an alternate option to recycle the nutrients contained in it.

Characteristics of paddy straw including wide C: N ratio (80:1) and richness in lignin (11 to 24 %) and silica (7 to 20 %) impede rapid decomposition of paddy straw as it resists microbial action (Kumar *et al.,* 2008; Hu *et al*., 2016). However, if composted using improved technologies, the prospects are immense with regard to recycling of plant nutrients.

Integrated farming system comprises of animal components, mostly cattle and poultry raised along with crops. Organic manures generated by these animal components in the form of dung and droppings could be composted by mixing with crop residues, to obtain nutrient rich organic manure. These composts could be recycled to soil for enriching soil organic carbon, plant nutrients and to sustain soil health in the long run.

Among the different alternatives available for recycling residues as manure, composting is considered most efficient and viable option. Several researchers have experimented with different composting techniques in bio recycling residues to manure. Good quality organic manure is generated from bio wastes with high C: N ratio when they are composted using different earth worm species as under vermicomposting technology (Shak *et al*., 2014). Co - composting of carbonaceous residues with nitrogen rich materials is reported as a green tool to bio convert crop residues to nutrient rich organic fertilizer (Qian *et al*., 2014). Lignocellulolytic activity of several fungal species can be utilized efficiently to decompose lignin rich crop residues (Kumar *et al*., 2008).

Nevertheless, research works on composting paddy straw has not been much explored in our state so far. Decomposition of paddy straw is comparatively slow and hence suitable methodologies and composting ratios should be evolved in order to hasten composting process. The methodology for composting paddy straw using vermicomposting, co - composting and microbial composting techniques needs to be standardized. The composted paddy straw could also be tested as a substitute for FYM in potting media for raising crops.

Keeping the above facts in view, the present study was planned with the following objectives.

- To find out an effective technology for composting paddy straw.
- To assess the effectiveness of paddy straw composts as potting media component on the growth, yield and quality of bhindi.
- To work out the economics of cultivation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The study entitled "Bio recycling of paddy straw for quality manure production" was conducted from March to December 2018, at Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala, with the objectives to find out an effective technology for composting paddy straw and to assess the effectiveness of paddy straw composts as potting media component on the growth, yield and quality of bhindi and to work out the economics.

Among cereal based cropping systems, rice based cropping systems are most common in Kerala and these are associated with generation of large amount of residues mainly in the form of straw and husk. The straw which is obtained after the crop harvest though useful as animal feed, often loses its feed value under unfavourable storage. The straw thus left as waste in fields is having immense potential to be recycled as a nutrient rich organic manure. Composting is a cost effective waste management strategy to recycle the nutrients that are present in the residues. This exposition is an attempt to review the findings of research works related to the composting of paddy straw and use of compost as a nutrient source for production of vegetables.

2.1 COMPOSITION OF PADDY STRAW

Rice is the major food grain crop cultivated worldwide and it generates large amount of straw as a residue after the harvest of the crop. Paddy straw is a lignocellulosic fibrous substance representative of most crop residues. However, it differs from most of the agricultural residues in high silica content, owing to its stiffness. Paddy straw has high C: N ratio of 80:1and is rich in silica and lignin (Kumar *et al.*, 2008).

Singh *et al.* (1995) reported that on dry matter basis, paddy straw contains 37 per cent cellulose, eight per cent lignin and eight per cent silica. High lignin content ranging from 13.5 to 25 per cent on dry weight basis has been reported by many scientists (Kadam *et al.*, 2000; Nakhshiniev *et al.*, 2014).

Nutrient concentration in paddy straw varies depending on variety, climatic condition and nutrient management practices adopted for the crop. On an average, it contains 51.76 per cent organic carbon, 0.65 per cent nitrogen (N), 0.20 per cent phosphorus (P) and 1.12 per cent potassium (K) (Goyal and Sindhu, 2011; Jusoh *et al.,* 2013; Chaudhary *et al*., 2017).

Abdelhamid *et al.* (2004) found that paddy straw on dry weight basis contains 0.64 per cent N, 0.11 per cent P and 0.26 per cent K and have a C: N ratio of 61.3:1.

In addition to primary nutrients, rice straw also contains appreciable quantities of secondary nutrients like Ca (0.23 %), Mg (0.15 %), S (0.08 %) and micro nutrients like Fe (310 mg kg^{-1}), Cu (9.3 mg kg^{-1}), Mn (720 mg kg^{-1}), Zn (38.40 mg kg^{-1}) and B (6.8 mg kg^{-1}) as reported by Mandal *et al.* (2004) and Jusoh *et al.* (2013).

2.2 COMPOSTING OF PADDY STRAW

Composting is a biological process in which the micro organisms utilize organic matter as a substrate and convert it into humic substances (de Guardia *et al.,* 2010; Roman *et al*., 2015). It is a natural process wherein decomposable organic wastes are transformed to a homogeneous, plant available and nutrient rich substance, known as compost (Azim *et al*., 2017).

The process of composting is mediated by the action of diverse microbial population under aerobic conditions. Various microbial communities namely, bacteria, fungi, and protozoa are involved in decomposition process with variable intensity depending on the temperature, moisture content, C: N ratio and nature of organic substance to be degraded (Hassen *et al.*, 2001).

Composting reduces the volume of waste, destroys harmful pathogenic organisms and produces good quality manure, thereby satisfies the needs of organic fertilizer (Sharholy *et al*., 2008). Nutrient elements that are present in the initial substrate are concentrated during composting and thereby create a stable soil enriching humified product (Atalia *et al.*, 2015).

Among different alternatives available for waste management, composting is viewed as the most economic and efficient strategy due to its eco friendly nature and the ability to produce good quality organic manure as the end product (Pascual *et al.*, 2002). High organic matter combined with nutrient richness and pathogen free nature makes compost a suitable component of growing media (Ghosh, 2004).

Paddy straw, the major crop residue generated in rice based cropping systems is not recycled as such to the soil due to its bulky volume, slow degradation and short term negative effect of N immobilization (Singh *et al.*, 2005). On the other hand, composting of paddy straw offers an efficient method to recycle the nutrients contained in it and to generate good quality organic manure (Dileep and Dixit, 2005). Even so, paddy straw is resistant to microbial degradation due to its wide C: N ratio, high lignin, cellulose and silica content (Zhu, 2007). However, use of improved techniques like vermicomposting, co - composting and microbial composting hasten the decomposition of paddy straw and result in production of quality compost as end product.

2.2.1 Vermicomposting

Vermicomposting is the process of biochemical degradation of organic wastes mediated by the action of earthworms and microbes under aerobic conditions. Epigeic earthworm species like *Eisenia foetida, Eudrillus euginea and Perionyx excavatus* were identified as suitable candidates for enhancing decomposition process (Khwairakpam and Bhargava, 2009; Sim and Wu, 2010).

During the process of vermicomposting, the compost material is initially conditioned by the microorganisms, which makes further decomposing activity of earthworms more easy. Extra cellular enzymes produced by the microbes assist the degradation of organic materials. Later, earthworms feed the partially decomposed organic material and further decomposition of ingested food takes place in the gut of worms. Worm casts obtained after this process is a fine granular product with no odour, which can serve as organic manure (Dominguez *et al.*, 2010).

2.2.1.1 Time Taken for Composting

Epigeic earthworms act as boosters of composting process and reduce the composting period to a significant extent, with production of high quality compost, compared to traditional composting method (Tripathi and Bhardwaj, 2004).

The time taken for compost maturation depends on the quality of initial substrate, its C: N ratio, source and quantity of organic manure added to the initial substrate as well as the microbial activity. Rice straw mixed with two parts of cowdung, not only encouraged the growth of *Eudrillus euginea*, but also provided the best quality vermicompost with the highest nutrient content and the lowest C: N ratio after 60 days of composting (Shak *et al.*, 2014).

Wei *et al.* (2012) experimented the potential of *Perionyx excavatus* and *Eudrillus euginea* on vermicomposting paddy straw. Eventhough *Eudrillus euginea* produced best quality compost with high nutrient content, complete decomposition took more time (171 days) compared to *Perionyx excavatus* (134 days).

Lim *et al.* (2011) claimed that soyabean residues with high C: N ratio could be vermicomposted within nine weeks by using earthworm species *Eudrillus euginea.* The authors also reported a reduction in C: N ratio from 35:1 to 16:1.

2.2.1.2 Recovery of Compost

Earthworms, the mediators of composting process consume organic materials approximately equal to their body weight and excrete about 50 per cent of the material ingested. Thus the process of vermicomposting reduces the volume of organic wastes by about 40 to 60 per cent (Nagavallemma *et al*., 2004).

Vermicomposting coconut litter using an indigenous strain of earthworm (*Eudrillus* sp) was standardized at Central Plantation Crops Research Institute. As per this low cost technique, lignin rich coconut leaves could be mixed with 10 per cent cowdung on weight basis for conversion to nutrient rich organic manure (1.2 to 1.8 % N, 0.1 to 0.2 % P and 0.2 to 0.4 % K) in just 60 to 75 days with a recovery of 70 per cent (Thomas *et al*., 2004).

2.2.1.3 Quality Parameters of Compost

Quality of compost is determined by compost maturity and stability. Nolan *et al.* (2011) claimed that maturity of the final composting product cannot be determined based on a single parameter.

Aparna *et al.* (2007) reported that compost maturity can be evaluated based on several factors like pH, electrical conductivity (EC), cation exchange capacity (CEC), moisture content, C: N ratio and nutrient status.

2.2.1.3.1 Major Chemical Properties

Nakhshiniev *et al*. (2014) revealed the pattern of change in pH during the composting process as a drop in pH during the initial stages due to the production of organic acids by microbes. These organic acids are released through the break down of organic matter. Towards the later stages, pH values tend to increase due to the liberation of ammonia as a result of protein degradation and also due to the decomposition of organic acids by microbes. Karanja *et al*. (2019) reported that pH approaches neutrality as the compost reaches maturity.

pH of compost ranging from 6 to 8.5 is considered as the ideal range by several authors (Ko *et al.,* 2008; Troy *et al*., 2012).

Jena *et al.* (2002) found that paddy straw composts generated through vermicomposting recorded neutral reaction and they suggested that neutrality of compost is an indication of its suitability for soil application. Sharma and Garg (2018) tested the efficacy of earthworm species *Eisenia foetida* on composting of paddy straw and they reported that these earthworms are efficient for generation of quality vermicompost with neutral pH within 105 days.

Worm casts contain minerals like K, phosphate and ammonium in available forms. These mineral ions are responsible for the increased EC of final compost (Garg *et al.*, 2006). Electrical conductivity indicates the salt concentration of the compost and shows an increasing trend with the degradation of complex organic molecules (Pan and Sen, 2013). Jiang *et al.* (2015) opined that EC is one of the chemical indicators of compost quality.

Ramnarain *et al.* (2019) while conducting an experiment on vermicoposting of rice straw mixed with cowdung and grass cuttings using the earthworm species *Eisenia foetida*, found that EC increases from 3 mS cm^{-1} to 3.7 mS cm^{-1} after 120 days of composting.

Ko *et al.* (2008) reported that application of compost with high EC can cause phytotoxicity. EC values of < 4 dS m^{-1} is considered as a maturity index by Silva *et al.* (2013). However Mulec *et al.* (2016) opined that an EC value of < 1.5 dS m^{-1} is necessary for using compost as an organic amendment.

Humic substances that are formed during composting process strongly binds the positively charged ions, that are later exchanged with other cations. This property of compost is referred to as CEC and it shows an increasing trend during composting as organic substances are humified with the advancement of composting (Wichuk and McCartney, 2013; Karanja *et al.*, 2019). Compost with higher CEC value is preferred for soil application as it ensures better nutrient availability.

C: N ratio, the most commonly used indicator of compost maturity, decreases as composting proceeds (Atiyeh *et al.*, 2000). During composting, microbes utilize carbon from organic substances as a source of energy to build up their cells. Throughout the composting period, microbes decompose the organic material and oxidize the organic carbon to CO_2. The reduction in organic carbon content with the progress of composting is an indication of degradation of organic substances (Goyal *et al.,* 2005). The decline in carbon content and simultaneous addition of N by the excretory materials of worms causes a decline in C: N ratio (Suthar, 2006).

Bernal *et al.* (2009) opined that C: N ratio of < 15:1 is suitable for plants for better uptake and assimilation of nutrients. According to Khater (2015), a C: N ratio of < 20:1 is considered as an indicator of compost maturity.

In a study conducted at Orissa, Jena *et al.* (2002) experimented paddy straw composting using earthworm species *Eisenia foetida* and reported that the C: N ratio of paddy straw narrowed down from the initial status of 80:1 to a favourable value of 10:1. Gopal *et al.* (2012) conducted an experiment on composting of coconut litter using *Eudrillus sp.* and reported that the vermicompost obtained was a rich source of plant beneficial microbes having a narrow C: N ratio of 9.54:1.

2.2.1.3.2 Nutrient Status

The process of composting concentrates the mineral nutrients that are present in the initial substrate and produces fine humus as the end product (Padmavathiamma *et al.*, 2008). Suthar (2008) found that vermicomposting of cereal residues with *Eudrillus euginea* improved the P content of the final product. Activity of earthworm gut phosphatase and P solubilising microbes in worm casts results in mineralization and mobilization of P, thereby increasing the P content of vermicompost. Enzymes produced by the gut micro flora of earthworms solubilise the insoluble K and increases its content in vermicompost (Lim *et al.*, 2011).

Different species of earthworms can have different impact on the quality of compost generated. In a study conducted by Reddy and Ohkura (2004), vermicomposting of rice straw was done using three species of earthworms *viz., Perionyx excavatus, Octochaetona phillotti and Octonochaeta rosea.* Vermicompost produced by *Perionyx excavatus* had higher concentrations of N, P, K, Ca and Na than other composts. Jaybhaye and Bhalerao (2016) reported many fold increase in nutrient content when paddy straw was vermicomposted using *Eisenia foetida*.

In a comparative study between vermicomposting technique and conventional composting, Abdul-Soud *et al.* (2009) reported that vermicompost generated from agricultural wastes contained 1.34 per cent N, 0.57 per cent P,1.04 per cent K, 16000 ppm Fe, 182 ppm Mn, 141 ppm Zn and 13 ppm Cu, which was much higher when compared to conventional compost.

Rice husk when vermicomposted using *Eudrillus euginea* produced good quality compost with 0.85 per cent P and 3.10 per cent K (Lim *et al.*, 2012). Shak *et al.* (2014) found that paddy straw composts produced using *Eudrillus euginea* showed increase in micronutrient status. Increase in Ca upto 34 per cent, that of Mg upto 40 per cent, P upto 57 per cent and K upto 350 per cent has been reported by the authors.

2.2.1.3.3 Microbial and Enzymatic Activity

Huang *et al.* (2013) opined that earthworm species *Eisenia foetida* is capable of enhancing decomposition of vegetable wastes by significantly increasing the diversity and activity of fungal and bacterial populations.

Hydrolytic enzymes released by the microbial activity determine the rate of decomposition of organic substances. Amylase, celluase, xylenase and protease are the major enzymes that are involved in composting process (Goyal *et al.*, 2005). Activity of dehydrogenase enzyme is a reflection of biological respiration and it varies with the properties of initial feedstock used for composting.

Dehydrogenase activity was found maximum during the initial composting period, indicating rapid decomposition of organic residues by microbes. With the maturation of compost, the activity of the enzyme tend to decline due to the decline in microbial population (Awasthi *et al.*, 2017).

2.2.2 Co - composting

Co - composting is an efficient technique for preparing good quality organic manure from crop residues with wider C: N ratio. Residues are mixed with organic materials having higher N content. Preparation of compost by adding 20 per cent cowdung slurry (w/w) to the recyclable wastes was found to be ideal for achieving desirable C: N ratio, nutrient content and presence of beneficial microorganisms (Yadukumar and Nandan, 2005). Li *et al.* (2008) opined that co - composting paddy straw with livestock manure is a suitable treatment method for waste and discarded paddy straw.

2.2.2.1 Time Taken for Composting

Rashad *et al.* (2010) found that co - composting of rice straw enriched with 10 per cent rock phosphate and soyabean residue is a good method for generating safe and stable composts that could be used as soil amendment within a period of 84 days.

Jusoh *et al.* (2013) stated that composting of paddy straw can be completed within 90 days when it was mixed with goat manure and green wastes. Rice straw when co - composted with swine manure (4:6 w/w), produced quality end product with a desirable C: N ratio within a period of 90 days (Qian *et al.*, 2014).

A composting period of 103 days was reported by Guerra-Rodriguez *et al.* (2003) when barley wastes were co - composted using poultry manure. Slightly higher composting period of 112 days was reported by Tian *et al.* (2012) when rice chaff was co - composted using dairy manure.

2.2.2.2 Recovery of Compost

Verma *et al.* (2014) assessed the potential of different composting methods on wheat straw composting. Wheat straw was mixed with cowdung slurry and composted in pits for 175 days. The authors recorded a recovery of 40 per cent from wheat straw composting.

Alten and Erdin (2005) reported a recovery of 50 per cent while conducting an experiment on co - composting of solid wastes using sludge. Shrivastava and Arya (2018) on experimenting insitu composting of rice straw, found that about 50 per cent weight reduction occurs with the formation of stable compost.

2.2.2.3 Quality Parameters of Compost

Adeniran *et al.* (2003) opined that quality of compost largely depends on the characteristics of initial feedstock *viz.,* nutrient content, C: N ratio, microbial population including bacteria, fungi and actinomycetes.

2.2.2.3.1 Major Chemical Properties

A stable pH value of 7.7 was obtained when paddy straw was co - composted with swine manure for 90 days (Qian *et al.*, 2014).

Composting of rice chaff with dairy manure produced good quality end product with slightly alkaline pH of 8.15 (Liu *et al.*, 2011).

Roca-Perez *et al.* (2009) opined that sewage sludge can be used as a bulking agent for composting paddy straw and produces good quality manure with a neutral pH, desirable EC (3.80 dS m^{-1}) and higher CEC (98 c mol kg^{-1}). Karanja *et al.* (2019) reported a significant increase in CEC (13.84 to 25.25 c mol kg^{-1}) and reduction in C: N ratio (60.33 to 10.84:1) when paddy straw was co - composted using poultry manure for a period of 62 days.

Co - composting of leaf litters with poultry manure was found ideal for generating good organic fertilizer with an acceptable EC of 2.15 dS m^{-1} (Guerra-Rodriguez *et al.,* 2001). High quality compost can be generated from pineapple leaves through co - composting technique using poultry manure as N source. The final compost showed an increase in CEC from 32 to 65 c mol kg^{-1} (Chng *et al.*, 2013).

Guerra-Rodriguez *et al.* (2000) explored the possibility of co - composting barley waste with poultry droppings. Authors recorded a drop in total C content from 36.2 to 23.7 per cent, which contributed to a narrower C: N ratio of 6:1. C: N ratio was dropped from 49.09 to 16.25 within 90 days of composting when paddy straw was co - composted with cowdung, distillery effluent and microbial consortia (Kumari *et al.*, 2018).

2.2.2.3.2 Nutrient Status

A co - composting study conducted on paddy straw using liquid poultry manure revealed that K content increases from three per cent to four per cent after composting (Guerra-Rodriguez *et al.*, 2003). According to Rashad *et al.* (2010), the concentration of P and K increases after composting rice straw using buffalo manure. Final paddy straw compost had a P content of 1.47 per cent and K content of one per cent, which were higher compared to the initial content in paddy straw.

Latifah *et al.* (2015) reported that N content increased from 1.1 to 1.6 per cent, P from 0.01 to 0.11 per cent and K from 1.6 to 2.7 per cent in rice husk co - composted using poultry manure.

2.2.2.3.3 Microbial and Enzymatic Activity

Co - composting process is mainly mediated by the action of microbes and microbial community varies depending on the stage of composting. Keener *et al.* (2000) identified three phases of composting *viz.,* mesophilic, thermophilic and cooling or maturation phase. The presence of easily available C source during the initial stages provides a favourable condition for the proliferation of mesophilic microbes. During this stage, the temperature generated is around 20 to 40 ^{0}C (Vargas-Garcia *et al.*, 2010).

During thermophilic stage of composting, when the temperature rises, mesophilic microbial population declines and the population of thermophilic micro organisms increases. Temperature may rise even upto 65 ^{0}C during the second phase of composting. With the last phase of composting when the temperature declines (< 40 ^{0}C), mesophilic organisms again start to increase (Hassen *et al.*, 2001).

Sugarcane trash co - composted with cowdung recorded a bacterial population of 72×10^7 g^{-1} of compost and fungal population of 24×10^7 g^{-1} of compost after 90 days of composting (Goyal *et al.*, 2005). Based on a study conducted on co - composting of poultry manure and rice straw, Devi *et al.* (2012) reported that the mature compost had 17×10^9 bacterial population g^{-1} of material, 2×10^6 fungal population g^{-1} and 5.2×10^4 actinomycetes population g^{-1}.

Significant reduction in dehydrogenase activity was observed at the end of composting process as the microbial population decreases. Tiquia (2005) reported a reduction in dehydrogenase activity from 160 μg TPF g^{-1} hr^{-1} to 12 μg TPF g^{-1} hr^{-1} while composting pig manure collected from deep litter system. Barrena *et al.* (2008) while conducting a research experiment on composting of solid wastes along with pruning wastes, also reported a similar reduction in dehydrogenase enzyme content from 0.8 to 0.2 mg TPF g^{-1} hr^{-1}.

2.2.3 Microbial Composting

Different types of micro organisms can be used as boosters to accelerate the composting process. Lignocellulolytic microbes producing hydrolytic enzymes were found suitable for composting of organic wastes (Toumela *et al.*, 2000). Composting of organic residues using microbes produces good quality end

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products and thereby provides an efficient method for recycling the residues (Kumar *et al.*, 2008). Pan *et al.* (2012) identified that a bacterial consortium of *Bacillus* and *Pseudomonas* are effective for recycling organic residues like vegetable wastes, fruit wastes and wheat straw to quality manure.

2.2.3.1 Time Taken for Composting

A fungal consortium consisting of *Aspergillus, Trichoderma and Phanerochaete,* when inoculated to a mixture of wheat straw, poultry droppings and oil seed cake, found to enhance decomposition and the mature compost was generated within a short period of 60 days (Gaind *et al.*, 2009). Gill *et al.* (2016) reported that the fungal species *Phanerochaete chrysosporium* is an efficient decomposer of paddy straw as it degrades maximum cellulose and lignin within a period of 60 days.

Addition of bacterial consortium to wheat straw enhances decomposition process and produces stable compost with neutral pH and narrow C: N ratio within 120 days (Pan and Sen, 2013). Paddy straw amended with a consortium of effective micro organisms hastened decomposition and narrowed down the C: N ratio from 90:1 to 15:1 after 60 days of composting (Sharma *et al.*, 2014).

Awasthi *et al.* (2015) while experimenting composting of solid wastes, reported a reduction in composting period with the addition of lignocellulolytic white rot fungus, mainly attributed to the enhanced release of hydrolytic enzymes. A field experiment was carried out by Praveena *et al.* (2018) to standardize the protocol for effective composting of cocoa wastes. Microbial composting using fungal species *Phanerochaete chrysosporium* and *Pleurotus sajor-caju* ensured rapid decomposition of these residues.

2.2.3.2 Recovery of Compost

Andrea *et al.* (1998) reported a weight loss of upto 70 per cent while composting solid wastes. Activity of mesophilic organisms occurring during composting results in degradation of protein and sugars, thereby results in loss of biomass (Pan *et al.,* 2012).

Whittle *et al.* (2014) opined that maximum weight loss of composting material occurred during the initial stages of composting. After the thermophilic stage of decomposition, weight loss was much less (< 1 per cent), indicating completion of degradation. The authors reported a recovery of 70 per cent from a mixture of farm wastes during composting.

2.2.3.3 Quality Parameters of Compost

2.2.3.3.1 Major Chemical Properties

Paddy straw supplemented with poultry manure, when composted with a mesophilic fungal culture of *Aspergillus nidulans, Trichoderma viride, Phanerochaete chrysosporium* and *Aspergillus aawamori* produced mature compost with a near neutral pH (7.80) and EC of 0.6 mS cm^{-1} (Pandey *et al.*, 2009). Surtiningsih and Mariam (2012) reported that quality compost with a near neutral pH of 7.6 was produced from rice straw when it was composted using a cellulolytic microbial consortium.

Kakezawa *et al.* (1992) suggested a two step composting process of paddy straw as an ideal technique for generation of quality manure. According to them, inoculation of lignolytic fungus initially followed by addition of poultry droppings to paddy straw enhanced decomposition and produced mature compost with a higher CEC of 74 c mol kg^{-1}.

Gaind *et al.* (2006) explored the potential of *Aspergillus awamori* for composting wheat straw. The authors stated that addition of bio inoculant cultures after partial degradation produces good quality manure with a low C: N ratio of 16:1 and a pH of 7.56. Goyal and Sindhu (2011) reported significant reduction in C: N ratio (16.6:1) with microbial composting of paddy straw in comparison to natural decomposition (34.5:1). Wagh and Gangurde (2015) reported lowering of

C: N ratio as well as enhancement in nutrient content of leaf litter when composted using the fungal species *Trichoderma*.

Jusoh *et al.* (2013) conducted an experiment to assess the suitability of effective microorganisms (EM) in hastening composting of paddy straw. Paddy straw was mixed with goat manure and vegetable wastes. EM solution containing lactic acid bacteria, yeast and phototrophic bacteria was added to the composting pile. Stable and non phytotoxic compost with a narrow C: N ratio (10.3:1) and optimum pH (7.55) was produced within 90 days duration. The compost obtained was rich in plant nutrients and contained 2.4 per cent N, 0.22 per cent P and 1.7 per cent K.

2.2.3.3.2 Nutrient Status

In an experiment conducted by Goyal and Sindhu (2011), it was found that composting of paddy straw with a fungal consortium (*Aspergillus awamori, Paecilomyces fusisporus and Trichoderma viride*) produced best quality compost with high nutrient status (2.09 % N, 0.164 % P and 0.169 % K) within 90 days.

A combination of three lignocellulolytic fungi *viz., Rhizopus oryzae, Aspergillus oryzae and Aspergillus fumigates* were found efficient for degrading paddy straw and produced superior quality compost with high nutritional status of 1.55 per cent N, 1.48 per cent P and 1.57 per cent K (Viji and Neelanarayanan, 2015).

2.2.3.3.3 Microbial and Enzymatic Activity

Antil and Raj (2012) conducted an experiment on composting of farm wastes using microbial inoculants. After 150 days of composting, the final product recorded a bacterial count of 90×10^6 g^{-1} of material, fungal count of 25×10^4 g^{-1} of material and actinomycetes count of 25×10^5 g^{-1} of material.

A study of Gaind and Nain, (2010) showed that rice straw amended with poultry manure can be converted to compost within two months on inoculation using a consortium of *Aspergillus, Trichoderma and Phanerochaete.* Stable and non phytotoxic compost was obtained, which recorded a dehydrogenase activity of 2026.21 μg TPF g^{-1} hr^{-1}.

Mature composts produced from wheat straw using fungal culture registered significant reduction in dehydrogenase activity from 2504.87 μg TPF g^{-1} hr^{-1} at 30 days to 946.88 μg TPF g^{-1} hr^{-1} at maturation (Gaind *et al.*, 2009).

2.3 EFFECT OF COMPOST ON GROWTH CHARACTERS

The results of a study conducted by Govindan *et al.* (1995) revealed that farm yard manure (FYM) substituted with vermicompost, applied along with the recommended dose of fertilizers (RDF) in bhindi could well improve the growth attributes like plant height and number of branches. Ushakumari *et al.* (1999) opined that supply of vermicompost in addition to RDF, significantly improved the plant height and number of leaves per plant of bhindi. Application of vemicompost @ 5 t ha^{-1} improved the vegetative characters of okra *viz.,* plant height and number of branches (Miglani *et al.*, 2017).

In a study conducted by Pushpavalli *et al.* (2014), substitution of K fertilizers with pressmud compost resulted in production of taller plants of bhindi (85.7 cm) as compared to muriate of potash application (70.8 cm). Sachan *et al.* (2017) opined that integrated application of fertilizers, FYM and vermicompost increased the growth and yield of bhindi. They reported a significant increase in plant height (154 cm) and number of branches (4.91) as result of integrated application of compost and fertilizers. A pot culture study conducted by Frimpong *et al.* (2017) revealed that application of compost to supply 200 kg N ha^{-1} significantly improved the plant height and dry matter when compared to control. However, application of compost to supply 100 kg N ha^{-1} was also found to be on par with it.

Use of vermicompost as organic manure in okra was found to improve the leaf length and breadth (Manonmani and Anand, 2002). In bhindi, application of compost @ 3 t ha^{-1} recorded significantly higher leaf area of 2048 cm^2 per plant as compared to non addition of compost (1747 cm^2 $plant^{-1}$) (Akanbi *et al.*, 2010).

Anal *et al.* (2018) conducted a study on the effect of chemical fertilizers and organic manures on growth, yield and quality of okra. They revealed that combined application of 75 per cent recommended dose of NPK and 5 t of vermicompost ha^{-1} significantly enhanced the leaf area and dry matter production.

Improved growth of barley was reported by Roca-Perez *et al.* (2009) when rice straw compost was used as a soil amendment. Lekshmi (2011) reported that compost prepared from banana pseudostem could increase the growth and development of chilli. Substituting 100 per cent of recommended dose of nitrogen (RDN) through water hyacinth compost could record significant increase in plant height, girth of shoot and total yield of amaranthus (Anushma, 2014).

2.4 EFFECT OF COMPOST ON YIELD ATTRIBUTES AND YIELD

Pradeepkumar *et al.* (2011) documented significantly higher yields of bhindi on substituting 100 per cent RDN through sludge compost. The authors also reported earliness in flowering with the addition of this compost. According to Raj *et al.* (2013), application of mature compost as manure significantly increased the yield of bhindi in addition to improvement in the population of soil microbes. In an experiment conducted by Smriti and Ram (2018) found that substitution of 50 per cent RDF as vermicompost could significantly increase the yield of okra by increasing fruit length, weight and diameter.

Attarde *et al.* (2012) reported that use of vermicompost as a manure could result in highest average fresh weight (25.5 g) of bhindi fruit compared to the application of FYM or inorganic fertilizer. Mal *et al.* (2013) reported the benefits of integrating vermicompost along with chemical fertilizers in the nutrition schedule of bhindi in realizing higher fruit length and weight.

Dada and Adejumo (2015) assessed the effect of different rates of compost application on the growth and yield of okra and found that application of compost at a higher rate (15 t ha^{-1}) performed well and increased the number of fruits by 66 per cent.

Singh *et al.* (2012) reported that an integrated nutrient management (INM) package which integrated vermicompost @ 10 t ha^{-1} with 75 per cent of NPK through chemical fertilizers could record significant earliness in fruit set of tomato (45 days).

Reddy *et al.* (1998) reported increased pod yield in pea with the application of compost along with 50 per cent recommended dose of NPK as chemical fertilizers. Vermicompost application @ 2 t ha^{-1} along with RDF recorded maximum fruit yield in tomato (Patil *et al.*, 2004). An increase in fruit weight upto 35 per cent was observed in strawberry with the application of vermicompost (Arancon *et al.*, 2004).

Vermicompost as a nutrient source could well improve the yield of cowpea (Karmegam and Daniel, 2000). In a work conducted at Shimoga in Karnataka, Sannathimmappa *et al.* (2015) reported yield advantage in rice upto 100 per cent with the application of paddy straw compost generated under microbial degradation compared to application of 100 per cent of RDF.

Koura *et al.* (2015) found that application of compost obtained from palm oil mill waste could significantly increase the yield of spinach upto 20.1 t ha^{-1}, whereas non addition of compost could register a yield of 17.9 t ha^{-1} only. Compost prepared from banana waste, coffee pulp and wood cuttings when mixed with soil in the ratio 1:3 (w/w) produced cabbage heads with higher fresh weigh (Dadi *et al.*, 2019).

Rice straw compost added as nutrient source for rice could result in yield enhancement and improvement of soil properties (Mahmoud *et al.*, 2014). Barus

(2012) reported yield advantage upto 26 per cent in rice with the application of paddy straw compost generated under microbial composting.

2.5 EFFECT OF COMPOST ON QUALITY PARAMETERS OF CROPS

According to Thirunavukkarasu and Balaji (2015), lower crude fibre content of 10.15 per cent in bhindi was recorded with vermicompost @ 5 t ha^{-1} applied along with 50 per cent of RDF.

Poonkodi *et al.* (2018) reported that all the quality parameters of bhindi were favourably influenced by the application of pressmud compost @ 15 t ha^{-1} supplied in addition to 100 per cent RDF. They recorded an ascorbic acid content of 16 mg 100 g^{-1} with compost application, which was significantly higher, compared to that obtained with the application of 100 per cent RDF alone (11 mg 100 g^{-1}). An experiment conducted by Santos *et al.* (2019) reported 52 per cent increase in ascorbic acid content of okra with the application of compost.

Adekayode and Ogunkoya (2011) conducted a study on the effect of organic compost and inorganic fertilizers on the growth and yield of amaranthus and reported significant increase in the content of vitamin C with compost application compared to application of chemical fertilizers. Protein content of french bean was significantly improved (31.6 %) by the application of paddy straw compost compared to the application of chemical fertilizers (Ansari and Jaikishun, 2011).

2.6 EFFECT OF COMPOST ON AND DRY MATTER PRODUCTION AND NUTRIENT UPTAKE

An experiment conducted by Kuppusamy *et al.* (2013) reported that application of 50 per cent RDN through urea and the remaining 50 per cent through vermicompost in bhindi significantly improved the dry matter (3.27 t ha^{-1}) compared to the application of 100 per cent RDN through urea (2.88 t ha^{-1}).

Application of organic manures along with fertilizers were found to increase the uptake and accumulation of macro nutrients in okra (Phonglosa *et al.*, 2015).

Ramnathan *et al.* (2019) studied the effect of varying levels of pressmud compost on the yield and nutrient uptake of bhindi and reported that application of compost @ 15 t ha^{-1} significantly improved the uptake of major plant nutrients.

Sailajakumari (1999) reported increased NPK uptake and resultant yield increase in cowpea with the application of vermicompost. Combined application of 50 per cent RDF and vermicompost @ 10 t ha^{-1} could increase the uptake of N by ridge gourd (Sreenivas *et al.*, 2000). Nishanth and Biswas (2008) while studying the effect of compost application on growth and yield of wheat, recorded a significant increase in the uptake of P and K.

2.7 EFFECT OF COMPOST ON SOIL PROPERTIES

Fertility of soil was well enhanced with the addition of compost to soil with no harmful effect on environment as compared to chemical fertilizers (Benitez *et al.*, 1998). Slowly degradable humic substances that are present in composts could improve the physical and chemical properties of soil (Chefetz *et al.*, 1998). Maheswarappa *et al.* (1999) reported that addition of organic matter through compost favourably influenced the soil pH, microbial and enzymatic activities. According to Lekshmi (2011), soil physical, chemical and biological properties were favourably influenced by the addition of compost prepared from farm wastes.

Soil physical properties like particle density, bulk density and porosity were favourably influenced by the application of vermicompost (Rajalekshmi, 1996). Use of vermicompost as a soil amendment was reported to reduce the fixation of P in soil and to increase its availability (Bijulal, 1997).

Gaind *et al.* (2006) conducted an experiment on composting of wheat straw and reported that wheat straw compost had the potential to supply plant nutrients in adequate quantities and to enhance soil fertility. Application of this compost to soil could improve the organic carbon, available P as well as enzymatic activity in soil.

Paddy straw compost applied @ 3 t ha^{-1} could improve the available N and P as well as enhance the microbial population of soil. The same treatment could also enhance the soil organic carbon content from 0.44 % to 0.65 % (Gaind and Nain, 2010). Wantanabe *et al.* (2017) observed significant increase in carbon content of soil with the application of compost along with moderate doses of chemical fertilizers, suggesting the positive influence of rice straw compost in INM schedule.

Rapid proliferation of soil microorganisms was reported by Gopal *et al.* (2009) when vermicompost prepared from coconut leaf litter was used as a nutrient source. The authors also reported increased availability of plant nutrients as a result of compost addition. Ng *et al.* (2016) stated that application of microbially enriched paddy straw compost significantly improved the soil microbial activity.

2.8 EFFECT OF COMPOST ON PEST AND DISEASE INCIDENCE

Prakash *et al.* (2002) while testing the effect of different organic manures on the incidence of fruit and shoot borer in bhindi, reported that application of FYM and vermicompost could reduce the incidence. Venkataswara *et al.* (2005) found that application of vermicompost increased the resistance of bhindi plants to pests and diseases.

Hussain *et al.* (2017) studied the effect of vermicompost prepared from *Salvinia molesta* on the growth and yield of okra and reported that application of the compost @ 5 t ha^{-1} reduced the incidence of fruit borer by about 82 per cent compared to non addition of compost.

Bhatnagar and Palta (1996) reported that vermicompost application could reduce the damage caused by thrips and jassids in groundnut. Abbasi *et al.* (2002)

while conducting an experiment on the effect of organic manures in influencing severity of diseases, observed that incidence of fruit rot in tomato was significantly lower with compost application. Sabarad *et al.* (2004) reported that combined application of chemical fertilizers and vermicompost reduces the incidence of nematode in banana.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Paddy straw generated from rice based cropping system is a potential source of organic input to be value added as a quality organic manure. Taking this into consideration, a study entitled "Bio recycling of paddy straw for quality manure production" was taken up. The major objectives were to find out an effective technology for composting paddy straw and to assess the effectiveness of paddy straw composts as potting media component on the growth, yield and quality of bhindi and to work out the economics. The research work was conducted at IFSRS, Karamana during the period of March to December 2018. The work was carried out as two experiments. Different paddy straw composts were prepared as part of experiment I. Compost generated from experiment I was used as potting media component in experiment II. The materials used and the methodology adopted for the study are discussed in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Experiment I - Composting of Paddy Straw

3.1.1.1 Location

The experiment was undertaken at IFSRS, Karamana, utilising the existing facilities of composting yard.

3.1.1.2 Time of Experiment

The composting process was initiated during March 2018 and completed by August 2018.

3.1.2 Experiment II - Pot Culture Study on Bhindi

3.1.2.1 Location

The experiment was conducted at IFSRS, Karamana, Thiruvananthapuram, Kerala, located at 8^0 28' 28" North latitude and 76^0 57'47" East longitude at an altitude of 5 m above mean sea level.

3.1.2.2 Climate and Season

The pot culture experiment with bhindi as test crop was carried out during August to December, 2018. Details on weekly average weather parameters *viz.*, maximum and minimum temperature, relative humidity and rainfall during the period of study were collected from class B meteorological observatory maintained at IFSRS, Karamana and are given in Appendix I and illustrated in Fig. 1.

3.2 MATERIALS

3.2.1 Experiment I - Composting of Paddy Straw

3.2.1.1 Composting Materials or Organisms

Paddy straw of variety Uma collected from IFSRS, Karamana during March 2018 was used for compost preparation.

Inorder to hasten the composting process, different organic manures (cowdung and poultry manure) and the earthworm species *Eudrillus euginea* were used. The mushroom species *Pleurotus sajor-caju* was also utilised for enhancing decomposition of paddy straw.

3.2.2 Experiment II - Pot Culture Study on Bhindi

3.2.2.1 Variety and Seeds

Seeds of the KAU hybrid variety *viz.*, Manjima (Gowreesapattom local × IC 282257) were obtained from Department of Plant Breeding & Genetics, College of Agriculture, Vellayani.

3.2.2.2 Grow Bags

UV stabilized grow bags of size of 40 cm × 24 cm × 24 cm with 600 gauge thickness and 15 kg capacity were used for raising bhindi plants.

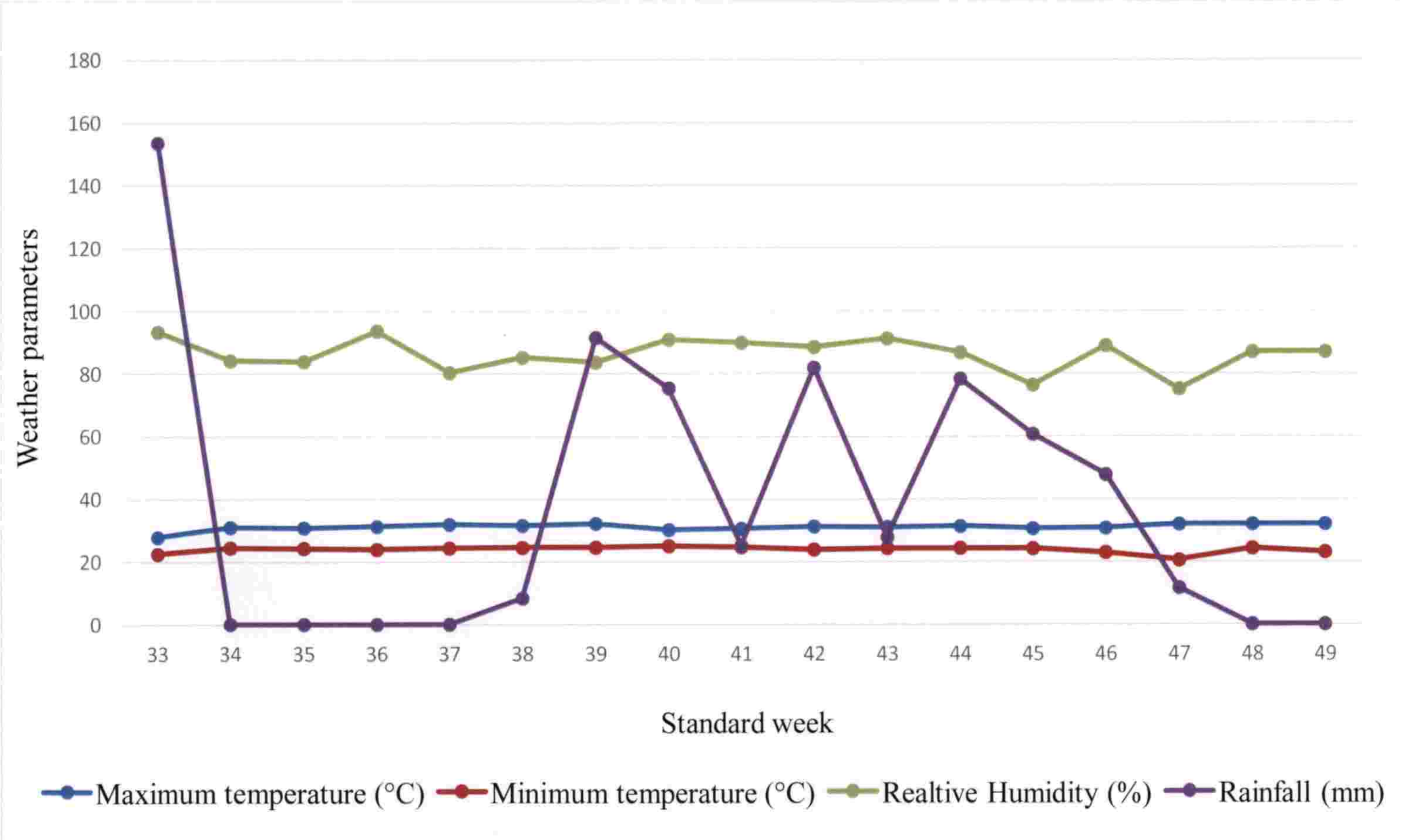

Fig. 1. Weather parameters during the crop period (15-08-2018 to 03-12-2018)

3.2.2.3 Potting Medium

The potting medium used for the experiment was a mixture of soil, rock sand, coir pith compost and paddy straw compost mixed in the ratio 1: 0.5: 0.5: 1 on volume basis. Farm yard manure substituted for paddy straw compost in the potting medium served as control.

3.2.2.4 Manures and Fertilizers

Urea (46 % N), rock phosphate (18 % P_2O_5) and muriate of potash (60 % K_2O) were used as chemical sources of N, P and K respectively. Dried and well rotten FYM (1.52 % N, 0.72 % P and 0.40 % K) was used as the organic manure for the pot culture experiment.

3.3 METHODS

3.3.1 Experiment I - Composting of Paddy Straw

3.3.1.1 Design and Layout

Design : Completely Randomised Design

Treatments : 8

Replications : 3

3.3.1.2 Treatments

Vermicomposting

T_1 - Paddy straw + cowdung (8:1) + earthworms

T_2 - Paddy straw + cowdung (6:1) + earthworms

T_3 - Paddy straw + cowdung (4:1) + earthworms

Co - composting

T_4 - Paddy straw + poultry manure (8:1)

T_5 - Paddy straw + poultry manure (6:1)

T_6 - Paddy straw + poultry manure (4:1)

T_7 - Paddy straw + cowdung + poultry manure (8:1:1)

Microbial composting

T_8 - Paddy straw + Urea + *Pleurotus* (For 100 kg straw, 500 g urea and 150 g *Pleurotus*)

Composting of paddy straw was carried out in concrete pits of size 1 m^3, maintained in roofed composting yards. Paddy straw collected during crop harvest in March 2018 was soaked and drained upto 50 per cent moisture level and was then mixed with cowdung, poultry manure or both in different ratios on volume basis as per the treatments described above. For vermicomposting treatments, earthworm species *Eudrillus euginea* were introduced @ 1000 nos per pit after 10 days of initial degradation when the heat in composting piles was reduced. Adequate moisture (50 to 60 %) was ensured in the composting material by periodic sprinkling of water. The materials were turned twice in a week, to ensure aeration and uniform decomposition. Maturity of composts was determined initially based on visual observation and then confirmed upon C: N ratio narrowed down to less than 20: 1, as suggested by (Khater, 2015). Mature composts were sieved, shade dried and stored as per the treatments. Initial and final stages of composting as well as mature composts are depicted in Plates 1, 2 and 3.

3.3.2 Experiment II - Pot Culture Study on Bhindi

3.3.2.1 Design and Layout

Design	: Completely Randomised Design
Treatments	: 9
Replications	: 3
Pots per treatment per replication	: 5

Plate 1. Initial stage of composting

Plate 2. Final stage of composting

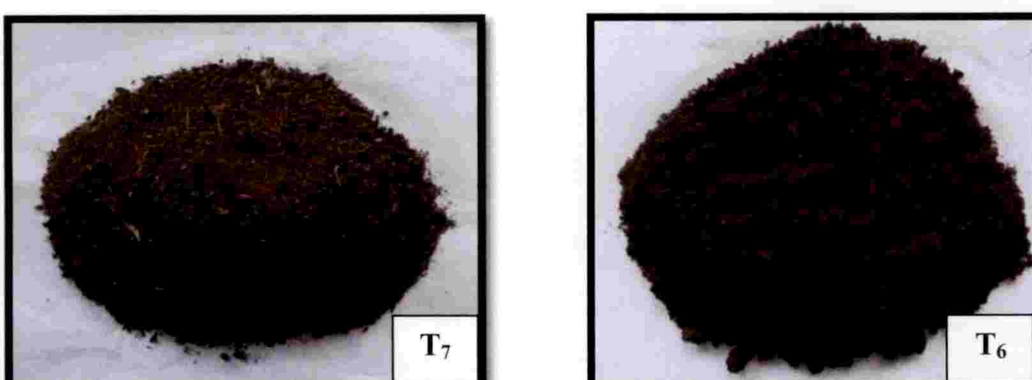

Plate 3. Mature composts generated from paddy straw

3.3.2.2 Treatments

In treatments T_1 to T_8, FYM was substituted with paddy straw compost in the potting media.

T_1 - Potting media with compost 1

T_2 - Potting media with compost 2

T_3 - Potting media with compost 3

T_4 - Potting media with compost 4

T_5 - Potting media with compost 5

T_6 - Potting media with compost 6

T_7 - Potting media with compost 7

T_8 - Potting media with compost 8

T_9 - Potting media with FYM

3.3.2.3 Crop Production

3.3.2.3.1 Grow Bag Preparation

Each grow bag was filled with 13 kg of the potting medium. Five bags were filled for each treatment per replication.

3.3.2.3.2 Sowing

Bhindi seeds were packed and tied in muslin cloth and kept in water for 12 hours for soaking. Thereafter, the seeds were taken out and kept overnight for drainage. Next day (15-08-2018), the pre germinated seeds were sown in pro trays. Coirpith compost and vermicompost mixed in the ratio 1:1 by weight were used to fill pro trays. Bhindi seeds were sown in three pro trays to raise seedlings for pot culture study.

3.3.2.3.3 Transplanting

Healthy seedlings were transplanted in grow bags after two weeks of sowing (29-08-2018).

3.3.2.3.4 Application of Manures and Fertilizers

KAU Package of Practices Recommendations (KAU, 2016) for bhindi was followed for crop nutrition. Basal organic manure was supplied through FYM @ 130 g per plant. The basal dose of chemical fertilizers was supplied as urea, rock phosphate and muriate of potash @ 0.78, 1.26 and 0.76 g per plant respectively. Top dressing with 0.78 g of urea per plant was done one month after planting (MAP).

Plate 4 indicates the general view of the experimental area.

3.3.2.3.5 After Cultivation

Irrigation was provided to bhindi seedlings two times a day upto one MAP. Further irrigation was limited to once in a day. Weeds which emerged in grow bags were removed as and when noticed. Plants were given staking at 45 DAP for providing better support to maintain an erect posture.

Different growth stages of the crop are depicted in Plate 5.

3.3.2.3.6 Plant Protection

Neem oil garlic emulsion (2 %) was sprayed once in a week during the initial stages of crop growth (upto one MAP) for the management of aphids. Fruit and shoot borers were controlled by spraying Quinalphos 25 EC @ 0.05 per cent. Two sprayings were given at 80 and 85 days after sowing (DAS). *Cercospora* leaf spot was controlled by the application of Copper oxy chloride 50 WP @ 0.2 per cent. The spray was given at 90 DAS.

Plate 4. General view of experimental area

Plate 5.1. Transplanting (14 DAS)

Plate 5.2. Crop stand at 40 DAS

Plate 5.3. Flowering

Plate 5.4. Fruiting

Plate 5. Different growth stages of the crop

3.3.2.3.7 Harvest

The fruits were harvested from 50 DAS and continued upto 110 DAS. The maturity of fruits were determined based on visual appearance.

3.4 OBSERVATIONS

3.4.1 Experiment I - Composting of Paddy Straw

3.4.1.1 Composition of Paddy Straw

Samples of paddy straw were collected, air dried and then oven dried at 70 ± 5^0C to a constant weight. The samples were ground well and digested for determination of nutrient content. Biochemical analysis was done as per the procedures described in Table 1. The characteristics of paddy straw used for the study are listed in Table 2.

Table 1. Analytical methods followed for analysis of paddy straw

Parameter	Method	References
Lignin	Acid detergent fibre method	Sadasivam and Manickam (2008)
Cellulose	Colorimetry	Updegroff (1969)
Nitrogen	Microkjeldhal method	Jackson (1973)
Phosphorus	Nitric-perchloric acid digestion (9:4) and spectrophotometry using Vanadomolybdate phosphoric yellow colour method	Jackson (1973)
Potassium	Nitric-perchloric acid digestion (9:4) and flame photometry	Jackson (1973)
Carbon	Weight loss on ignition	FAI (2017)
Iron, Copper, Manganese and Zinc	Nitric-perchloric acid digestion (9:4) and Atomic Absorption Spectrophotometer	Jackson (1973)

Boron	Spectrophotometry-Azomethane-H method	Roig *et al.* (1996)
Silicon	Blue silicomolybdous acid method	Ma *et al.* (2004)

Table 2. Composition of paddy straw before composting

Parameters	Content
Lignin (%)	26
Cellulose (%)	54
Major nutrients (%)	
N	0.68
P	0.12
K	1.35
Micro and beneficial nutrients (mg kg^{-1})	
Fe	544.2
Cu	23.88
Mn	144.19
Zn	36.31
B	3.24
Si	68000
C: N ratio	60:1

3.4.1.2 Nutrient Content of Cowdung and Poultry Manure

The content of N, P and K in cowdung and poultry manure were determined by the standard procedures as mentioned in Table 1 and presented in Table 3.

Table 3. Nutrient content of cowdung and poultry manure

Manure	Nutrient content (%)		
	N	P	K
Cowdung	1.21	0.40	0.60
Poultry manure	2.30	1.40	1.35

3.4.1.3 Total Microbial Count

Total microbial population (bacteria, fungi and actinomycetes) in paddy straw, cowdung and poultry manure were determined before composting using serial dilution and plate count technique as described in Table 4. Total microbial count in composting materials is given in Table 5.

Table 4. Media used for enumeration of microbes

Microbes	Medium used	Dilution factor	Reference
Bacteria	Nutrient agar	10^{-6}	Jhonson and Curl (1972)
Fungi	Martin's rose bengal agar	10^{-3}	
Actinomycetes	Kenknight agar	10^{-4}	

Table 5. Microbial count in composting materials

Composting materials	Microbial count (cfu g^{-1})		
	Bacteria ($\times 10^6$)	Fungi ($\times 10^3$)	Actinomycetes ($\times 10^4$)
Paddy straw	92.67	62.00	19.66
Cowdung	86.00	15.50	18.00
Poultry manure	216.00	40.33	17.33

3.4.1.4 Time Taken for Composting

Maturity of composts were determined based on visual observation and the time taken for composting was recorded in days.

3.4.1.5 Recovery of Compost

The quantity of compost generated from each treatment was recorded and recovery in percentage was worked out.

3.4.1.6 Chemical Properties of Compost

3.4.1.6.1 pH

Compost samples obtained on maturity were mixed with water in 1:5 ratio and pH was measured using pH meter with glass electrode (Jackson, 1973).

3.4.1.6.2 Electrical Conductivity

Compost - water solution used for determination of pH was used for estimating EC. Electrical conductivity was determined using conductivity meter (Jackson, 1973) and expressed as dS m^{-1}.

3.4.1.6.3 Cation Exchange Capacity

Cation exchange capacity of composts were determined by extracting the cations using $BaCl_2$ and taking filtration reading of cations in Atomic Absorption Spectrophotometer and Flame photometer (Hendershot and Duquette, 1986) and expressed as c mol kg^{-1}.

3.4.1.6.4 Nutrient Content

Composts were analysed for major (N, P and K), micro (Fe, Cu, Mn, Zn and B) and beneficial nutrients (Si) as per the procedures outlined in Table 1.

3.4.1.6.5 C: N Ratio

Organic carbon content of compost samples were determined using weight loss on ignition method (FAI, 2017) and N content using microkjeldhal method (Jackson, 1973). The ratio of organic carbon to nitrogen was worked out and expressed as C: N ratio.

3.4.1.7 Total Microbial Count

Total microbial population (bacteria, fungi and actinomycetes) in mature composts were determined using serial dilution and plate count technique as mentioned in Table 4.

3.4.1.8 Dehydrogenase Enzyme

Dehydrogenase activity in composts were determined using colorimetric determination of 2,3,5- triphenyl formazan (TPF) as outlined by Casida *et al.* (1964) and expressed as μg TPF hr^{-1} g^{-1}.

One gram of air dried sample was mixed with 0.2 g $CaCO_3$, one ml three per cent 2,3,5 - triphenyl tetrazolium chloride (TTC) and 2.5 ml distilled water. It was then incubated for one day. After 24 hours, 10 ml methanol was added and shaken for one minute. A glass funnel plugged with absorbent cotton was used for filtering the sample. Entire sample was transferred to the funnel by washing with methanol. The funnel was washed repeatedly with methanol until the reddish colour on the absorbent cotton disappeared. The filtrate was then made upto 100 ml with methanol and the intensity of red colour was read using spectrophotometer at 485 nm. The dehydrogenase activity in compost sample was determined by plotting standard curve using TPF as standard.

3.4.2 Experiment II - Pot Culture Study on Bhindi

Three plants per treatment per replication were tagged as observational plants.

3.4.2.1 Growth Characters

3.4.2.1.1 Plant Height

Plant height was measured in cm from the base of the observational plant to the terminal bud at 45, 60, 75 DAS and at final harvest and the average was worked out.

3.4.2.1.2 Number of Branches

Number of branches in each observational plant was noted at 45, 60, 75 DAS and at final harvest and the average values were recorded.

3.4.2.1.3 Leaf Area per Plant

Leaf area of plants was calculated by using linear measurement method (Musa *et al.*, 2016). Length, breadth and number of small, medium and large sized leaves were recorded at 30 and 60 DAS. Leaf area was estimated using the formula,

Leaf area (cm^2) = Length × Width × Number of leaves × 0.62

3.4.2.2 Yield Attributes and Yield

3.4.2.2.1 Days to 50 per cent Flowering

Days taken for 50 per cent of the plant population to flower in each of the treatments were recorded.

3.4.2.2.2 Number of Fruits per Plant

Number of fruits harvested from each plant was recorded and the mean was worked out.

3.4.2.2.3 Length of Fruit

The length of fruits which were obtained from each plant in each harvest was recorded and the mean was worked out and expressed in cm.

3.4.2.2.4 Girth of Fruit

Girth of the fruits obtained from each plant in each harvest was recorded by winding a twine around the top one-third portion of fruit and the mean was worked out and expressed in cm.

3.4.2.2.5 Weight of Fruit

Weight of fruits obtained from each plant in each harvest was recorded and the mean was worked out and expressed in g.

3.4.2.2.6 Total Fruit Yield

Total weight of fruits from each plant at different harvests were recorded and expressed as fruit yield in kg per plant.

3.4.2.2.7 Total Dry Matter Production at Final Harvest

Sample plants were uprooted at final harvest and oven dried at 80 ^{0}C to a constant weight and the total dry matter production (DMP) was expressed in g per plant.

3.4.2.3 Quality Parameters

3.4.2.3.1 Crude Protein Content

The N content of the fruits was determined and the values were multiplied with the factor 6.25 to obtain protein content and the values were expressed in percentage (Simpson *et al.*, 1965).

3.4.2.3.2 Crude Fibre Content

The crude fibre content was determined by acid-alkali treatment (Sadasivam and Manickam, 2008) and expressed in percentage.

3.4.2.3.3 Ascorbic Acid Content

The ascorbic acid content of fruits were determined by titrimetric method (Sadasivam and Manickam, 2008) and expressed as mg 100 g^{-1} on fresh weight basis.

3.4.2.4 Uptake of Major Nutrients

Plant and fruit samples were separately chopped and oven dried and were analysed for N, P and K content at final harvest as per the procedures described in Table 1. Uptake of N, P and K were calculated as the product of N, P and K content of plant/fruit samples (expressed in percentage) and their respective dry weights. Total nutrient uptake was calculated by adding plant and fruit uptake and expressed as g per plant.

3.4.2.5 Analysis of Potting Media

Samples were drawn from different potting media and analysed for the following properties before and after the experiment.

Table 6. Procedures followed for analysis of potting media

Parameter	Procedure	Reference
pH	pH meter with glass electrode	Jackson (1973)
Organic carbon	Walkely and Black rapid titration	Jackson (1973)
Available N	Alkaline potassium permanganate method	Subbiah and Asija (1956)
Available P	Bray No.I extraction and spectrophotometry	Jackson (1973)
Available K	Neutral normal ammonium acetate extraction and flamephotometry	Jackson (1973)
Microbial count	Serial dilution and plate count technique	Johnson and Curl (1972)

3.4.2.6 Incidence of Pests and Diseases

Pest and disease incidence during the experiment was observed visually and noted in each treatment.

3.4.2.7 Economic Analysis

Economics of cultivation was worked out by taking into account the cost of inputs, labour and prevailing market price of bhindi during the cropping period as given in Appendix II.

3.4.2.7.1 Net Returns

Net returns from the experiment was calculated using the following formula and was expressed in ₹ bag^{-1}.

Net returns = Gross returns - Total cost of cultivation

3.4.2.7.2 Benefit - Cost Ratio

Benefit: Cost Ratio (BCR) was calculated as follows.

$$BCR = \frac{\text{Gross returns}}{\text{Total cost of cultivation}}$$

3.4.2.8 Statistical Analysis

The data generated from the experiment were statistically analysed using OPSTAT software package. Wherever the treatment effects were found significant, critical differences at 5 per cent significance level were used to compare the treatment means.

RESULTS

4. RESULTS

The results of the experiment entitled "Bio recycling of paddy straw for quality manure production" conducted at Integrated Farming System Research Station, Karamana during March to December 2018 are presented in this chapter.

4.1 EXPERIMENT I - COMPOSTING OF PADDY STRAW

4.1.1 Time Taken for Composting

The influence of different composting methods on the time taken for compost production is given in Table 7.

The time taken for production of mature compost varied significantly among different treatments. Paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 (T_7) recorded the lowest time for composting (97.67 days). Co - composting using poultry manure in the ratios 6:1 and 4:1 (T_5 and T_6 respectively) also recorded comparable and lower time for composting (108 and 108.33 days respectively) when compared to other treatments. Among different composting methods, microbial composting (T_8) took the longest time (144 days) and was comparable to the time taken by T_1 *i.e.* vermicomposting of paddy straw with cowdung in the ratio 8:1 (138.67 days).

4.1.2 Recovery of Compost

The data pertaining to recovery of different composts produced in this experiment are presented in Table 7. Different composting methods could significantly influence the percentage recovery of compost. In general, co - composting treatments recorded higher recovery compared to other methods of composting.

Table 7. Effect of different composting methods on time taken for composting and recovery of compost

Treatments	Time taken for composting (days)	Recovery of compost (%)
T_1 - Paddy straw + cowdung (8:1) + earthworms	138.67	10.03
T_2 - Paddy straw + cowdung (6:1) + earthworms	130.00	11.42
T_3 - Paddy straw + cowdung (4:1) + earthworms	130.00	14.58
T_4 - Paddy straw + poultry manure (8:1)	119.33	27.38
T_5 - Paddy straw + poultry manure (6:1)	108.33	41.22
T_6 - Paddy straw + poultry manure (4:1)	108.00	44.59
T_7 - Paddy straw + cowdung + poultry manure (8:1:1)	97.67	27.29
T_8 - Paddy straw + Urea + *Pleurotus*	144.00	13.52
SE m (±)	2.03	0.50
CD (0.05)	6.152	1.517

Co - composting of paddy straw with poultry manure in the ratio 4:1 (T_6) recorded significantly higher recovery of 44.59 per cent. This was followed by T_5 *i.e.* co - composting of paddy straw with poultry manure in the ratio 6:1 (41.22 %). The treatment T_1, *i.e.* vermicomposting of paddy straw with the lowest quantity of cowdung (8:1 ratio) recorded the lowest recovery of 10.03 per cent and was statistically on par with T_2 *i.e.* vermicomposting in the ratio 6:1 (11.42 %).

4.1.3 Major Chemical Properties of Paddy Straw Compost

The major chemical properties of paddy straw composts including pH, EC CEC and C:N ratio were studied. The results of the same are presented in Table 8.

4.1.3.1 pH

Different composting methods were found to have no significant influence on the pH of paddy straw composts. All the composts generated had a neutral pH ranging from 7.39 to 7.47.

4.1.3.2 Electrical Conductivity

There was no significant influence of different composting methods on the EC of mature compost. The EC values ranged from 0.08 to 0.16 dS m^{-1}.

4.1.3.3 Cation Exchange Capacity

Cation exchange capacity of different composts were significantly influenced by various treatments. Paddy straw co - composted with poultry manure in the ratio 4:1 recorded a higher CEC of 77.91 c mol kg^{-1} and was comparable to all other co - composting treatments (T_4, T_5 and T_7) as well as the vermicomposting treatment with the addition of higher quantity of cowdung (T_3). The remaining composting treatments (T_1, T_2 and T_8) registered lower and comparable CEC values.

4.1.3.4 C: N Ratio

C: N ratio of the mature compost was significantly influenced by different composting methods. Among the different composting methods, paddy straw co - composted with poultry manure in the ratio 4:1 (T_6) registered a lower C: N ratio (9.54:1) and was comparable to T_7 (10.32:1) and T_5 (11.11:1). Microbial composting technique (T_8) recorded higher C: N ratio of 19.29:1 and was comparable to T_1 *i.e.* paddy straw vermicomposted with cowdung in the ratio 8:1 (18.48:1).

4.1.4 Nutrient Status of Paddy Straw Compost

Data pertaining to major (N, P and K), micro (Fe, Cu, Mn, Zn and B) and beneficial nutrient (Si) content of different paddy straw composts produced are furnished in Table 9.

4.1.4.1 Major Nutrients

Different composting methods were found to significantly influence the N content of paddy straw composts. Paddy straw co - composted with poultry manure in the ratio 4:1 (T_6) had the highest N content of 2.67 per cent and was statistically on par with T_7 *i.e.* co - composting of paddy straw with cowdung and poultry manure in the ratio 8:1:1 (2.40 %). The treatment T_8 *i.e.* paddy straw compost generated using microbial composting method recorded a lower N content of 1.57 per cent, comparable to that with T_1 (1.83 %).

Different composting technologies could significantly influence the total P content of the composts. Paddy straw compost produced through co - composting with the addition of poultry manure in the ratio 4:1 (T_6) recorded the highest P content of 0.93 per cent, comparable to T_7 *i.e.* paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 (0.85 %). Among different composting methods, microbial composting of paddy straw using *Pleurotus* (T_8) recorded significantly lower P content (0.27 %).

Table 8. Major chemical properties of compost

Treatments	pH	EC (dS m^{-1})	CEC (c mol kg^{-1})	C: N ratio
T_1	7.39	0.08	65.01	18.48
T_2	7.45	0.12	69.29	16.37
T_3	7.42	0.13	74.07	12.09
T_4	7.42	0.15	73.38	12.92
T_5	7.39	0.16	74.32	11.11
T_6	7.39	0.16	77.91	9.54
T_7	7.40	0.16	74.02	10.32
T_8	7.47	0.10	65.18	19.29
SE m (±)	0.03	0.10	1.91	0.71
CD (0.05)	-	-	5.780	2.148

T_1 - Paddy straw + cowdung (8:1) + earthworms

T_2 - Paddy straw + cowdung (6:1) + earthworms

T_3 - Paddy straw + cowdung (4:1) + earthworms

T_4 - Paddy straw + poultry manure (8:1)

T_5 - Paddy straw + poultry manure (6:1)

T_6 - Paddy straw + poultry manure (4:1)

T_7 - Paddy straw + cowdung + poultry manure (8:1:1)

T_8 - Paddy straw + Urea + *Pleurotus*

The total K content of mature compost was significantly influenced by different composting methods. The highest K content (3.15 %) was observed in the treatment T_6 (co - composting of paddy straw with poultry manure in the ratio 4:1) and it was comparable to T_7 *i.e.* co - composting of paddy straw with cowdung and poultry manure in the ratio 8:1:1 (3.03 %), as well as other co - composting treatments *i.e.* T_5 (2.78 %) and T_4 (2.70 %). Paddy straw generated using microbial composting with no addition of organic manure (T_8) recorded the lowest K content of 1.71 per cent and was comparable to treatments T_1 (2.18 %) and T_2 (2.22 %).

4.1.4.2 Micro and Beneficial Nutrients

The content of Fe and B in different composts were significantly influenced by composting methods. Paddy straw co - composted with poultry manure in the ratio 4:1 (T_6) recorded higher Fe content (3586.67 mg kg-1) and was comparable to T_5 *i.e.* co - composting in the ratio 6:1 (2998.67 mg kg^{-1}). The lowest Fe content (1084.33 mg kg^{-1}) was recorded in paddy straw compost generated through microbial composting (T_8) and was on par with T_1 (1189.67 mg kg^{-1}) and T_2 (1244.33 mg kg^{-1}).

The treatment T_6 (paddy straw co - composted with poultry manure in the ratio 4:1) recorded the higher B content of 19.74 mg kg^{-1}, comparable to T_7 (paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1) with 17.90 mg kg^{-1} of B. T_8 (microbial composting) recorded a lower B content of 11.28 mg kg^{-1}, but was on par with the treatments T_1 (12.92 mg kg^{-1}) and T_2 (13.16 mg kg^{-1}).

Statistical analysis of the data revealed that different composting methods had no significant influence on Cu, Mn and Zn content of the composts produced. Cu content in organic manures ranged from 26.61 to 37.80 mg kg^{-1}, Mn content ranged from 154.80 to 190.57 mg kg^{-1} and Zn content ranged from 163.20 to 217.37 mg kg^{-1}.

Table 9: Nutrient status of compost prepared by different composting methods

Treatments	Major nutrients (%)			Micro and beneficial nutrients (mg kg^{-1})					
	N	P	K	Fe	Cu	Mn	Zn	B	Si
T_1	1.83	0.48	2.18	1189.67	28.15	158.57	174.27	12.92	71333.34
T_2	1.90	0.51	2.22	1244.33	33.72	159.93	186.10	13.16	71333.34
T_3	2.12	0.58	2.58	2001.33	37.80	162.03	187.77	13.50	72000.00
T_4	2.06	0.63	2.70	2251.33	27.32	170.30	180.23	14.61	71333.34
T_5	2.22	0.79	2.78	2998.67	32.30	184.07	191.83	16.55	72666.66
T_6	2.67	0.93	3.15	3586.67	34.21	187.60	217.37	19.74	73333.34
T_7	2.40	0.85	3.03	2358.67	28.45	190.57	170.90	17.90	71333.34
T_8	1.57	0.27	1.71	1084.33	26.61	154.80	163.20	11.28	70666.66
SE m (±)	0.11	0.04	0.20	205.03	4.54	9.75	12.821	0.91	849.84
CD (0.05)	0.317	0.129	0.591	619.975	-	-	-	2.749	-

Different composting methods failed to produce any significant variation in the Si content of paddy straw composts. Si content of the composts ranged from 70.67 to 73.33 g kg^{-1}.

4.1.5 Microbial and Enzymatic Status of Paddy Straw Compost

The microbial status of different paddy straw composts as well as the status of dehydrogenase enzyme recorded in the study are given in Table 10. Different treatments of composting could significantly influence the microbial status as well as content of dehydrogenase enzyme. In general, the microbial population and dehydrogenase status were higher in co - composting treatments. Among microbes, the population of bacteria was found higher and comparable with co - composting treatments T_7 (156.33×10^6 cfu g^{-1}) and T_6 (147.33×10^6 cfu g^{-1}). The lower bacterial count was registered in T_1 (86.00×10^6 cfu g^{-1}), comparable to T_8. The fungal count was the highest with T_6 (112×10^3 cfu g^{-1}), significantly superior to all other treatments. Lower and comparable fungal population was observed in the treatments T_1, T_2 and T_8. The population of actinomycetes was significantly higher in the treatment T_7 (41.67×10^4 cfu g^{-1}) and lower in the treatment T_8 (23.00×10^4 cfu g^{-1}).

On analyzing the data on dehydrogenase content, it was clear that different composting treatments had a significant influence on the enzymatic activity in composts. Paddy straw composted using cowdung and poultry manure in the ratio 8:1:1 (T_7) recorded higher enzyme activity (27.55 µg TPF hr^{-1} g^{-1}), comparable to T_6 (26.87 µg TPF hr^{-1} g^{-1}) and T_5 (23.87 µg TPF hr^{-1} g^{-1}). Microbial composting (T_8) recorded a lower enzymatic activity of 13.24 µg TPF hr^{-1} g^{-1} and was comparable to the treatments T_1 (16.84 µg TPF hr^{-1} g^{-1}) and T_2 (17.54 µg TPF hr^{-1} g^{-1}).

Table 10. Microbial and enzymatic status of paddy straw composts obtained under different treatments

Treatments	Microbial count (cfu g^{-1})			Dehydrogenase enzyme (µg TPF hr^{-1} g^{-1})
	Bacteria ($\times 10^6$)	Fungi ($\times 10^3$)	Actinomycetes ($\times 10^4$)	
T_1	86.00	37.67	26.33	16.84
T_2	101.33	49.67	30.33	17.54
T_3	133.00	83.67	28.00	19.14
T_4	120.00	71.67	35.33	21.95
T_5	142.67	84.00	32.67	23.87
T_6	147.33	112.00	39.00	26.87
T_7	156.33	95.33	41.67	27.55
T_8	87.67	38.33	23.00	13.24
SE m (±)	4.50	5.26	0.86	1.48
CD (0.05)	13.602	15.917	2.594	4.483

4.2 EXPERIMENT II - POT CULTURE STUDY ON BHINDI

4.2.1 Growth Characters

4.2.1.1 Plant Height

Plant height recorded at different stages of crop growth (45, 60, 75 DAS and at final harvest (at 110 DAS)) is presented in Table 11. On analyzing the data, it was noted that plant height at different crop growth stages were significantly influenced by different paddy straw composts supplied as potting media component.

The data revealed that potting media having composts generated through co - composting *i.e.* treatments T_6 and T_7 (having more quantity of N source) produced taller plants at all stages of crop growth. At 45 DAS, these treatments registered significantly higher and comparable plant height of 74.75 cm and 71.87 cm respectively. This was followed by the treatments T_4 and T_5 (potting media having composts generated through co - composting but, with lower quantity of N source compared to T_6 and T_7) recording comparable plant height.

At 60 DAS, the plant height was found higher and comparable for all the treatments having co - composted paddy straw as potting media component. The plant height was more for T_6 (103.02 cm), followed by T_7 (99.48 cm), T_5 (95.50 cm) and T_4 (91.63 cm). This same trend was followed for plant height at 75 DAS and at final harvest. At final harvest, plants were higher with treatment T_6 (138.67 cm), followed by T_7 (128.70 cm), T_5 (126.42 cm) and T_4 (120.20 cm).

The treatment T_1 having vermicomposted paddy straw in the ratio 8: 1 as potting media component produced shorter plants at all the growth stages (35.17 cm, 45.63 cm, 62.50 cm, 81.85 cm respectively at 45, 60, 75 DAS and at final harvest).

Table 11. Influence of different treatments on plant height of bhindi at various growth stages, cm

Treatments	Plant height			
	45 DAS	60 DAS	75 DAS	Final harvest
T_1 - PM with compost 1	35.17	45.63	62.50	81.85
T_2 - PM with compost 2	42.70	79.73	105.67	113.27
T_3 - PM with compost 3	45.68	82.51	110.50	115.84
T_4 - PM with compost 4	58.98	91.63	116.23	120.20
T_5 - PM with compost 5	52.93	95.50	117.22	126.42
T_6 - PM with compost 6	74.75	103.02	129.60	138.67
T_7 - PM with compost 7	71.87	99.48	120.21	128.70
T_8 - PM with compost 8	41.57	53.58	74.60	85.83
T_9 - PM with FYM	35.80	48.63	85.06	107.13
SE m (±)	4.80	6.19	5.96	6.97
CD (0.05)	14.377	18.532	17.843	20.875

PM - Potting media

4.2.1.2 Number of Branches per Plant

The data on number of branches per plant at different stages is presented in Table 12. As evidenced from the table, different paddy straw composts as potting media component could not significantly influence the number of branches at various crop stages (45, 60, 75 DAS and at final harvest).

4.2.1.3 Leaf Area per Plant

Leaf area was worked out at two stages of crop growth - vegetative (30 DAS) and flowering (60 DAS) and is presented in Table 13.

The data revealed that different paddy straw composts as potting media component significantly influenced the leaf area produced per plant. At 30 DAS, higher leaf area of 960.06 cm^2 was recorded with T_6 (potting media with paddy straw co - composted using poultry manure in the ratio 4:1) and it was on par with the treatments T_7 (864.04 cm^2) and T_5 (788.18 cm^2). Lower leaf area of 479.05 cm^2 was observed in the control treatment T_9 (potting media containing FYM as organic source) and it was comparable to the treatments having vermicomposted paddy straw as component (T_1, T_2 and T_3) as well as to the treatment with microbial compost (T_8).

At 60 DAS, the leaf area was higher (3909.70 cm^2) with the treatment T_7 (potting media with co - composted paddy straw, cowdung and poultry manure in the ratio 8:1:1), which was on par with T_6 (3827.26 cm^2), T_5 (3354.97 cm^2) and T_4 (3271.30 cm^2). Significantly lower and comparable leaf area were noted with the treatments T_1 (2257. 92 cm^2), T_8 (2507.25 cm^2) and T_9 (2489.99 cm^2).

4.2.2 Yield Attributes and Yield

Yield and yield attributes including days to 50 per cent flowering, number of fruits per plant, length, girth and weight of fruits, total fruit yield as well as dry matter production are shown in Table 14.

Table 12. Influence of different treatments on number of branches per plant of bhindi at various growth stages

Treatments	Number of branches			
	45 DAS	60 DAS	75 DAS	Final harvest
T_1 - PM with compost 1	1.50	1.67	1.83	2.17
T_2 - PM with compost 2	1.83	2.10	2.27	2.33
T_3 - PM with compost 3	1.83	2.10	2.33	2.43
T_4 - PM with compost 4	1.83	2.27	2.33	2.50
T_5 - PM with compost 5	2.00	2.33	2.43	2.50
T_6 - PM with compost 6	2.22	2.33	2.50	2.60
T_7 - PM with compost 7	2.00	2.33	2.60	2.70
T_8 - PM with compost 8	1.83	2.00	2.10	2.27
T_9 - PM with FYM	1.83	2.10	2.27	2.33
SE m (±)	0.17	0.24	0.28	0.30
CD (0.05)	-	-	-	-

PM - Potting media

Table 13. Influence of different treatments on the leaf area of bhindi at 30 and 60 DAS, cm^2

Treatments	Leaf area per plant	
	30 DAS	60 DAS
T_1 - PM with compost 1	537.06	2257.92
T_2 - PM with compost 2	581.75	3030.35
T_3 - PM with compost 3	612.09	3064.88
T_4 - PM with compost 4	727.27	3271.30
T_5 - PM with compost 5	788.18	3354.97
T_6 - PM with compost 6	960.06	3827.26
T_7 - PM with compost 7	864.04	3909.70
T_8 - PM with compost 8	560.12	2507.25
T_9 - PM with FYM	479.05	2489.99
SE m (±)	77.240	256.466
CD (0.05)	231.271	767.904

PM - Potting media

4.2.2.1 Days to 50 per cent Flowering

On analyzing the data, it was found that, 50 per cent flowering was achieved much early in the treatment T_7 (48.67 days) but was comparable to all other treatments except T_9 and T_8. Flowering was significantly delayed and was comparable in the treatments T_9 and T_8 (60 and 57.33 days respectively) and these treatments were found inferior compared to all other treatments.

4.2.2.2 Number of Fruits per Plant

Comparable and significantly higher number of fruits per plant was registered in the treatments in which co - composted paddy straw was used as potting media component. *i.e.* T_7 (27.67), T_6 (26.67), T_5 (26.00) and T_4 (25.67). The lowest number of fruits per plant was recorded by the treatment T_1 (17.33) and it was comparable to T_9 (18.33) and T_8 (19.00).

4.2.2.3 Length of Fruit

Analysis of the data revealed that length of fruit was significantly influenced by different paddy straw composts supplied as potting media component. Significant and comparably longer fruits were produced by the treatments T_7 (16.40 cm) and T_6 (16.01 cm). In both these treatments, paddy straw was co - composted with poultry manure or poultry manure and cowdung in different ratios and was utilized as potting media component. Control treatment which had FYM as potting media component (T_9) produced shorter fruits (14.35 cm) and was on par with T_8 (potting media with paddy straw compost generated from microbial composting as the organic source) and T_1 (vermicomposted paddy straw in the ratio 8:1 as potting media component). T_8 and T_1 registered fruit length of 14.69 cm and 14.81 cm respectively.

4.2.2.4 Girth of Fruit

In the present study, different paddy straw composts failed to produce any significant influence on the girth of the bhindi fruits.

4.2.2.5 Weight of Fruit

The highest fruit weight (27.05 g) was observed with the treatment T_7 (paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 as potting media component) and it was statistically on par with T_6 (26.26 g) and T_5 (25.21 g). The treatment T_9 recorded a lower fruit weight of 21.07 g and was comparable to T_8 (22.59 g) and T_1 (22.93 g).

4.2.2.6 Total Fruit Yield

Different paddy straw composts supplied as potting media component could significantly influence the total fruit yield in bhindi. Among the different potting media, the highest yield per plant (0.619 kg) was recorded with the treatment T_7 and it was statistically on par with the treatment T_6 (0.590 kg per plant). Comparable and significantly lower fruit yields were recorded in treatments T_1 (0.345 kg per plant), T_9 (0.361 kg per plant) and T_8 (0.382 kg per plant).

4.2.2.7 Total Dry Matter Production

The total DMP of bhindi at final harvest (110 DAS) varied significantly among treatments. The highest DMP of 128.35 g per plant was registered by T_7, which was comparable with the treatment T_6 (119.67 g per plant). Treatments T_1 (68.34 g per plant), T_8 (75.44 g per plant) and T_9 (80.07 g per plant) registered significantly lower and comparable DMP.

4.2.3 Quality Parameters

The observations made on the effect of different potting media on quality parameters of bhindi fruit are presented in Table 15. All the quality characters were found to be significantly influenced by the different treatments of the study.

Table 14. Influence of different treatments on yield attributes and yield of bhindi

Treatments	Days to 50 percent flowering	Fruits per plant	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Fruit yield (kg per plant)	Dry matter production (g per plant)
T_1	53.00	17.33	14.81	6.19	22.93	0.345	68.34
T_2	52.67	23.00	15.18	6.12	23.78	0.482	95.15
T_3	51.33	23.67	15.20	6.13	24.21	0.508	103.88
T_4	51.33	25.67	15.29	6.14	24.71	0.515	106.61
T_5	50.67	26.00	15.49	6.18	25.21	0.534	113.37
T_6	49.33	26.67	16.01	6.11	26.26	0.590	119.67
T_7	48.67	27.67	16.40	6.21	27.05	0.619	128.35
T_8	57.33	19.00	14.69	6.22	22.59	0.382	75.44
T_9	60.00	18.33	14.35	6.08	21.07	0.361	80.07
SE m (±)	2.34	1.25	0.16	0.09	0.76	0.013	4.09
CD (0.05)	6.994	3.734	0.478	-	2.272	0.0390	12.240

4.2.3.1 Crude Protein Content

Among the different treatments, T_7 (paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 as potting media component) was found to be statistically superior in terms of crude protein content (21.12 %) compared to all other treatments. This was followed by T_6 (paddy straw co - composted with poultry manure in the ratio 4:1 as potting media component) and T_5 (paddy straw co - composted with poultry manure in the ratio 6:1 as potting media component) recording comparable crude protein contents of 19.25 per cent and 17.97 per cent respectively. The treatments T_1 (11.55 %), T_2 (12.72 %), T_8 (12.25 %) and T_9 (12.37 %) recorded lower and comparable crude protein content.

4.2.3.2 Crude Fibre Content

Significantly lower crude fibre content (11.10 %) was recorded by the treatment T_7 and the highest by T_9 (19.30 %). Increase in crude fibre being a negative trait with respect to quality, T_9 could be rated inferior with regard to this aspect.

4.2.3.3 Ascorbic Acid Content

The treatments T_7, T_6 and T_5 recorded significantly higher and comparable ascorbic acid content of 21.05, 19.30 and 17.54 mg 100 g^{-1} respectively. The lower values for ascorbic acid content were recorded by the treatments T_1 and T_9 (10.53 mg 100 g^{-1}).

4.2.4 Uptake of Major Nutrients

The results on effect of different treatments on the uptake of major plant nutrients by bhindi crop are depicted in Table 16.

Table 15. Influence of different treatments on quality parameters of bhindi fruits

Treatments	Crude protein (%)	Crude fibre (%)	Ascorbic acid (mg 100 g^{-1})
T_1 - PM with compost 1	11.55	17.90	10.53
T_2 - PM with compost 2	12.72	16.70	12.28
T_3 - PM with compost 3	13.65	15.23	14.04
T_4 - PM with compost 4	17.62	15.47	12.28
T_5 - PM with compost 5	17.97	14.93	17.54
T_6 - PM with compost 6	19.25	14.37	19.30
T_7 - PM with compost 7	21.12	11.10	21.05
T_8 - PM with compost 8	12.25	16.7	12.28
T_9 - PM with FYM	12.37	19.3	10.53
SE m (±)	0.54	0.33	1.43
CD (0.05)	1.622	0.978	4.286

PM - Potting media

4.2.4.1 N uptake

Uptake of N was higher (2.92 g per plant) with T_7 (paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 as potting media component) and was on par with T_6 (paddy straw co - composted with poultry manure in the ratio 4:1 as potting media component). The lowest N uptake was recorded with treatment T_1 (1.17 g per plant) and was comparable to the treatments T_8 and T_9, which recorded an uptake of 1.24 and 1.28 g per plant respectively.

4.2.4.2 P uptake

Different potting media had a significant influence on the uptake of P by bhindi plants. Plants grown in potting media with paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 substituted for FYM (T_7) registered highest P uptake of 0.48 g per plant, however, on par with T_6, which recorded an uptake of 0.42 g per plant. The lowest P uptake was observed in T_1 (0.14 g per plant) and was comparable with T_8 and T_9.

4.2.4.3 K uptake

Plants grown in potting media with paddy straw co - composted with poultry manure in the ratio 4:1 (T_6) registered higher uptake of K (2.96 g per plant) and it was found comparable with the uptake of T_7 (2.88 g per plant). The uptake of K was lower and comparable for treatments T_1 (1.61 g per plant) *i.e.* paddy straw vermicomposted with cowdung in the ratio 8:1 as potting media component and T_8 (1.91 g per plant) and T_9 (1.81 g per plant).

4.2.5 Analysis of Potting Media

Properties of potting media like pH and organic carbon are given in Table 17 and available nutrient status in Table 18.

Table 16. Influence of different treatments on nutrient uptake of bhindi plants, g per plant

Treatments	Nutrient uptake		
	N	P	K
T_1 - PM with compost 1	1.17	0.14	1.61
T_2 - PM with compost 2	1.56	0.28	2.13
T_3 - PM with compost 3	1.74	0.31	2.36
T_4 - PM with compost 4	2.11	0.32	2.45
T_5 - PM with compost 5	2.52	0.33	2.50
T_6 - PM with compost 6	2.73	0.42	2.96
T_7 - PM with compost 7	2.92	0.48	2.88
T_8 - PM with compost 8	1.24	0.15	1.91
T_9 - PM with FYM	1.28	0.23	1.81
SE m (±)	0.12	0.04	0.12
CD (0.05)	0.350	0.124	0.353

PM - Potting media

4.2.5.1 pH

It is clear from the table that different paddy straw composts as potting media component failed to produce any significant effect on pH of the potting media before and after the experiment. Initial pH of the potting media ranged from 7.41 to 7.51. A slight lowering of pH was observed after the experiment and it ranged from 6.71 to 6.93.

4.2.5.2 Organic Carbon

Perusal of the data in Table 17 revealed that use of different paddy straw composts prepared under different treatments as potting media component had significant influence on the organic carbon content both before and after the experiment.

Among different potting mixtures prepared, organic carbon was found higher and comparable for all treatments wherein paddy straw compost was used as potting media component (T_1 to T_8). Towards the end of the study, the organic carbon content was found higher and comparable for treatments having co - composted paddy straw as potting media component (T_4 to T_7). Organic carbon content was the lowest for control treatment (T_9) before (0.86 %) and after (1.16 %) the pot culture study.

4.2.5.3 Available Nitrogen

The data in Table 18 revealed that different paddy straw composts as potting media component have significant influence on the availability of N before the start of the experiment. Available N was higher (0.017 %) in potting media containing paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 (T_7) and this was comparable to T_6 (potting media containing co - composted paddy straw and poultry manure in the ratio 4:1), with an available N content of 0.016 per cent. The available N was found lower (0.008 %) with the treatment T_9 *i.e.* potting media with FYM as component and was on par with treatments T_8 (0.009 %) and T_1 (0.010 %).

Table 17. Influence of different treatments on pH and organic carbon content of potting media

Treatments	pH		Organic carbon (%)	
	Before experiment	After experiment	Before experiment	After experiment
T_1	7.42	6.93	1.76	1.80
T_2	7.47	6.78	1.76	1.83
T_3	7.50	6.88	1.83	1.85
T_4	7.41	6.72	1.76	1.88
T_5	7.43	6.71	1.84	1.94
T_6	7.45	6.72	1.89	1.98
T_7	7.51	6.83	1.87	1.98
T_8	7.42	6.85	1.75	1.79
T_9	7.42	6.74	0.86	1.16
SE m (±)	0.03	0.05	0.05	0.04
CD (0.05)	-	-	0.144	0.121

Available N status of different potting media estimated after the completion of experiment however had no significant difference.

4.2.5.4 Available Phosphorus

Different paddy straw composts as potting media component have significant influence on the available P content both before and after the experiment.

At the start of the experiment, available P was higher and comparable for treatments T_6 (0.013 %), T_7 (0.011 %) and T_5 (0.011 %). Comparable and significantly lower available P status was recorded with the treatments T_8 (0.005 %) and T_9 (0.007 %).

Slightly different trend was observed in available P status after the completion of the experiment. All the treatments except T_8 and T_9 recorded higher available P content.

4.2.5.5 Available Potassium

As evidenced from Table 18, available K content of the potting mixture was significantly influenced by different paddy straw composts as potting media component.

Before the planting the crop, available K status was higher and comparable for the treatments in which co - composted paddy straw was used as potting media component *i.e.* T_6 (0.041 %), T_7 (0.040 %), T_5 (0.039 %) and T_4 (0.038 %). The treatment T_9 recorded the lower available K status of 0.017 % and was statistically on par with T_8 (0.018 %).

Available K content of different potting media estimated after the completion of experiment however had no significant difference.

Table 18. Available nutrient status of potting media before and after experiment, per cent

Treatments	Available nutrient content					
	N		P		K	
	Before experiment	After experiment	Before experiment	After experiment	Before experiment	After experiment
T_1	0.010	0.005	0.008	0.007	0.033	0.013
T_2	0.011	0.004	0.009	0.007	0.037	0.013
T_3	0.013	0.003	0.010	0.008	0.037	0.015
T_4	0.013	0.003	0.010	0.008	0.038	0.014
T_5	0.014	0.004	0.011	0.008	0.039	0.012
T_6	0.016	0.004	0.013	0.009	0.041	0.014
T_7	0.017	0.004	0.011	0.007	0.040	0.015
T_8	0.009	0.003	0.005	0.004	0.018	0.009
T_9	0.008	0.002	0.007	0.006	0.017	0.009
SE m (±)	0.001	0.001	0.001	0.001	0.001	0.002
CD (0.05)	0.0020	-	0.0020	0.0020	0.0030	-

4.2.5.6 Microbial Count

The microbial population in the potting media including bacteria, fungi and actinomycetes were recorded before and after the experiment. The data on microbial population is furnished in Table 19. The bacterial population in the potting media before the start of pot culture study was higher and comparable for treatments T_7 (93.67×10^6 cfu g^{-1}), T_6 (90.67×10^6 cfu g^{-1}), T_5 (89.33×10^6 cfu g^{-1}), and T_4 (80.67×10^6 cfu g^{-1}). The bacterial count was maintained higher in three of these treatments *i.e.* T_7, T_6 and T_5 after the pot culture study also. Lower bacterial count was registered in T_8 (54.67×10^6) before the experiment and was comparable with T_9, T_1, T_2 and T_3 and continued so at the end of experiment also.

Comparable and higher fungal population was recorded in the treatments T_7 (34.67×10^3), T_6 (35×10^3), T_5 (30.33×10^3) and T_3 (36.67×10^3) before the experiment and the same trend was noted at the end of pot culture study also. Lower fungal count was registered with the treatment T_8 (20.67×10^3) before the experiment and was comparable with T_9 and T_2 and continued so at the end of experiment also.

The population of actinomycetes did not vary significantly among different treatments before the start of pot culture study. However, after the experiment the population was found significantly influenced by different treatments. Higher and comparable actinomycetes population were recorded in the treatments in which co - composted paddy straw was used as potting media component. *i.e.* T_7 (28.67×10^4), T_6 (21.33×10^4), T_5 (21.00×10^4) and T_4 (23.67×10^4). Lower and comparable count was recorded in treatments T_1, T_2, T_8 and T_9.

Table 19. Influence of different treatments on soil microbial population, cfu g^{-1}

Treatments	Microbial count					
	Bacteria ($\times 10^6$)		Fungi ($\times 10^3$)		Actinomycetes ($\times 10^4$)	
	Before experiment	After experiment	Before experiment	After experiment	Before experiment	After experiment
T_1	59.33	64.67	27.67	31.33	6.00	10.33
T_2	66.67	71.00	26.67	31.33	9.00	14.67
T_3	62.00	74.67	36.67	38.33	9.67	19.33
T_4	80.67	81.00	29.33	38.00	10.67	23.67
T_5	89.33	96.33	30.33	47.00	12.00	21.00
T_6	90.67	98.33	35.00	45.33	10.67	21.33
T_7	93.67	97.33	34.67	48.67	12.33	28.67
T_8	54.67	69.33	20.67	25.67	8.00	11.33
T_9	62.67	72.67	22.67	24.33	10.00	13.67
SE m (±)	4.89	4.31	2.28	4.36	1.25	2.64
CD (0.05)	14.642	12.915	6.834	13.043	-	7.894

4.2.6 Incidence of Pests and Diseases

Pest and disease incidence were recorded periodically and no serious pest and disease were noted.

4.2.7 Economics of Cultivation

Economics of bhindi cultivation was worked out interms of net returns and BCR and are given in Table 20.

4.2.7.1 Net Returns

Net returns was higher and comparable for treatments T_7 (₹ 7.04 bag^{-1}) and T_6 (₹ 6.01 bag^{-1}). The lowest net returns was registered in T_1 (₹ -19.99 bag^{-1}), where paddy straw vermicomposted with cowdung in the ratio 8:1 was used as the potting media component.

4.2.7.2 B: C Ratio

B: C ratio followed the same trend as net returns. The treatment T_7 registered the highest BCR of 1.23, comparable to T_6 (1.20). The lowest BCR of 0.51 was recorded with the treatment T_1.

Table 20. Influence of different treatments on net returns and BCR

Treatments	Net returns (₹ bag^{-1})	BCR
T_1 - PM with compost 1	-19.99	0.51
T_2 - PM with compost 2	-9.10	0.76
T_3 - PM with compost 3	-4.72	0.87
T_4 - PM with compost 4	0.58	1.01
T_5 - PM with compost 5	2.51	1.09
T_6 - PM with compost 6	6.01	1.20
T_7 - PM with compost 7	7.04	1.23
T_8 - PM with compost 8	-15.92	0.59
T_9 - PM with FYM	-7.32	0.75
SE m (±)	0.80	0.02
CD (0.05)	2.394	0.073

PM - Potting media

DISCUSSION

5. DISCUSSION

The research work entitled "Bio recycling of paddy straw for quality manure production" was conducted at IFSRS, Karamana with the objectives to find out an effective technology for composting paddy straw and to assess the potential of paddy straw composts as potting media component in influencing the growth, yield and quality of bhindi. The results obtained from the experiment are discussed in this chapter.

5.1 EXPERIMENT I - COMPOSTING OF PADDY STRAW

5.1.1 Time Taken for Composting

As revealed from experimental results, different methods of composting could significantly influence the time taken for maturation of compost. Fig. 2 illustrates the influence of different treatments on the maturation of compost. In general, co - composting of paddy straw with poultry manure alone or in combination with cowdung recorded lower time for compost maturation.

Co - composting of paddy straw with cowdung and poultry manure (T_7) was the most efficient treatment in terms of significant earliness in maturation of compost. Under this treatment, compost maturity was ensured in 97.67 days. Conjunctive use of cowdung and poultry manure results in rapid mineralization of nutrients, especially N, through the synergistic interaction of humic substances and organic acids present in cowdung and poultry manure (Edward and Daniel, 1992). Rapid mineralization of N achieved in a faster pace could have thus contributed to the lowering of C: N ratio in a speedy manner. With decline in C: N ratio, degradation of cellulose and hemicelluloses also becomes faster (Eiland *et al.*, 2004). These could result in early maturation of compost.

Organic manures added during the start of experiment helps in proliferation of microbes during the progress of composting. Jusoh *et al.* (2013) reported that enhanced microbial activity results in rapid decomposition of organic wastes. Microbial activity in terms of bacteria and actinomycetes were quite high in the treatment T_7 (Table 10). Enhanced microbial activity recorded in this treatment could also be attributed to the shorter composting period.

The treatments T_6 and T_5 (co - composting of paddy straw with poultry manure in the ratios 4:1 and 6:1 respectively) also recorded lower periods (108 and 108.33 days respectively) for compost maturity. Nitrogen from poultry droppings undergo rapid mineralization, with most of the inorganic N released within 28 days (Dorivar and Ruiz, 2007). This could be attributed to the faster maturation of compost observed under co - composting of paddy straw with poultry manure. Also, the microbial population in poultry manure was found higher compared to cowdung (Table 5). Rapid release of N coupled with higher microbial activity in poultry manure (Devi *et al.*, 2012) resulted in faster decomposition of organic residues. Guerra-Rodriguez *et al.* (2001) reported that addition of poultry droppings as a constituent in co - composting increased the rate of decomposition of organic wastes during composting process.

In general, microbial composting (T_8) and vermicomposting using lower quantity of N source (T_1) registered prolonged periods for composting. Composting period was significantly higher for the treatments T_1 (138.67 days) and T_8 (144 days). This could be related to the fact that in these treatments, organic manure addition was either avoided or else was only in very little quantities. Microbial activity was also low in these two treatments (Table 10), which could have slowed up the whole decomposition process. Higher carbon content of the substrate and lower addition of N source into it could slow down the initial degradation and may result in prolonged composting period (Toumela *et al.*, 2000). Eventhough, several researchers (Goyal and Sindhu, 2011; Kumari *et al.*, 2018) have identified microbial composting as a suitable technique for composting cereal residues, Baker *et al.* (2019) reported that the fungal species *Pleurotus ostreatus* failed to colonize on wheat straw and the biomass decomposition was very slow.

5.1.2 Recovery of Compost

Effect of different treatments on the recovery of composts is depicted in Fig. 3. In general, the recovery of compost was more with the co - composting of paddy straw using poultry manure. With the increased addition of poultry manure, percentage recovery of compost was also more. Poultry manure as N source in co - composting could result in complete decomposition avoiding wastage and hence better recovery (Guerra-Rodriguez *et al.*, 2000). Low moisture and higher dry matter content of poultry manure (Nicholson *et al.*, 1996; Leconte *et al.*, 2009) resulted in more deposition of organic matter to the composting lot compared to supply of cowdung. This could be an important reason for more recovery of compost in treatments supplemented with poultry manure as organic source.

Paddy straw co - composted with the highest quantity of poultry manure (T_6) recorded the highest recovery (44.59 %). Yadav (2005) while experimenting on composting of organic materials could observe that increased quantity of poultry manure added to the composting material could increase the recovery of compost. Gaind *et al.* (2009) conducted an experiment on co - composting wheat straw and found that the use of N sources like poultry droppings, jatropha cake and neem cake hastened the decomposition of straw and with the increased addition of these bulking agents, degradation was more complete. Gaind and Nain (2010) reported that mixing paddy straw with poultry droppings resulted in complete decomposition of initial substrata. These findings are in line with the results of the present experiment with respect to higher recovery with more addition of organic material.

Vermicomposting technique with addition of lower quantity of cowdung (T_1 and T_2) could register lower recovery only. Bernal *et al.* (2009) found that the dry matter content of cowdung is very less when compared to poultry manure. The authors also stated that the loss of organic matter from cowdung is much higher than poultry manure due to high moisture content of cowdung. Michel *et al.* (2004) while experimenting on composting of paddy straw with cowdung

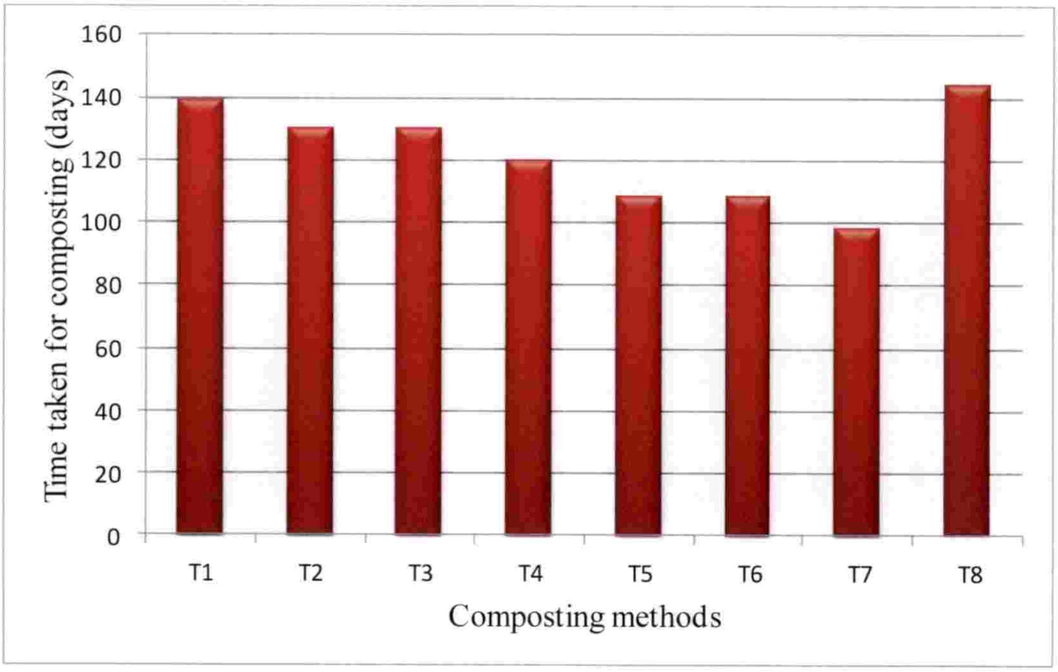

Fig. 2. Influence of different composting methods on maturation of compost

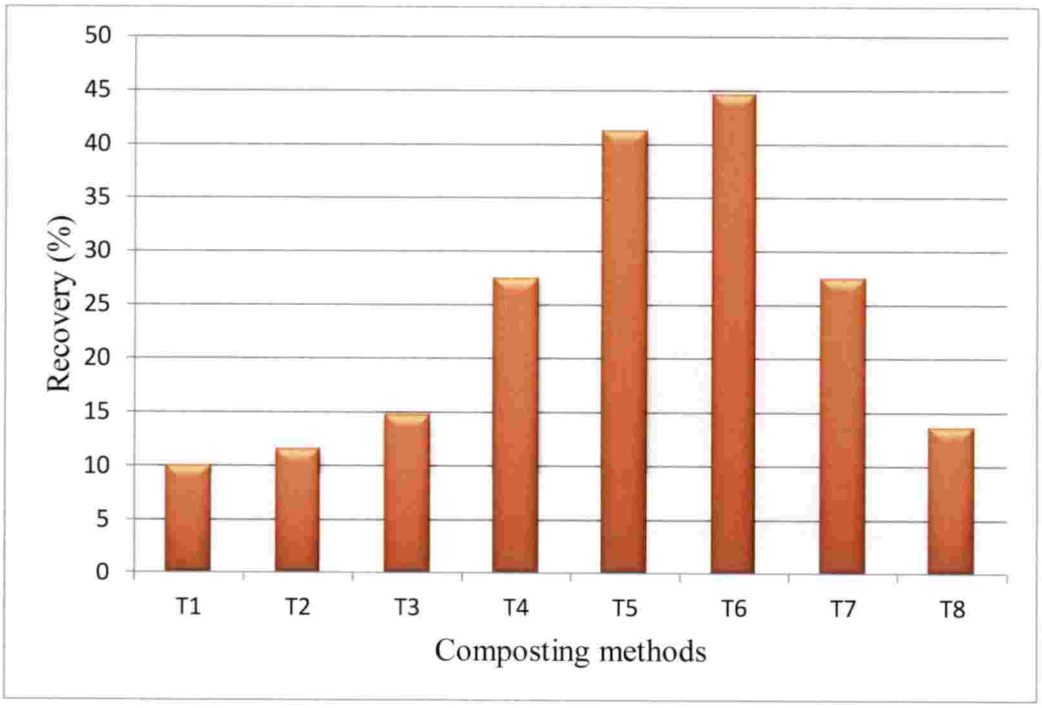

Fig. 3. Effect of different composting methods on recovery of compost

reported a total biomass reduction upto 83 per cent. They attributed the substantial loss of biomass from the mixture to the increased moisture content of cowdung (83 %). Loss of higher quantities of organic matter from cowdung might have resulted in lower recovery. In addition, a part of the organic material is utilized for the biomass build up of earthworms. Their voracious feeding activity combined with high multiplication rate results in higher biomass reduction after vermicomposting (Shak *et al.*, 2014).

5.1.3 Major Chemical Properties of Paddy Straw Compost

5.1.3.1 pH

The acceptable pH range for compost is 6 to 8.5 as reported by several authors (Ko *et al.,* 2008; Troy *et al.*, 2012). All the composts generated as part of the study were in this range. After an initial drop, an increase in pH is usually observed with the progress of composting due to the degradation of organic acids which are produced in the initial stage of composting. The release of ammonia during protein degradation also contributes to the increase in pH towards the later stages of composting (Nakhshiniev *et al.*, 2014). Because of these, usually the pH of composts advances towards neutrality on maturation (Karanja *et al.*, 2019). In line with all the above, in the present study also, a neutral pH (ranging from 7.39 to 7.47) was observed towards maturation of compost. However different composting treatments could not make a significant influence on pH.

5.1.3.2 Electrical Conductivity

Electrical conductivity is an indicator of salinity of a substrate and it varies depending on the release of mineral ions during the decomposition (Yadav and Garg, 2013). Higher EC causes phytotoxicity and hence EC values of < 4 dS m^{-1} are preferred for manures (Silva *et al.*, 2013). The EC values obtained by different composts generated in the present study were in the safe limits and hence suitable for soil application. However, different composting methods could not significantly influence the EC of composts.

5.1.3.3 Cation Exchange Capacity

Cation exchange capacity of different composts was significantly influenced by various composting methods as illustrated in Fig. 4. Humic substances that are formed during composting process strongly binds the positively charged ions, that are later exchanged with other cations (Karanja *et al.*, 2019). This property of compost referred to as CEC tend to elevate during composting since organic substances are humified with the advancement of composting (Wichuk and McCartney 2013).

Higher and comparable CEC recorded with the treatments T_3, T_4, T_5, T_6 and T_7 could be attributed to the increased rate of humified organic matter. CEC is directly related to the humified organic matter as reported by several scientists. Harada and Inoko (1980) opined that CEC and organic matter decomposition are highly related. With increased rate of decomposition of organic matter, CEC also becomes more. The decomposition of materials was more and complete in co - composting treatments as evidenced from the recovery of composts (Table 7), which could be attributed the increased CEC in these treatments. Furthermore, Burns *et al.* (1986) revealed that humic substances and microbial activity are positively related. Higher microbial population observed with co - composting treatments (Table 10) could result in increased amount of humic substances, which might have contributed to higher CEC. In addition to this, an inverse relationship between CEC and C: N ratio was found out by Ameen *et al.* (2016). The results of the present study were also in conformity with this finding, wherein, treatments with lower C: N ratio recorded higher CEC values (Table 8).

5.1.3.4 C: N Ratio

Different composting methods could significantly influence the C: N ratio of composts as depicted in Fig. 5. Initial C: N ratio of paddy straw was around 60:1 and in all the composts generated in this study, the C: N ratio was considerably narrowed down after composting. Release of CO_2 during composting due to the breakdown of complex organic substances by microbial activity reduces the total carbon content (Devi *et al.*, 2012). Simultaneously an increase in N levels also occurs due to the activity of N fixing bacteria (Raj and Antil, 2011). This decrease in carbon content and increase in N results in lowering of C: N ratio. The reduction in C: N ratio associated with paddy straw composts indicates that paddy straw can be effectively composted and C: N ratio can be brought down to desired levels for using it as organic manure. In all the composts generated, C: N ratio was within the acceptable limit of < 20:1(Khater, 2015).

Paddy straw composts produced through co - composting technique recorded lower C: N ratio when compared to vermicomposting and microbial composting technology. Co - composting with the addition of highest quantity of poultry manure (T_6) registered a narrow C: N ratio of 9.54:1 and was comparable with the treatments T_7 and T_5. This could be related with the N content of these composts, which was higher in comparison to other treatments due to the addition of higher quantity of N through poultry manure. Abdelhamid *et al.* (2004) reported that paddy straw co - composted using poultry manure and rape seed cake produced final composts with a C: N ratio ranging from 9:1 to 13:1. The C: N ratios recorded by co - composts of the present study were also in this range. Compost generated through microbial composting (T_8) had the lowest N content (1.57 %), possibly due to the non addition of organic manure during the start of the experiment. Furthermore, the quantity of N supplied through urea was much less compared to the addition of N from organic manures. Thus the low N content in microbial compost resulted in higher C: N ratio (19.29:1).

5.1.4 Nutrient Status of Paddy Straw Compost

5.1.4.1 Major Nutrients

Nutrient composition of composts obtained in the present study revealed that the process of composting enhances the nutrient (major, micro and beneficial) concentration. As a result of biomass loss, the concentration of nutrient in final compost increases over the initial substrate, indicating composting maturity (Jusoh *et al.*, 2013).

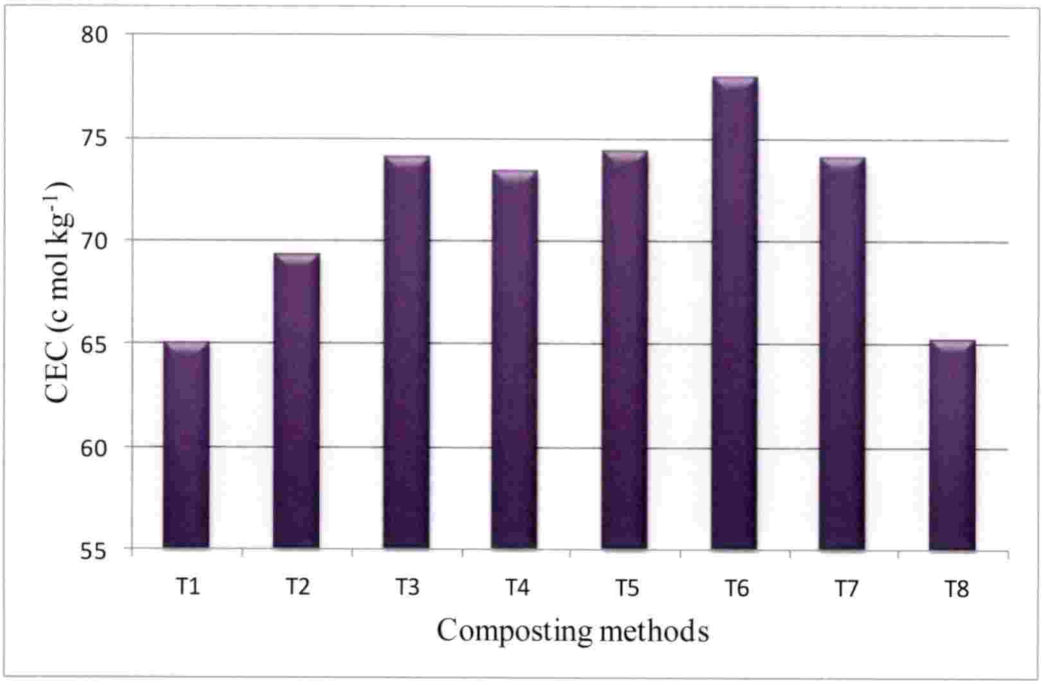

Fig. 4. Effect of different composting methods on CEC of mature compost

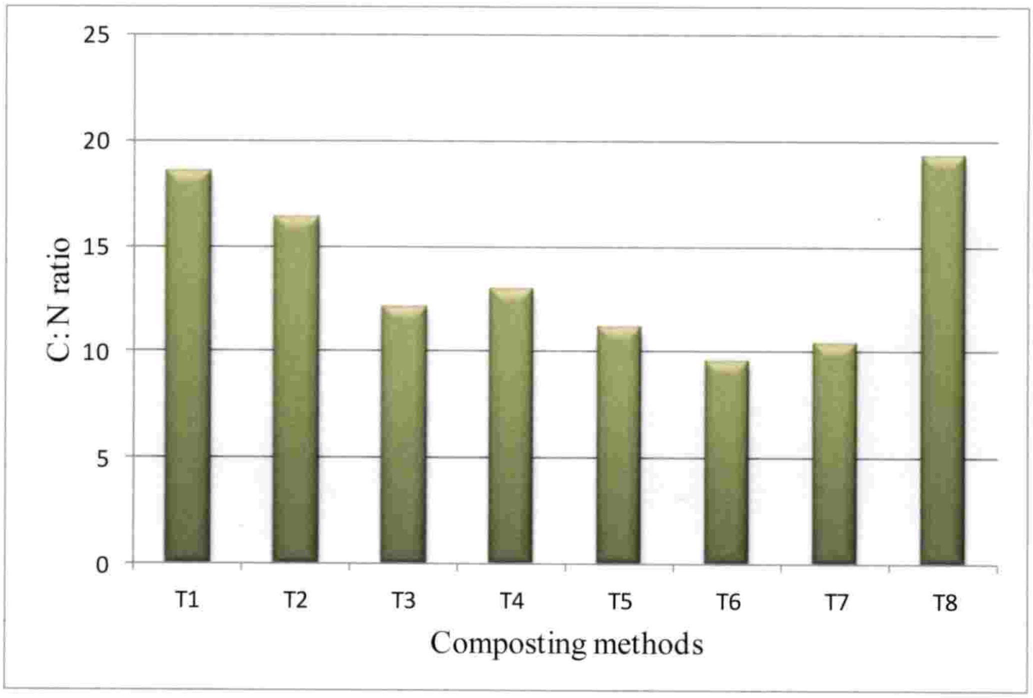

Fig. 5. Effect of different composting methods on C: N ratio of mature compost

The nutrient status of paddy straw composts as influenced by different composting methods is depicted in Fig. 6. In all the composting methods tested in the present study, an increase in N content was observed on compost maturity, compared to the initial content in paddy straw (0.68 %). Elevated levels of N in the final compost are the resultant of N fixing bacterial activity occurring towards the end of composting period (Raj and Antil, 2011).

Co - composting treatments with the addition of poultry manure as N source recorded higher N content in the final compost when compared to vermicompost and microbial compost. Treatment T_6 with the highest dose of poultry manure had the highest N content, followed by comparable N content in the treatment T_7. This can be directly related with the higher N content of poultry manure (2.3 %) over cowdung (1.21 %) used in the present study. Furthermore, improved N content of poultry manure might have accelerated the growth of nitrifying bacteria, contributing to increased level of N in final compost. Abdelhamid *et al.* (2004) reported that as the quantity of poultry manure added to the initial material increases, total N content of paddy straw compost also increases. In line with the above finding, in the present study also, paddy straw compost generated with the addition of higher quantity of poultry manure registered higher N content. Microbial compost (T_8) had the lowest N content (1.57 %), attributed mainly to the reduced supply of N from urea, the only N source supplied at the start of composting. Moreover, lower microbial activity recorded in this treatment due to non addition of organic manure also resulted in the least buildup of N. Longer composting period taken by this treatment might have resulted in loss of some mineralized N through volatilization as reported by Chan *et al.* (2016).

Concentration of P in the final paddy straw composts were higher when compared to the initial content in paddy straw (0.12 %). Co - composting of paddy straw with higher quantity of poultry manure (T_6) registered a higher P content (0.93 %) and was on par with the treatment T_7. Variation in P status of paddy straw composts could be attributed to the differences in P content of the initial organic manure added to the composting treatments. As the poultry manure used for the experiment was rich in P (1.4 %) over cowdung (0.4 %), the composts produced using poultry manure could naturally record high P content. Higher quantity of poultry manure as well as its increased P content in the treatment T_6 might be responsible for its higher P status. The treatment T_8, *i.e.* microbial composting with non addition of organic manure recorded the lowest P content (0.27%). Similarly, K content was also found higher for co - composting treatments. Higher K content registered in T_4, T_5, T_6 and T_7 could be due to the increased amount of K supplied by poultry manure (1.35 %) than cowdung (0.60 %). In addition, enhanced microbial activity recorded in these treatments might have increased the mineralization of P and K as suggested by Shak *et al.* (2014). Similar results of increased P and K content with the composting of paddy straw was reported by Guerra-Rodriguez *et al.* (2001) and Goyal and Sindhu (2011).

5.1.4.2 Micro and Beneficial Nutrients

Eventhough all the paddy straw composts generated in this experiment recorded an increase in micro and beneficial nutrient status, Cu, Mn, Zn and Si content were statistically non significant. However, Fe and B content of the composts varied significantly among treatments. Both of these micronutrients were higher in the treatment T_6 and were comparable with T_5 in terms of Fe content and with T_7 in terms of B content. Higher micro nutrient status registered in these treatments could be attributed to the nutrient richness of initial N source (poultry manure) added to the paddy straw. Poultry manure due to its low moisture content resulted in addition of higher dry matter, which in turn contributed to increased nutrient content in co - composted paddy straw. Similar results of increased micronutrient content (Fe, Cu, Mn, Zn and B) with the process of composting were reported by several authors (Jusoh *et al.,* 2013; Shak *et al.*, 2014).

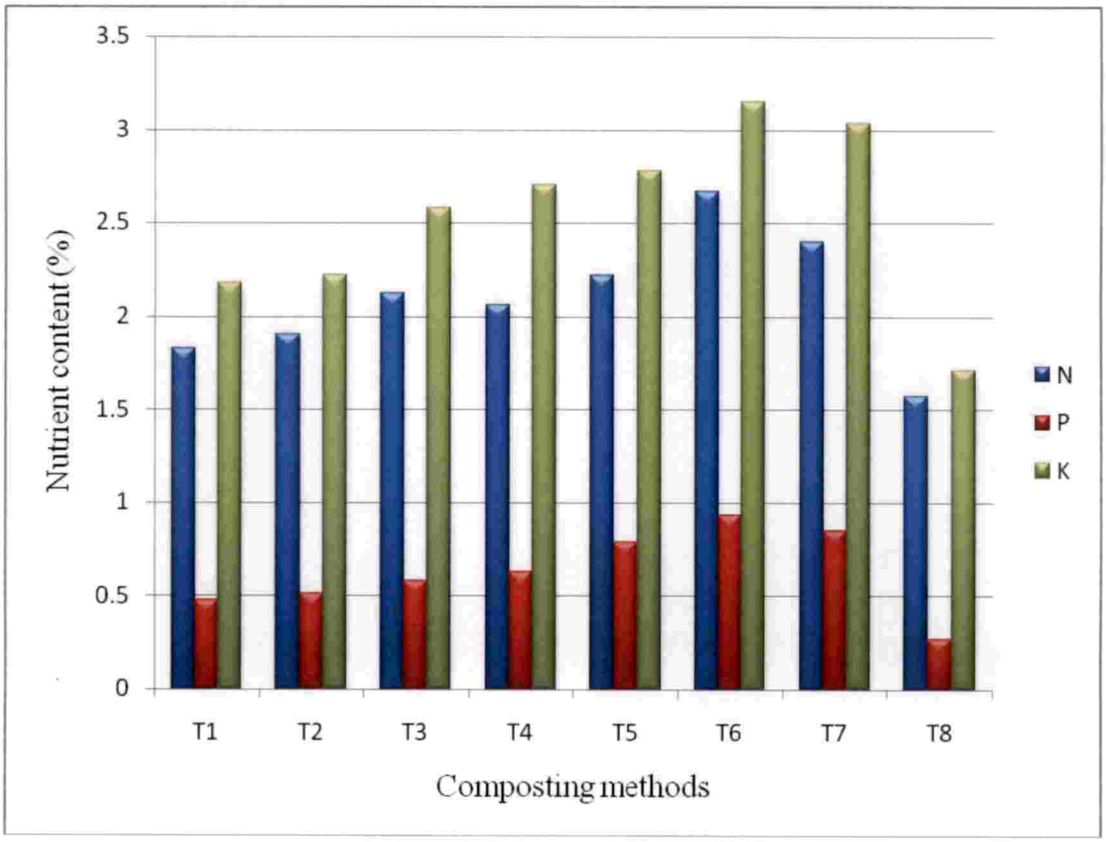

Fig. 6. Influence of different composting methods on nutrient status of compost

5.1.5 Microbial and Enzymatic Activity of Paddy Straw Compost

The microbial activity of different components of composting material *i.e.* paddy straw, cowdung and poultry manure were estimated at the start of the experiment. Towards the maturity, different composts prepared out of different composting procedures were analyzed for microbial and dehydrogenase enzyme activity. The variation in microbial population observed with different treatments is depicted in Plate 6. The treatments with increased supply of poultry manure at the start of composting (T_6 and T_7) recorded more bacterial, fungal and actinomycetes population (Fig. 7). This could be related with the higher microbial activity of poultry manure, compared to cow dung (Table 5). Addition of higher quantities of poultry manure in the above treatments could therefore result in proliferation of microbes. Also, a narrow C: N ratio favours rapid multiplication of microbes compared to a wide ratio. Increased supply of N through poultry manure in these treatments might have ensured a narrow C: N ratio initially. Nitrogen is required for protein bulid up of microbes which is ensured under narrow C: N ratio (Azim *et al.*, 2017). With the addition of only lower quantities of N source in the treatments T_8 and T_1, initial C: N ratio was not favourably lowered, resulting in lower microbial population in these treatments.

Dehydrogenase enzyme being a reflection of biological activity (Neyla *et al.*, 2009), was found to be higher and comparable in the treatments T_7, T_6 and T_5 (Fig. 8). Higher enzymatic activity registered in these treatments could be attributed to the proliferation of microbes, which occurred as a result of favourably low C: N ratio during the start of composting with the addition of more quantity of N. Lower enzymatic activity registered in the treatments T_8 and T_1 might be due to the least microbial activity registered in these treatments.

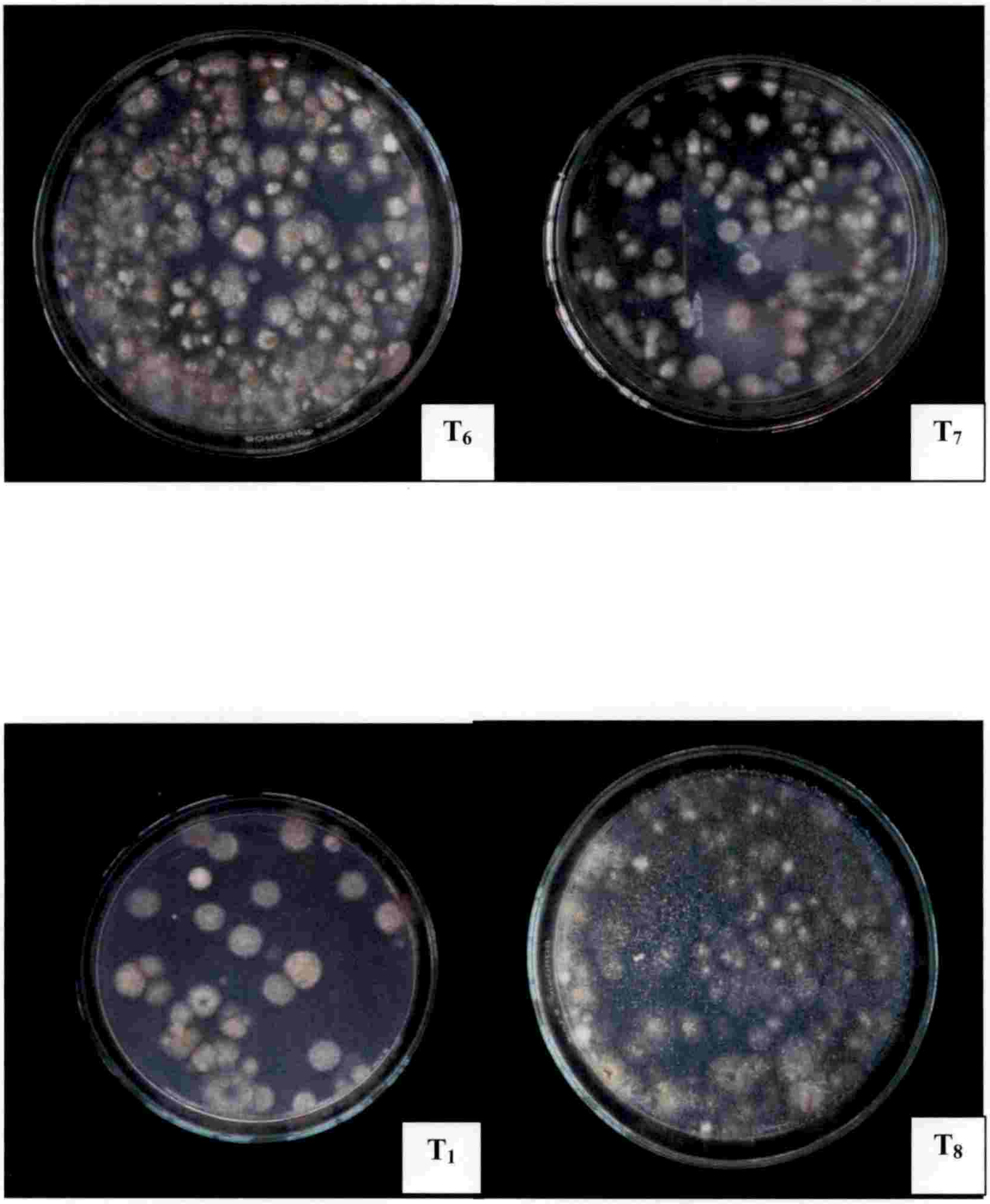

Plate 6. Fungal count in mature composts

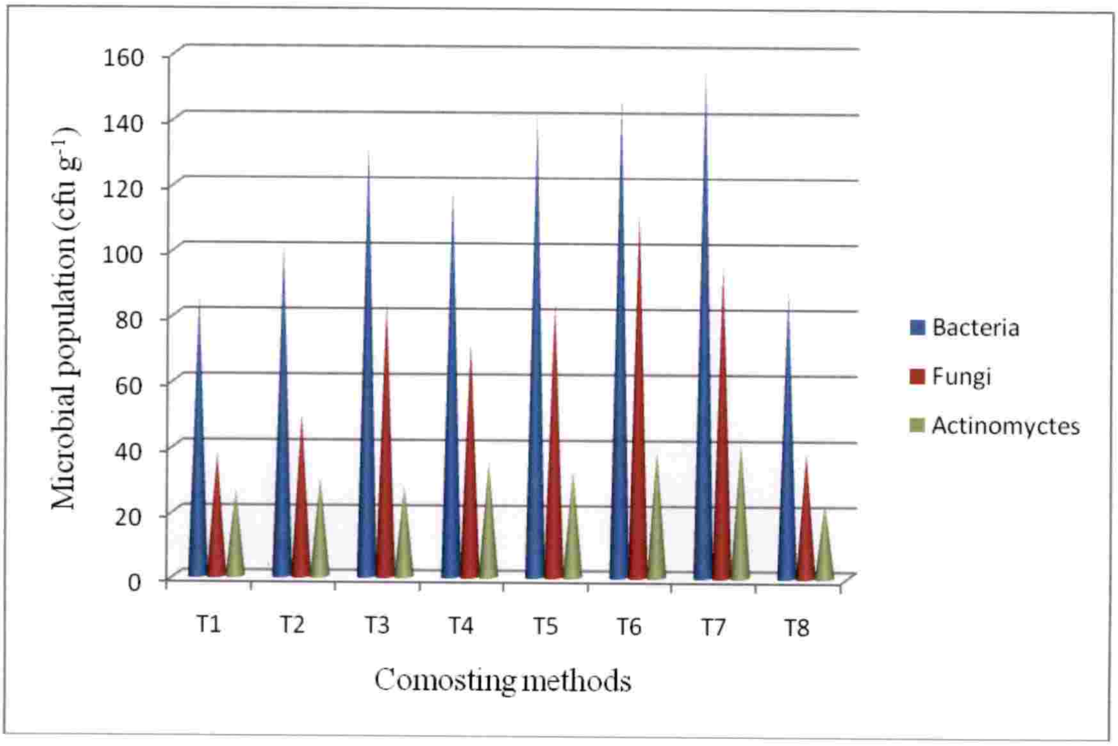

Fig. 7. Influence of different treatments on microbial population

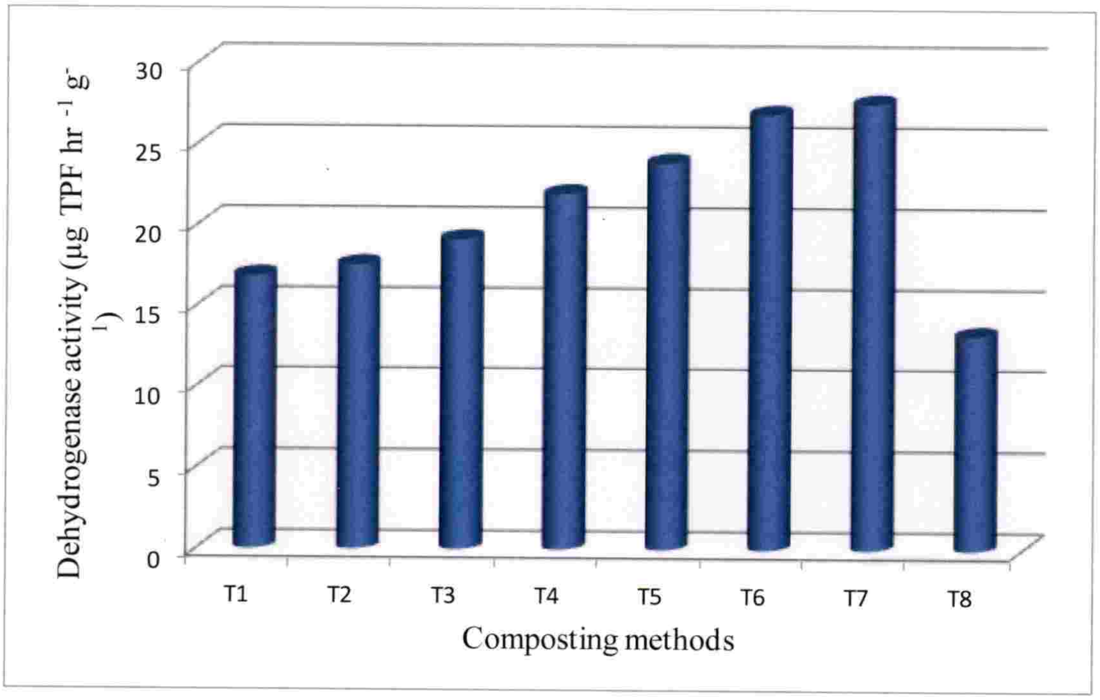

Fig. 8. Effect of different composting methods on dehydrogenase activity

5.2 EXPERIMENT II - POT CULTURE STUDY ON BHINDI

5.2.1 Growth Characters

Use of different paddy straw composts as potting media component significantly influenced growth parameters of bhindi. This could be attributed to the difference in quality aspects of different composts, especially the nutrient content. The plant height at all stages of crop growth (45, 60 and 75 DAS and at final harvest) varied significantly among treatments. As in the case of quality parameters of compost, which were favorable for co - composts, plants grown in potting media with co - composted paddy straw recorded better growth parameters.

Compost T_6 (paddy straw co - composted using poultry manure in the ratio 4:1) when used as potting media component could produce taller plants throughout the cropping period, however, comparable with T_7 at all stages of crop growth. In addition to treatments T_6 and T_7, other treatments having co - composted paddy straw as potting media component (T_4 and T_5) also produced taller plants at all stages of crop growth except at 45 DAS. Increased availability of nutrients in these treatments could be related with the better plant height. It is evident from Table 18 that the availability of N and P was much higher for these treatments compared to other treatments. Mohsen and Abdel-Fattah (2015) reported that increased supply of nutrients especially N and P increases growth attributes like plant height and number of branches in bhindi. Similar results of increased growth of bhindi with increased dose of N were also reported by Thirunavukkarasu and Balaji (2015) and Khetran *et al.* (2016). Increased supply of N enhances cell division, leading to the formation of new plant tissues, thereby producing taller plants (Leghari *et al.*, 2016). Shorter plants at all the stages were produced by T_1 wherein paddy straw vermicomposted using cowdung in the ratio 8:1 was used as potting media component. The treatment T_1 was comparable with T_8 and T_9 at almost all crop growth stages. Lower nutrient availability registered in the treatments T_9, T_8 and T_1 because of low nutrient content of FYM or composts generated with lower addition of organic manure at the start of experiment, could be related with reduction in growth in terms of plant height.

Different paddy straw composts could not produce any significant influence on the number of branches of bhindi at different growth stages (45, 60 and 75 DAS and at final harvest).

Observations made at two stages of crop growth (30 DAS and 60 DAS) revealed that different potting media had a significant influence on leaf area of crop. At both these stages, the treatments T_7, T_6 and T_5 (potting media with co - composted paddy straw as manure component) produced larger leaves with significantly higher leaf area when compared to other treatments. This could be related to the nutrient content of composts added to these potting media, which was much higher compared to other treatments (Table 9). Khandaker *et al.* (2017) opined that supply of N significantly influences the leaf area. With increasing levels of N, leaf area was also found to be higher. The lowest leaf area was obtained with the least supply of N. They attributed increased leaf area to increase in size and number of cells. This finding was in line with the results of the present experiment, where plants grown in potting media with lower availability of N (T_1, T_8 and T_9) recorded minimum leaf area.

5.2.2 Yield Attributes and Yield

As observed with growth parameters, yield attributes and yield were also significantly superior with the treatments T_7 and T_6, especially in terms of fruit length and weight. This could be attributed to the increased availability of plant nutrients in both these treatments (Table 18). Similar results of increased fruit length with higher levels of NPK were reported by Khetran *et al.* (2016). Higher fruit weight recorded in these treatments could be also due to the increased availability of primary plant nutrients (Khandaker *et al.*, 2017). The variation in fruit length observed with different treatments is depicted in Plate 7.

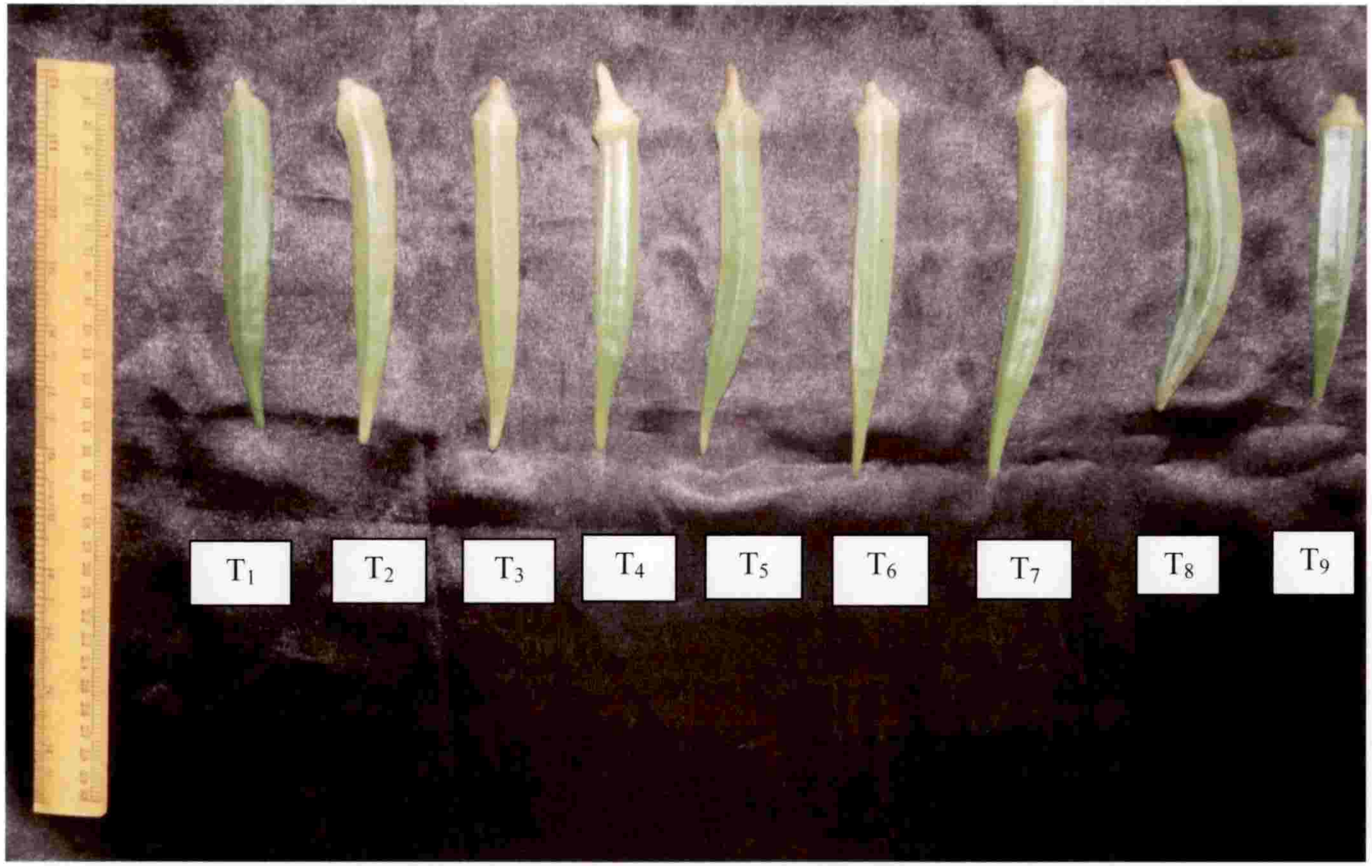

Plate 7. Variation in fruit length observed with different treatments

Better growth and leaf area recorded with the treatments T_6 and T_7 could essentially be related to increased photosynthetic efficiency of crop, resulting in higher yields (Fig. 9). More number of fruits produced in T_7, T_6, T_5 and T_4 could be attributed to the increased and balanced nutrient availability and hence better nutrient uptake by plants (Table 16 and 18). Enhanced availability and uptake of nutrients increases the number of fruits of bhindi plants (Nazir, 2017). The results of the present study are in agreement with the findings of Barus (2012), who stated that application of composted paddy straw in addition to RDF significantly increased the number of grains per panicle and total grain yield in rice. He attributed the yield increase to the increased availability of nutrients from compost. Lower nutrient supply from the treatments T_9, T_8 and T_1 might have resulted in production of fewer fruits when compared to supply of nutrient rich media.

Total number of fruits as well as the weight of individual fruit contributes to the final fruit yield. More number of fruits with higher fruit weight registered in the treatments T_6 and T_7 ultimately contributed to significantly higher yields over other treatments.

Different potting media have a significant influence on the time taken for 50 per cent flowering. Earliness in flowering achieved in the treatments T_1 to T_7 could be attributed to the increased P availability in these treatments compared to T_8 and T_9. Blooming in bhindi is related to the availability of P in soil. Accelerated growth of reproductive parts with the increased supply of P stimulates flowering and fruiting in bhindi (Khan *et al.*, 2000). Enhanced bud differentiation as a result of compost application helps in achieving earlier flowering (Mal *et al.*, 2013).

5.2.3 Quality Parameters

All the quality parameters *viz.*, crude protein, crude fibre and ascorbic acid content were influenced significantly by different treatments (Fig. 10). In general, plants grown in nutrient rich media produced fruits with better quality attributes.

Significantly higher crude protein content recorded in T_7 could be attributed to the increased availability and uptake of N by plants maintained under this treatment. Nitrogen plays a direct role in protein synthesis. Akande *et al.* (2010) reported an increase in synthesis and storage of protein with the enhanced availability of nutrients. Similar results of increased crude protein content of bhindi with increased levels of N were already reported by Kumar *et al.* (2017a). Integrated use of organic manures and chemical fertilizers results in production of better quality fruits with higher crude protein content (Sachan *et al.*, 2017). Furthermore, application of soil amendments like compost was found to improve the quality parameters of bhindi due to their increased plant nutrient availability (Adewole and Ilesanmi, 2011).

Reduction in crude fibre content of bhindi fruit is considered a desirable attribute. Significantly lower crude fibre content was registered by the treatment T_7 whereas control treatment (T_9) registered significantly higher crude fibre. The availability of nutrient N was higher in the treatment T_7 and this might have resulted in lower crude fibre content. Reduction in crude fibre content with the increased levels of N was reported by Kumar *et al.* (2017b). Mani and Ramanathan (1981) attributed the reduction in crude fibre content to the increased succulence obtained with the increased availability of N. Similar reduction in crude fibre attained with the use of compost over FYM was already reported by Raj and Kumari (2001).

Different paddy straw composts made used as potting media component had a significant influence on ascorbic acid content of bhindi fruits. Ascorbic acid content was higher and comparable in the treatments T_7, T_6 and T_5. This could be attributed to the increased supply of K in these treatments. Potassium plays a key role in carbohydrate metabolism and ascorbic acid formation. Increased carbohydrate synthesis as a result of increased availability of K ultimately contributes to enhanced levels of ascorbic acid (Bidari and Hebsur, 2011). This finding was in line with the results of the present study, wherein treatments with higher availability of K (T_7, T_6 and T_5) produced fruits with more ascorbic acid

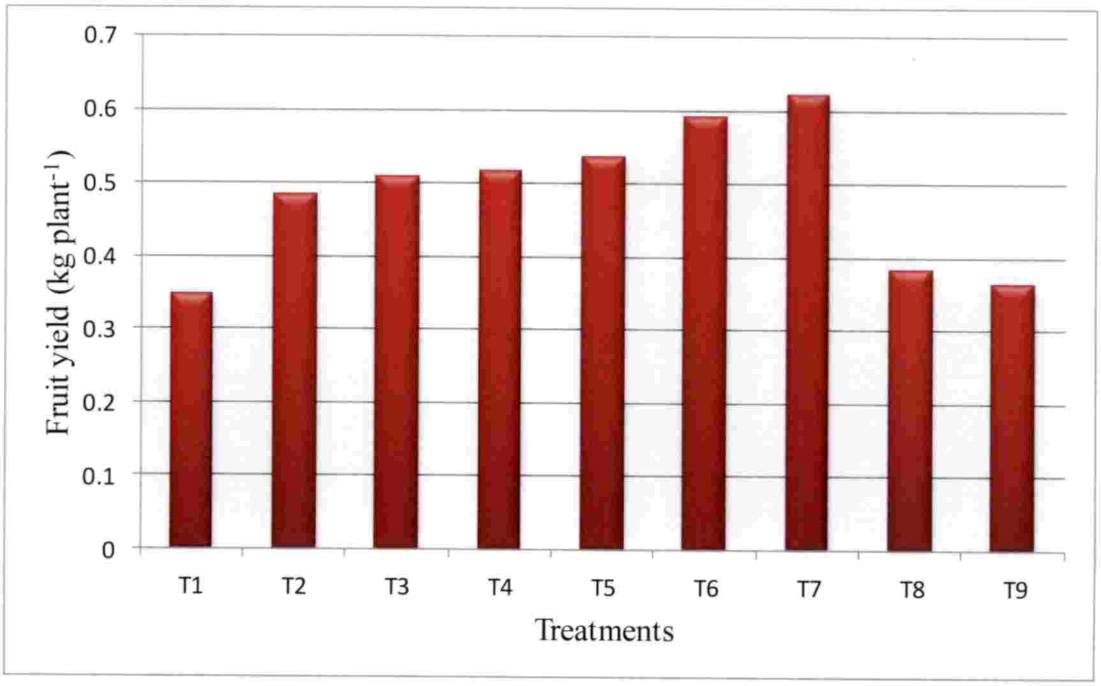

Fig. 9. Influence of different treatments on fruit yield of bhindi

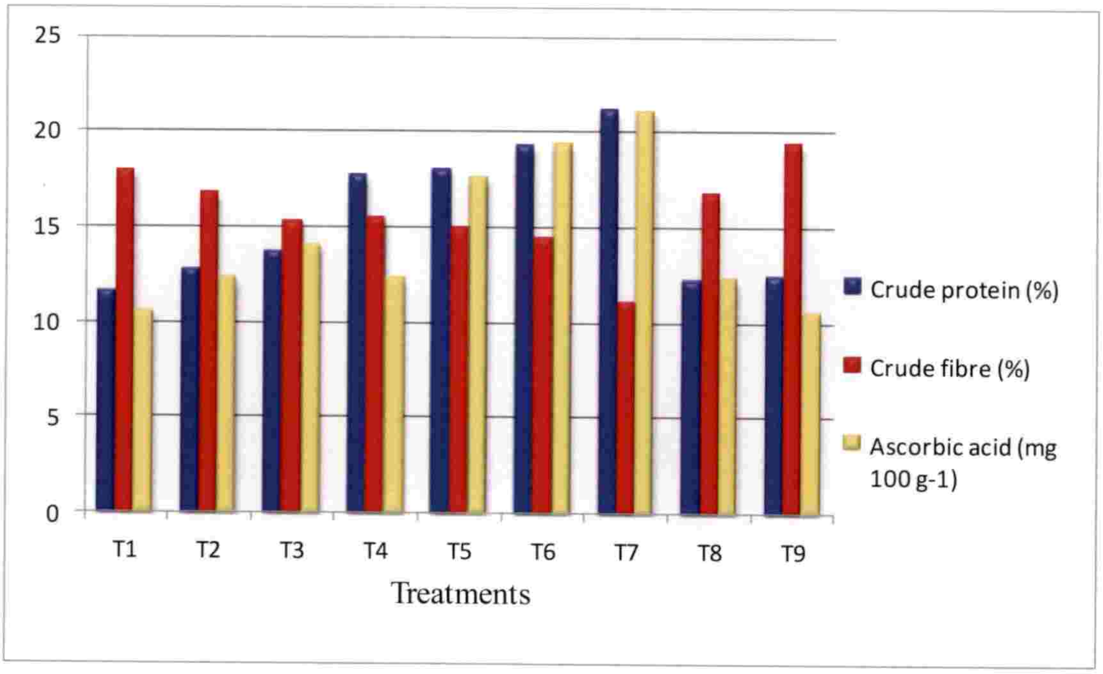

Fig. 10. Influence of different treatments on quality of bhindi fruits

content. Similar results of increased level of vitamin C in chilli were observed with increased levels of K (Bidari and Hebsur, 2011).

5.2.4 Dry Matter Production and Nutrient Uptake

Different paddy straw composts prepared as part of the study and tested as potting media component could produce a significant impact on the total DMP of bhindi plants. Higher and comparable DMP was recorded in the treatments T_7 and T_6. Increased plant height and leaf area observed with these treatments resulted in higher DMP. Furthermore, higher DMP in these treatments could also be related to the increased availability and uptake of N as reported earlier by Moustakas *et al.* (2011). Availability and uptake of N was much higher for the treatments T_7 and T_6 (Table 16 and 18), compared to all other treatments, which might have contributed to increased DMP. Among different nutrients, N has a key role in enhancing vegetative growth through the formation of new plant tissues (Leghari *et al.,* 2016), which could be attributed to higher DMP.

Uptake of N, P and K were significantly influenced by different treatments. Significantly higher and comparable uptake of major nutrients was observed in the treatments T_7 and T_6. Better growth of plants observed with these treatments might be an indication of better root growth. Enhanced root growth and root activity might have resulted in significantly higher nutrient uptake.

5.2.5 Analysis of Potting Media

Analysis of potting media revealed that different treatments could not produce any significant influence on pH of the media before and after the experiment. All the treatments registered near neutral pH ranging from 7.41 to 7.51 before the pot culture experiment. However, a slight decrease in pH observed generally in all the treatments after the experiment could be attributed to the release of organic acids with organic manure addition (Wakene *et al.,* 2005). A similar reduction in soil pH with the application of paddy straw compost was reported by Mahmoud *et al.* (2014).

On analyzing the data (Table 17), it was clear that organic carbon content was significantly influenced by different treatments. All the treatments having paddy straw compost as potting media component (T_1 to T_8) registered higher and comparable organic carbon before the pot culture study. This could be due to the increased organic matter present in compost than in FYM as reported by Jacob (2018). In general, an increase in organic carbon content was observed with the completion of pot culture study. Basal application of FYM after the planting of crop along with addition of dried leaves from crop to the soil might be responsible for the increased organic carbon. Also, the rhizodeposits of plants were found to be a source of easily oxidisable C (Cheng and Gershenson, 2007) and is applicable in this situation also. Better plant growth recorded with the treatments T_4, T_5, T_6 and T_7 is an indication of increased root activity and nutrient uptake. Better root activity in these treatments might have accelerated the release of rhizodeposits, which ultimately contributed to higher organic carbon after the pot culture study.

Available nutrient status of the potting media was significantly influenced by different paddy straw composts applied as potting media component. Since co - composted paddy straw recorded superior nutritional status as well as chemical properties, potting media prepared with co - composted paddy straw as component (T_4, T_5, T_6 and T_7) registered better availability of N, P as well as K, compared to vermicompost or microbial compost or FYM as potting media component. A reduction in available nutrient status was observed after the pot culture study, which could be attributed to the uptake of nutrient elements by bhindi plants.

The effect of paddy straw composts as potting media component on microbial population was found significant before and after the experiment. Microbial population was higher in potting media with co - composted paddy straw as component (T_4 to T_7). Better growth, root activity as well as higher organic carbon content registered in these treatments might be responsible for the increased microbial population. Furthermore, paddy straw compost generated through co - composting technique recorded higher microbial population. This could also be attributed to the increased microbial activity in potting media supplied with these composts. In general all the microbial communities (bacteria, fungi and actinomycetes) shows an increasing trend after the experiment compared to the initial microbial population. In line with the findings of the present study, Zhen *et al.* (2014) reported that application of compost improves the soil microbial population and diversity. Enhanced microbial population after the cropping period could be attributed to the increase in soil organic carbon as a result of organic manure application. In addition to this, root exudates released by plants also favours proliferation of microbes (Shi *et al.*, 2011). Carbon compounds that are contained in the root exudates act as a source of energy for the microbes and thereby promote the microbial population (Kapoor and Mukerji, 2006).

5.2.6 Economics of Cultivation

Economics of bhindi cultivation using different potting media was worked out in terms of net returns and BCR. Fig. 11 depicts the influence of different treatments on the BCR. Higher net returns and BCR was obtained with the treatments T_7 and T_6, where co - composted paddy straw was used as the potting media component. Higher net returns from these treatments could be attributed to the increased yield from plants grown in these potting media. Furthermore, the cost of cultivation associated with these treatments was also less. With more recovery from the treatments T_6 and T_7, more of composts were generated from unit volume of compost pit, thereby indirectly reducing the cost of production of unit quantity of compost. The cost of cultivation of bhindi was less when composts with low production cost were used as component. Significantly lowest net returns and BCR was recorded in the treatment T_1, wherein paddy straw vermicomposted with cowdung in the ratio 8:1 was used as the potting media component. This could be attributed to lower yields registered with this treatment. Furthermore, the cost of cultivation associated with this treatment was much higher compared to other treatments. The lowest recovery recorded with the treatment T_1 (paddy straw vermicomposted with cowdung in the ratio 8:1) resulted in higher cost of production for unit compost material. This would have caused an

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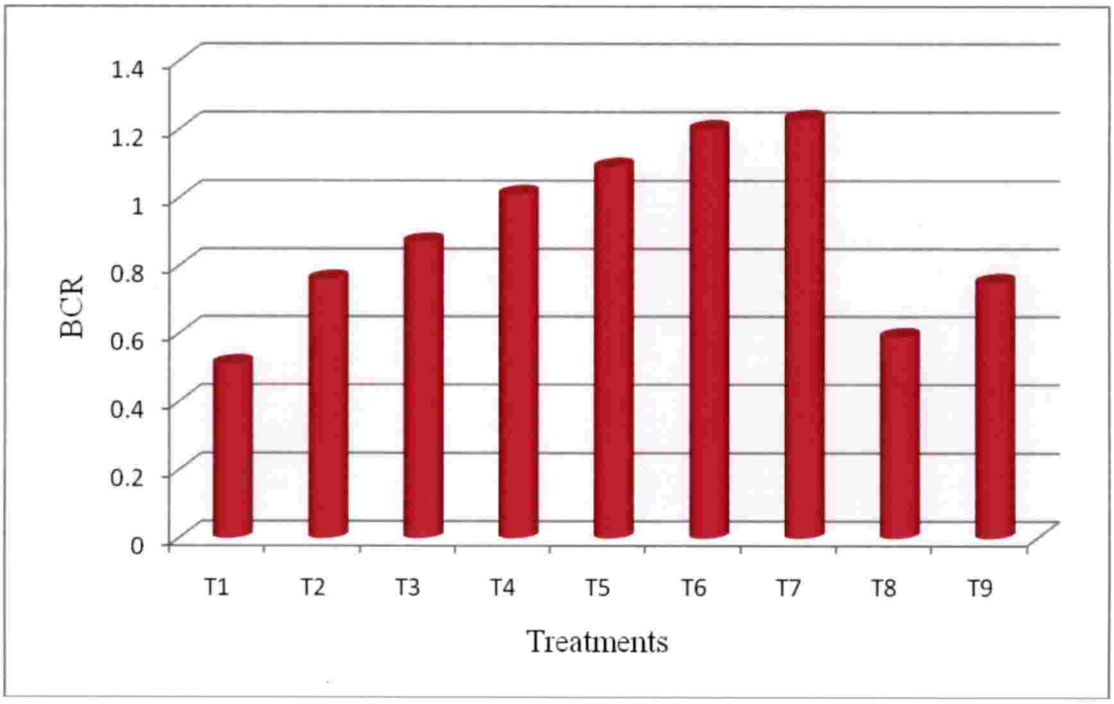

Fig. 11. Influence of different treatments on BCR

increase in cost of cultivation of bhindi when this compost was used as a potting media component.

SUMMARY

6. SUMMARY

The study entitled "Bio recycling of paddy straw for quality manure production" was conducted during 2017-2019, at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, with the objectives to find out an effective technology for composting paddy straw and to assess the effectiveness of paddy straw composts as potting media component on the growth, yield and quality of bhindi and to work out the economics.

The research work was carried out as two experiments, which were conducted at Integrated Farming System Research Station (IFSRS), Karamana. Under Experiment I, different methods of composting were tried to generate manure from paddy straw. The experiment was laid out in completely randomized block design with eight treatments and three replications and was conducted during the period March to August, 2018. The treatments included vermicomposting of paddy straw with cowdung in the ratios 8:1, 6:1 and 4:1 (T_1, T_2 and T_3 respectively), co - composting of paddy straw with poultry manure in the ratios 8:1, 6:1 and 4:1 (T_4, T_5 and T_6 respectively), co - composting of paddy straw with cowdung and poultry manure in the ratio 8:1:1 (T_7) and microbial composting of paddy straw using the fungus *Pleurotus* (T_8).

Different paddy straw composts generated from Experiment I were used as potting media component in Experiment II. The pot culture experiment was laid out in completely randomized block design with nine treatments and three replications during August to December, 2018. Potting media used for the study was a mixture of soil, rock sand, coir pith compost and different paddy straw composts in the ratio 1:0.5:0.5:1 on volume basis (T_1 to T_8). In treatment T_9 (control), the potting media was prepared by substituting FYM for paddy straw composts. Hybrid variety of bhindi, Manjima (Gowreesapattom local × IC 282257) released from KAU was the test crop.

The salient findings of the present study are summarized in this chapter.

Different methods of composting had a significant influence on the time taken for maturation of composts. Among the different composting methods tested, paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 (T_7) recorded significantly lowest time for composting (97.67 days).

Percentage recovery of composts varied significantly with different methods of composting. In general, co - composting treatments with poultry manure as N source recorded higher recovery compared to other methods of composting. Paddy straw co - composted with the highest quantity of poultry manure (T_6) recorded the highest recovery of 44.59 per cent.

Different composting methods were found to have no significant influence on the pH and EC of paddy straw composts. All the composts generated in the present study had a neutral pH ranging from 7.39 to 7.47. The EC values of these composts ranged from 0.08 to 0.16 dS m^{-1} and were within the acceptable limit of < 4 dS m^{-1}.

Paddy straw co - composted with poultry manure in the ratio 4:1 (T_6) recorded a higher CEC of 77.91 c mol kg^{-1} but was comparable with all the treatments except T_1, T_2 and T_8. Composting could significantly narrow down the initial wide C: N ratio of paddy straw. Treatment T_6 registered a lower C: N ratio (9.54:1) and was on par with T_5 and T_7.

Different composting methods could significantly influence the major and micro nutrient status of paddy straw composts. Nutrient content of the composting material was found to increase with the progress of composting. The compost obtained from paddy straw co - composted with poultry manure in the ratio 4:1 was found rich in plant nutrients and recorded higher N (2.67 %), P (0.93 %) and K (3.15 %) contents and was comparable with the treatment T_7. The K content of other composts obtained from co - composting treatments T_5 and T_4 was also found comparable with treatments T_6 and T_7.

With respect to micro nutrient status, Fe and B content of different composts were significantly influenced by composting methods. In general, co -

composting treatments T_5, T_6 and T_7 recorded higher micro nutrient status. Paddy straw co - composted with poultry manure in the ratio 4:1 (T_6) recorded the higher Fe content (3586.67 mg kg-1) and was comparable to T_5 (2998.67 mg kg^{-1}). The treatment T_6 also recorded a higher B content of 19.74 mg kg^{-1}, comparable to T_7 (17.90 mg kg^{-1}). Different composting methods were found to have no significant influence on the content of micro nutrients like Cu, Mn and Zn and beneficial nutrient (Si).

The total microbial population (bacteria, fungi and actinomycetes) in composts was found higher with the treatments T_6 and T_7. Among microbes, the population of bacteria was higher and comparable in co - composting treatments T_7 (156.33×10^6 cfu g^{-1}) and T_6 (147.33×10^6 cfu g^{-1}). The fungal population was the highest with T_6 (112×10^3 cfu g^{-1}) whereas that of actinomycetes was for T_7 (41.67×10^4 cfu g^{-1}). Enzymatic activity with respect to dehydrogenase was higher for T_7 (27.55 µg TPF hr^{-1} g^{-1}), however comparable to T_5 and T_6.

The results of the pot culture study indicated that paddy straw composts as potting media component had significant influence on growth, yield attributes, yield and quality parameters of bhindi. Potting media with co - composted paddy straw (T_6 and T_7) produced taller plants at all stages of crop growth. At 45 DAS, these treatments registered significantly higher and comparable plant heights of 74.75 cm and 71.87 cm respectively. Towards the later stages of crop growth (60 DAS, 75 DAS and at final harvest), plant height was found higher and comparable for all the treatments where co - composted paddy straw was made used as potting media component (T_4 to T_7). At final harvest (110 DAS), the plant height was higher for T_6 (138.67 cm), followed by T_7 (128.70 cm), T_5 (126.42 cm) and T_4 (120.20 cm).

Different paddy straw composts as potting media component could not significantly influence the number of branches at various crop stages (45, 60, 75 DAS and at final harvest).

At 30 and 60 DAS, treatments T_7, T_6 and T_5 (co - composted paddy straw as potting media component) recorded higher and comparable leaf area. At 30 DAS, higher leaf area of 960.06 cm^2 was recorded with the treatment T_6. Whereas, at 60 DAS, the leaf area was higher (3909.70 cm^2) with the treatment T_7.

Different paddy straw composts added as potting media component could exert significant influence on the yield attributes and yield of test crop bhindi. The number of fruits per plant, length and weight of fruit as well as fruit yield were higher with treatments T_6 and T_7. Treatment T_7 recorded earliness in flowering and attained 50 per cent flowering in 48.67 days, however comparable to all other treatments except T_8 and T_9. Fruit length of bhindi was found significantly more and comparable in treatments T_7 (16.40 cm) and T_6 (16.01 cm).

Different paddy straw composts failed to produce any significant influence on the girth of the bhindi fruits. Highest fruit weight (27.05 g) was observed with the treatment T_7 and it was statistically on par with T_6 (26.26 g) and T_5 (25.21 g). Among the different potting media, the highest yield per plant was recorded with the treatment T_7 (0.619 kg) and it was statistically on par with the treatment T_6 (0.59 kg per plant).

The important quality parameters of the crop *viz.,* crude protein, crude fibre and ascorbic acid content were favourably influenced by the treatment T_7. Higher and comparable dry matter production and nutrient uptake were recorded with treatments T_6 and T_7. The treatment T_7 could register a higher DMP of 128.35 g per plant and it was comparable to that with T_6 (119.67 g per plant).

Different paddy straw composts added as potting media component failed to produce any significant influence on pH of the potting media tested before and after the pot culture trial. Organic carbon content of the potting media observed before the pot culture study was higher and comparable in all the treatments except control. However, after the pot culture study, organic carbon content was found higher and comparable in treatments where co - composted paddy straw was supplied as potting media component (T_4 to T_7). Paddy straw composts obtained by co - composting when supplied as potting media component recorded higher availability of major plant nutrients before the pot culture study. Available N was significantly higher in treatments T_6 and T_7. Higher and comparable availability of P and K was recorded by the treatments T_4, T_5, T_6 and T_7. Microbial population also was found higher in these treatments.

The net returns and benefit cost ratio were significantly higher and comparable with the treatments T_7 and T_6. The treatment T_7 recorded a net return of ₹ 7.04 per bag, followed by T_6 (₹ 6.01 per bag). The treatment T_7 registered the highest BCR of 1.23, comparable to T_6 (1.20).

From the results of the study it could be concluded that

Paddy straw could be bio recycled as quality manure using appropriate composting techniques. Co - composting is an efficient technology for producing quality manure from paddy straw. Co - composting of paddy straw with poultry manure in the ratio 4:1 or with cowdung and poultry manure in the ratio 8:1:1 were identified as the best methods for production of nutrient rich compost with high recovery within a short period of time, compared to vermicomposting and microbial composting.

Substituting the above composts for FYM in potting medium could result in better growth, yield attributes, yield and net income of bhindi. With respect to quality parameters of crop, use of paddy straw compost generated under co - composting performed better. Paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 could register superior quality attributes.

Future line of work

- As part of organic recycling in rice based cropping systems, assess the possibility of partial substitution of chemical fertilizers with paddy straw composts for vegetables grown in summer rice fallows during third crop season.

- Explore the possibility of composting of paddy straw with other organic sources like oil cakes.
- Enrichment of paddy straw composts using other organic inputs.

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APPENDICES

APPENDIX I

Weather parameters during the crop period (15-08-2018 to 03-12-2018)

Standard week	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (%)	Rainfall (mm)
33	27.80	22.40	93.40	153.6
34	31.00	24.42	84.28	0
35	30.85	24.28	84.00	0
36	31.28	23.92	93.71	0
37	31.92	24.35	80.42	0
38	31.57	24.50	85.28	8.3
39	32.21	24.57	83.71	91.6
40	30.21	25.00	91.00	75.4
41	30.57	24.64	90.00	25.2
42	31.25	23.85	88.57	82.0
43	31.07	24.28	91.28	27.8
44	31.29	24.28	86.86	78.4
45	30.57	24.14	76.43	60.7
46	30.71	22.86	89.00	47.8
47	31.92	20.42	75.14	11.6
48	31.93	24.21	87.00	0
49	32.00	23.00	87.00	0

APPENDIX II

AVERAGE COST OF INPUTS AND MARKET PRICE OF PRODUCE

COST OF INPUTS

Cowdung	- ₹ 1 kg^{-1}
Poultry manure	- ₹ 1.50 kg^{-1}
Pleurotus spawn	- ₹ 35 packet^{-1}
Seeds of bhindi variety Manjima	- ₹ 5000 kg^{-1}
Grow bag	- ₹ 10 bag^{-1}
Rock sand	- ₹ 1.50 kg^{-1}
Coirpith compost	- ₹ 10 kg^{-1}
Urea	- ₹ 8 kg^{-1}
Rock phosphate	- ₹ 9 kg^{-1}
Muriate of potash	- ₹ 15 kg^{-1}
Farm yard manure	- ₹ 5 kg^{-1}
Labour charge	- ₹ 748 labourer^{-1}

PRICE OF PRODUCE

Bhindi fruits	- ₹ 60 kg^{-1}

BIO RECYCLING OF PADDY STRAW FOR QUALITY MANURE PRODUCTION

By

AMALA MARY GEORGE

(2017-11-055)

ABSTARCT

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ABSTRACT

The study entitled "Bio recycling of paddy straw for quality manure production" was undertaken during 2017-2019, at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, with the objectives to find out an effective technology for composting paddy straw and to assess the effectiveness of paddy straw composts as potting media component on the growth, yield and quality of bhindi and to work out the economics.

The research work was carried out as two experiments, which were conducted at Integrated Farming System Research Station (IFSRS), Karamana. Under Experiment I, composts were generated from paddy straw through different methods of composting. The experiment was laid out in completely randomized block design with eight treatments and three replications during the period March to August, 2018. The treatments included vermicomposting (using earthworm species *Eudrillus euginea*) of paddy straw with cowdung in the ratios 8:1, 6:1 and 4:1 (T_1, T_2 and T_3 respectively), co - composting of paddy straw with poultry manure in the ratios 8:1, 6:1 and 4:1 (T_4, T_5 and T_6 respectively), co - composting of paddy straw with cowdung and poultry manure in the ratio 8:1:1 (T_7) and microbial composting using the fungus *Pleurotus* (T_8).

The time taken for maturation of composts, percentage recovery, quality parameters, microbial and enzymatic activity varied significantly with different composting methods. Paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 (T_7) recorded significant earliness (97.67 days) with respect to generation of mature compost. Co - composting of paddy straw with poultry manure in the ratio 4: 1 (T_6) recorded significantly higher recovery (44.59 %). The treatment T_6 registered a lower C: N ratio (9.54:1) and was on par with T_5 and T_7. It also recorded a higher CEC of 77.91 c mol kg^{-1} but was comparable with most of the treatments except T_1, T_2 and T_8. The treatment T_6 was found rich in plant nutrients and recorded higher N (2.67 %), P (0.93 %) and K (3.15 %)

content and was comparable with T_7. Co - composting treatments T_5, T_6 and T_7 also recorded higher micro nutrient status.

The total microbial population was higher with the treatments T_6 and T_7. The fungal population was the highest with T_6 whereas that of actinomycetes was for T_7. Enzymatic activity with respect to dehydrogenase was higher with T_7 (27.55 µg TPF hr^{-1} g^{-1}), which was comparable to T_5 and T_6.

Different paddy straw composts generated from Experiment I were used as potting media component in Experiment II. The pot culture experiment was laid out in completely randomized block design with nine treatments and three replications during August to December, 2018. Potting media used was a mixture of soil, rock sand, coir pith compost and different paddy straw composts in the ratio 1:0.5:0.5:1 on volume basis (T_1 to T_8). In treatment T_9 (control), FYM was substituted for paddy straw composts in the potting medium. The KAU hybrid variety of bhindi, Manjima (Gowreesapattom local × IC 282257) was the test crop.

The results indicated that paddy straw composts as potting media component had significant influence on growth, yield attributes, yield and quality parameters of bhindi. Potting media with co - composted paddy straw (T_6 and T_7) produced taller plants at all stages of crop growth. These treatments also resulted in higher and comparable leaf area at 30 DAS and 60 DAS.

Number of fruits per plant, length and weight of fruit as well as fruit yield were higher with the treatments T_6 and T_7. The treatment T_7 also recorded earliness in flowering and attained 50 per cent flowering in 48.67 days, which was comparable to all other treatments except T_8 and T_9. All the quality parameters *viz.,* crude protein, crude fibre and ascorbic acid content were favourably influenced by T_7. Higher and comparable dry matter production and nutrient uptake were recorded with the treatments T_6 and T_7.

Organic carbon content of the potting media observed before the pot culture study was higher and comparable in all the treatments except control. The treatments T_4, T_5, T_6 and T_7 recorded higher availability of plant nutrients before the pot culture study. However, after the pot culture study, organic carbon content was higher and comparable in all the treatments in which co - composted paddy straw was used as a component (T_4, T_5, T_6 and T_7). Microbial population was higher in the treatments T_6 and T_7, before and after the experiment.

The net returns and benefit cost ratio were significantly higher and comparable with the treatments T_7 and T_6.

The results of the study revealed that co - composting is an efficient technology for producing quality manure from paddy straw. Co - composting of paddy straw with poultry manure (4:1) or with cowdung and poultry manure (8:1:1) were identified as the best methods for production of nutrient rich compost with high recovery within a short period of time (97.67 days and 108 days respectively), compared to vermicomposting and microbial composting. Substituting these composts instead of FYM in potting medium (T_6 and T_7) resulted in better growth, yield attributes, yield and net income for bhindi. With respect to quality parameters, paddy straw co - composted with cowdung and poultry manure in the ratio 8:1:1 as potting media component was found superior.

സംഗ്രഹം

''വയ്ക്കോലിൽ നിന്ന് ഗുണമേന്മയുള്ള ജൈവവളം ജൈവചംക്രമണത്തിലൂടെ'' എന്ന വിഷയത്തെ ആസ്പദമാക്കി ഒരു ഗവേഷണ പഠനം വെള്ളായണി കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. ഇതിലേക്കുള്ള ജൈവവളങ്ങളുടെ ഉത്പാദനവും തുടർന്ന് വെണ്ടയിൽ നടത്തിയ വിളപരീക്ഷണവും കരമനയിലുള്ള സംയോജിത കൃഷി ഗവേഷണ കേന്ദ്രത്തിൽ 2018 മാർച്ച് മുതൽ ഡിസംബർ വരെയുള്ള സമയത്ത് നടത്തി. വയ്ക്കോലിൽ നിന്നും പല കമ്പോസ്റ്റിങ്ങ് രീതികളിലൂടെ ജൈവവളം ഉത്പാദിപ്പിക്കുക, ഈ ജൈവവളങ്ങൾ നടീൽ മിശ്രിതത്തിൽ ഉൾപ്പെടുത്തി ഗ്രോബാഗുകൾ നിറച്ച് അവയിൽ വെണ്ട കൃഷി ചെയ്യുക വഴി വിളയുടെ വളർച്ചയിലും ഉത്പാദനത്തിലുമുള്ള അവയുടെ സ്വാധീനം കണ്ടെത്തുക എന്നിവയായിരുന്നു ഈ ഗവേഷണ പഠനത്തിന്റെ പ്രധാന ലക്ഷ്യങ്ങൾ.

ഗവേഷണ പഠനം രണ്ട് ഘട്ടങ്ങളായാണ് നടത്തിയത്. ആദ്യ ഘട്ടത്തിൽ വിവിധ കമ്പോസ്റ്റിങ്ങ് രീതികളിലൂടെ വയ്ക്കോലിൽ നിന്നും പലതരം കമ്പോസ്റ്റുകൾ ഉത്പാദിപ്പിച്ചു. മണ്ണിര കമ്പോസ്റ്റിങ്ങ്, കോ കമ്പോസ്റ്റിങ്ങ്, സൂക്ഷ്മ ജീവികളെ (പ്ലൂറോട്ടസ് എന്നയിനം കുമിൾ) ഉപയോഗിച്ചുള്ള കമ്പോസ്റ്റിങ്ങ് എന്നീ മൂന്ന് രീതികളാണ് പ്രധാനമായും പരീക്ഷിച്ചത്. മണ്ണിര കമ്പോസ്റ്റ് ഉത്പാദനത്തിനായി വയ്ക്കോലും ചാണകവും വ്യാപ്തം അടിസ്ഥാനപ്പെടുത്തി പല അനുപാദങ്ങളിൽ (4:1, 6:1, 8:1) സംയോജിപ്പിച്ചു. കോകമ്പോസ്റ്റിങ്ങ് രീതിയിൽ വയ്ക്കോലും കോഴിക്കാരവും മേൽപ്പറഞ്ഞ അനുപാതങ്ങളിൽ യോജിപ്പിച്ചു. ഇവയ്ക്കു പുറമെ വയ്ക്കോലും ചാണകവും കോഴിക്കാരവും 8:1:1 എന്ന അനുപാതത്തിലും സംയോജിപ്പിച്ചു. സൂക്ഷ്മ ജീവികളെ ഉപയോഗിച്ചുള്ള കമ്പോസ്റ്റ് നിർമ്മാണത്തിന് 100 കി. ഗ്രാം വയ്ക്കോലും 500 ഗ്രാം യൂറിയയും 150 ഗ്രാം പ്ലൂറോട്ടസ് വിത്തും ഉപയോഗിച്ചു.

കമ്പോസ്റ്റ് പാകപ്പെടാനാവശ്യമായ സമയം പല കമ്പോസ്റ്റിങ്ങ് രീതികളിൽ നിന്നും ലഭിച്ച ജൈവ വളത്തിന്റെ അളവ്, അവയുടെ ഗുണമേന്മ എന്നിവ പഠനത്തിൽ വിലയിരുത്തി. വയ്ക്കോലും കോഴിക്കാരവും 4:1 എന്ന അനുപാതത്തിൽ യോജിപ്പിച്ചും വയ്ക്കോലും ചാണകവും കോഴിക്കാരവും 8:1:1 എന്ന അനുപാതത്തിൽ യോജിപ്പിച്ചുമുള്ള കമ്പോസ്റ്റ് ഉത്പാദന രീതികളിൽ കുറഞ്ഞ കാലയളവിൽ തന്നെ മേന്മയേറിയ ജൈവവള ഉത്പാദനം നടക്കുന്നതായി കണ്ടെത്തി. ഭാവകം, പാക്യജനകം, ക്ഷാരം തുടങ്ങിയ പ്രധാന

സസ്യ മൂലകങ്ങളുടെ അളവും ഈ രണ്ട് കമ്പോസ്റ്റുകളിൽ കൂടുതലാണെന്ന് കണ്ടെത്തി, ഇതിന് പുറമെ സൂക്ഷ്മ ജീവികളുടെ എണ്ണത്തിലും ഇവ മികവ് പുലർത്തി.

രണ്ടാം ഘട്ട പരീക്ഷണത്തിനായി വെണ്ടയ്ക്കുള്ള നടീൽ മിശ്രിതം തയ്യാറാക്കിയതിൽ വയ്ക്കോലിൽ നിന്ന് വിവിധ രീതികളിലൂടെ ഉത്പാദിപ്പിച്ച കമ്പോസ്റ്റും മണലും ചകിരിച്ചോർ കമ്പോസ്റ്റും മണ്ണും 1: 0.5 : 0.5 : 1 എന്ന അനുപാതത്തിൽ സംയോജിപ്പിച്ചു. ഇതിനോടൊപ്പം തന്നെ താരതമ്യ പഠനത്തിനായി വയ്ക്കോലിൽ നിന്നുള്ള കമ്പോസ്റ്റിന് പകരം ഉണക്കച്ചാണകം ചേർത്തുള്ള നടീൽ മിശ്രിതവും തയ്യാറാക്കി. വെള്ളായണി കാർഷിക കോളേജിൽ നിന്ന് പുറത്തിറക്കിയ മഞ്ജിമ എന്ന സങ്കരയിനം വെണ്ടയാണ് വിള പരീക്ഷണത്തിനായി തിരഞ്ഞെടുത്തത്.

ആദ്യ ഘട്ട പരീക്ഷണത്തിൽ മികച്ചു നിന്ന കമ്പോസ്റ്റുകൾ തന്നെ വിള പരീക്ഷണത്തിലും മികവ് പുലർത്തി. വയ്ക്കോലും ചാണകവും കോഴിക്കാരവും (8 : 1 : 1) ഉപയോഗിച്ച് ഉത്പാദിപ്പിച്ച കമ്പോസ്റ്റും കോഴിക്കാരം കൂടിയ അളവിൽ (4 : 1) ഉപയോഗിച്ച് ഉത്പാദിപ്പിച്ച കമ്പോസ്റ്റും നടീൽ മിശ്രിതത്തിൽ ഉൾപ്പെടുത്തിയപ്പോൾ വെണ്ടയുടെ വളർച്ച മെച്ചപ്പെട്ടു. രണ്ട് കമ്പോസ്റ്റുകളും ചേർത്ത നടീൽ മിശ്രിതത്തിൽ വളർത്തിയ ചെടികൾക്ക് കൂടുതൽ ഉയരവും കൂടുതൽ ഇലകളുമുള്ളതായി കണ്ടു. കായ്കളുടെ നീളം, തൂക്കം, മൊത്തത്തിലുള്ള വിളവ് എന്നിവയിലും ഇവ തന്നെ മികച്ചു നിന്നു. കൃഷിയിൽ നിന്നുള്ള ലാഭം കൂടുതലായി കിട്ടിയതും ഇവയിൽ തന്നെയാണ്. സസ്യമൂലകങ്ങളുടെ ആഗിരണവും ഇവയിലാണ് കൂടുതലായി കണ്ടത്. വയ്ക്കോലും ചാണകവും കോഴിക്കാരവും (8 : 1 : 1) ഉപയോഗിച്ച് ഉത്പാദിപ്പിച്ച ജൈവവളമാണ് കൂടുതൽ പോഷകഗുണമുള്ള കായ്കൾ ഉത്പാദിപ്പിച്ചത്.