CROP RESIDUE RECYCLING FOR ORGANIC PRODUCTION OF FODDER MAIZE IN A RICE BASED INTEGRATED FARMING SYSTEM

ATHIRA K.V.

(2018-11-108)

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695522
KERALA, INDIA

2020

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by

ATHIRA K.V.
(2018-11-108)

THESIS

Submitted in partial fulfilment of the
requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695 522
KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"CROP RESIDUE RECYCLING FOR ORGANIC PRODUCTION OF FODDER MAIZE IN A RICE BASED INTEGRATED FARMING SYSTEM"** 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, associateship, fellowship or other similar title, of any other University or Society.

Vellayani
15-03-2021

ATHIRA K.V.
(2018-11-108)

CERTIFICATE

Certified that this thesis entitled **"CROP RESIDUE RECYCLING FOR ORGANIC PRODUCTION OF FODDER MAIZE IN A RICE BASED INTEGRATED FARMING SYSTEM"** is a record of research work done independently by Ms. Athira K.V. (2018-11-108) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Sudha

Vellayani
15-03-2021

Dr. B. Sudha
(Major Advisor, Advisory Committee)
Assistant Professor (Agronomy)
Integrated Farming System Research Station
Karamana, Thiruvananthapuram

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Athira K.V. (2018-11-108), a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that the thesis entitled **"CROP RESIDUE RECYCLING FOR ORGANIC PRODUCTION OF FODDER MAIZE IN A RICE BASED INTEGRATED FARMING SYSTEM"** may be submitted by Ms. Athira K.V., in partial fulfillment of the requirement for the degree.

Sudha

Dr. B. Sudha
(Major Advisor, Advisory Committee)
Assistant Professor (Agronomy)
Integrated Farming System Research Station
Karamana,Thiruvananthapuram

Dr. Jacob John
(Member, Advisory Committee)
Professor (Agronomy) and Head
Integrated Farming System Research Station
Karamana, Thiruvananthapuram

Shalini Pillai

Dr. Shalini Pillai P.
(Member, Advisory Committee)
Professor and Head
Department of Agronomy
College of Agriculture
Vellayani, Thiruvananthapuram

Dr. R.V. Manju
(Member, Advisory Committee)
Professor
Department of Plant Physiology
College of Agriculture
Vellayani,Thiruvananthapuram

ACKNOWLEDGEMENT

First of all, I bow my head before the Almighty God for making me confident and optimistic throughout my journey and enabled me to complete the thesis work successfully on time.

I am inexpressibly happy to extend my deep sense of gratitude to my guide ***Dr. B. Sudha,*** *Assistant Professor (Agronomy), Integrated Farming System Research Station, Karamana and Chairperson of my Advisory Committee for her valuable suggestions, constant support, extreme patience and diligent assistance and co-operation throughout the research work. This work would not have been possible without her valuable help and support. It was her sincerity, dedication and perfectionism which influenced me deeply to improve myself in all aspects.*

I am indebted to ***Dr. Shalini pillai, P.*** *Professor and Head, Department of Agronomy, College of Agriculture, Vellayani and a member of Advisory Committee, for her support, constant criticism and valuable suggestions rendered throughout the period of research work.*

I am ineffable to express my esteemed thanks to ***Dr. Jacob John,*** *Professor (Agronomy) and Head, IFSRS, Karamana and a member of Advisory Committee, for his valuable advice and whole hearted approach for the successful completion of the thesis.*

With great pleasure, I express my gratitude to ***Dr. R.V. Manju*** *Professor (Plant Physiology), College of Agriculture Vellayani and a member of Advisory Committee for her encouragement, wholehearted help and support throughout the period of my research work.*

I am extremely thankful to ***Dr. Sansamma George (Rtd.)*** *,* ***Dr. Elizabeth K. Syriac (Rtd.),*** ***Dr. O. Kumari Swadija (Rtd.),*** ***Dr. A.S. Anil kumar (Rtd.)*** *and* ***Dr. L. Girija devi (Rtd.)*** *Professor and Head, Department of Agronomy, College of Agriculture, Vellayani for their support and valuable advice rendered throughout the period of research work and course of study.*

I sincerely extend my gratitude to ***Dr. Meera A.V,*** *Assistant Professor (Soil Science and Agricultural Chemistry) and* ***Dr. Sajeena. A,*** *Assistant Professor (Plant Pathology), IFSRS, Karamana for their encouragement, valuable suggestion and continued support throughout my research work.*

I greatfully acknowldge ***Sri. Krishnakumar G.****, Technical Assistant, IFSRS, Karamana for his support and suggestions rendered throughout the period of field work.*

I sincerely express my obligation and respect to all teachers of Department of Agronomy for their constant encouragement, support, and valuable advice. I also express my gratitude to all non teaching staff members of agronomy for their sincere co-operation, timely help and assistance during the lab work and throughout my course work.

I wish to express my heartfelt thanks to **Hirosh sir, Arun chettan, Nidhin chettan, Sheeba chechi, Aneesha chechi** and all the non teaching members of IFSRS, Karamana for their constant encouragement and support. Words are scarce to express my deep sense of gratitude to the labourers of IFSRS, Karamana for their timely help and support during the field work.

I duly acknowledge the encouragement, help, love and moral support by my dear class mates **Dhyana, Anna, Anupama, Sarin, Sruthi, Ramya, Sinchana, Aisha, Ram, Sarath, Aswathy, Swathi, Arunima and Alekhya.**

I am also indebted to express my thanks to my seniors **Amala chechi, Lekshmi chechi, Dhana chechi**, **Anjana chechi** and **Jithettan** and my juniors **Sandra, Elizabeth**, **Deepthi** and **Jeseem** for their help and support rendered throughout my research work.

At this moment, I recall with love, cooperation and caring extended by my roommates, **Arya and Shamna,** who were with me during all hardships I passed through and kept me encouraged and happy throughout the course of study. Words are inadequate to express my thanks to my beloved friends **Akhil, Arun, Elso, Aswathy and Anju** for their constant support, love, care and for the happiest moments we cherished together. A special mention of thanks to my dearest **Deepa chechi, Smitha chechi** and **Ajith chettan** for their constant support and encouragement.

Mere words cannot express my profound indebtness to my beloved father **Sri.Velayudhan,** my dearest mother **Smt. Usha,** my beloved brother **Arjun,** sister in law **Athulya**, cousins **Abin, Ajin, Vyshakh, Vishakh,** my beloved grandma **Pennutti,** uncle **Vinodhan,** and aunties **Suma** and **Mini** for their unconditional love, sacrifices and support bestowed on me during my hard periods.

I once again express my sincere gratitude to all those who helped me in one way or another in the successful completion of this venture.

Athira K.V

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
B	Boron
BCR	Benefit cost ratio
CD (0.05)	Critical difference at 5 % level
CEC	Cation exchange capacity
CGR	Crop growth rate
cm	Centimetre
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
Fig	Figure
FYM	Farm yard manure
g	Gram
g^{-1}	Per gram
Ha	Hectare
ha^{-1}	Per hectare
IFSRS	Integrated Farming System Research Station
K	Potassium
kg^{-1}	Per kilogram
K_2O	Potassium Oxide

KAU	Kerala Agricultural University
LAI	Leaf Area Index
M	Metre
m^3	Cubic metre
mt	Metric tonnes
mg	Milligram
Mn	Manganese
N	Nitrogen
P	Phosphorus
pH	Negative logarithm of H^+ ion concentration
P_2O_5	Phosphorus Pentoxide
RDF	Recommended dose of fertilizers
RDN	Recommended dose of nitrogen
RGR	Relative growth rate
Si	Silicon
SCMR	SPAD chlorophyll meter reading
T	Tonnes
t ha^{-1}	Tonnes per hectare
Zn	Zinc

LIST OF SYMBOLS

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

INTRODUCTION

1. INTRODUCTION

Integrated Farming Systems (IFS) have been recognized as the most viable strategy for maximizing farmers' income and ensuring food security. This holds much importance for Kerala, where 96.70 per cent of the farmers are marginal farmers, having average holding size as less as 0.12 ha (Department of Economics and Statistics, 2019).

Livestock especially dairy forms an integral and complimentary enterprise in IFS. High cost of concentrate cattle feeds is a major constraint contributing to escalated cost of production rendering dairy farming a non - economic activity. Cattle are often left underfed leading to suboptimal production, considerably influencing the milk production of Kerala. The import of milk into the state is estimated as 2 lakh litres per day (Sreeram *et al.* 2017). This necessitates generation of adequate quantities of green fodder within farms.

Among different fodder crops, fodder maize is much important owing to its higher production potential, wider adaptability, quick growing nature, succulence, palatability and excellent fodder quality. Also, the crop is free from toxicants and can be fed safely to animals. Most important is that being a short duration crop, it can also fit well in different cropping systems. African tall is a fodder maize variety with high herbage yield up to 40 t ha^{-1}.

Rice based IFS generate large quantities of crop residues mainly straw and husk. Though straw is quite useful as dry fodder, a large fraction of straw is going waste as a result of improper storage and drying. In Kerala's double cropped conditions, at least one harvest falls during wet season, which limits the chances of spreading and drying of straw resulting in mouldy growth, reducing its feed value considerably. This straw, which is not suitable as feed material is often discarded as bio waste in fields.

With the increasing trend towards organic farming, recycling of all possible resources generated in a farm assumes greater importance. Crop residues like rice straw owing to its bulky volume, slow decomposition and short term negative effect of nitrogen immobilization (Buresh and Sayre, 2007) is difficult to be recycled as such to soils. Wide C: N ratio, high lignin (11-24%) and silica (7-20%) content makes degradation of rice straw a difficult process (Kumar *et al.*, 2008; Hu *et al.*, 2016). Composting of straw is an alternate option to recycle the nutrients contained in it.

With improved composting technologies, the prospects of nutrient recycling from rice straw are immense. Co-composting with nitrogen rich organic inputs is a proven technology in generating nutrient rich manures from rice straw (George, 2019). Especially in an IFS, the dung and droppings obtained from livestock mainly cow dung, goat manure, poultry manure etc. and green leaf manures like glyricidia could be utilized as nitrogen sources for co-composting. This helps for efficient recycling of resources within an IFS thereby supporting organic production of crops. This in turn will result in favourable impacts on soil health in the long run.

The present experiment entitled **“**Crop residue recycling for organic production of fodder maize in a rice based integrated farming system” was thus formulated in standardising an ideal co-composting strategy for generating quality composts from rice straw and to assess the effectiveness of those composts in organic production of fodder maize grown in summer rice fallows. The specific objectives of the project were,

- To generate nutrient rich manures from rice straw through co-composting technique.
- To evaluate the efficacy of these composts in influencing the growth, yield, quality and economics of fodder maize.

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REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The study entitled “Crop residue recycling for organic production of fodder maize in a rice based integrated farming system” was conducted from July 2019 to May 2020, at Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala, with the objectives to generate nutrient rich manures from rice straw through co-composting and to evaluate their efficacy in influencing the growth, yield, quality and economics of fodder maize.

Rice (*Oryza sativa*) is the most important staple food of the world. In Kerala, among different cereal based cropping systems, rice based cropping systems are most common and these systems generate large amount of residues in the form of straw and husk. The straw, is obtained after harvest of rice is useful as animal feed, but looses its feed value under unfavourable storage. It is one of the most abundant lignocellulosic crop residues in the world and its improper management causes serious problems in the environment. The straw thus left as waste in fields is having immense potential to be recycled as nutrient rich organic manure. The best method of rice straw management is its composting. Composting is an environment friendly waste management strategy to recycle the nutrients that are present in the crop residues. According to many scientific studies, suggests that composting of rice straw is a safe alternative for reusability of nutrients contained in it.

This exposition is an attempt to review the findings of research works related to co-composting of rice straw and use of compost as a nutrient source for production of fodder maize.

2.1 Composition of rice straw

Rice is the major food grain crop grown world wide with annual production about 800 mt. The crop also generates large quantities of rice straw. On dry matter basis, rice straw contains 37 per cent cellulose, 48 per cent lignin and 8 per cent silica (Singh *et al.*, 1995). Rice straw is one of the most abundant lignocellulosic waste material generated in fields and is comprised of lignin (10-20%), cellulose (45%) and hemicellulose (25%) (Kadam *et al.*, 2000; Drake *et al.*, 2002). Rice straw has high

C:N ratio of about 80:1 and the presence of silica, lignin and polysaccharides make it difficult to be degraded (Kumar *et al*., 2008). Nakhshiniev *et al*. (2014) reported high lignin content of rice straw ranging from 13.5 to 25 per cent on dry weight basis.

Abdelhamid *et al*. (2004) reported that rice straw on dry weight basis contains 0.64 per cent N, 0.11 per cent P and 0.26 per cent K and recorded a C: N ratio of 61:1. In addition to primary nutrients, rice straw also contains appreciable quantities of secondary nutrients including Ca (0.23 %), Mg (0.15 %), S (0.08 %) and micronutrients Mn (720 mg kg^{-1}), Fe (310 mg kg^{-1}), Zn (38.40 mg kg^{-1}), Cu (9.3 mg kg^{-1}) and B (6.80 mg kg^{-1}) as reported by Mandal *et al*. (2004) and Jusoh *et al*. (2013). According to Chaudhary *et al*. (2017), on an average, rice straw contains 51.76 per cent organic matter, 0.65 per cent nitrogen, 0.20 per cent phosphorus and 1.12 per cent potassium.

2.2 Composting of rice straw

Rice straw, the major crop residue generated in rice based integrated farming systems is not recycled as such to soil due to its bulky volume, slow degradation and short term negative effect of nutrient immobilization especially nitrogen (Singh *et al*., 2005).

Among different alternatives available for management of rice straw, composting is viewed as the most economic and efficient strategy due to its ecofriendly nature and the ability to produce good quality organic manure (Imbeah 1998; Pascual *et al*., 2002). On the other hand, composting of rice straw offers an efficient method to recycle the nutrients contained in it to generate good quality end product (Dileep and Dixit, 2005). Rice straw being a poor source of nitrogen, supplementation with nitrogen rich materials of both plant and animal origin is a good alternative to generate quality composts as reported by Neklyudov *et al*. (2006). According to Zhu (2007), rice straw is resistant to microbial degradation due to its wide C:N ratio, high lignin, cellulose and silica content, and improved techniques like co-composting could hasten the decomposition process and result in the production of good quality composts (Herwijnen *et al*., 2007).

Co-composting refers to the composting of two or more materials in the same vessel or process, thus providing cost and space savings. It is an effective solid waste management technique for preparing good quality organic manure from crop residues having wider C: N ratio (Kumar *et al.*, 2005). In this method, residues are mixed with organic materials having higher nitrogen content. Agro wastes like rice straw, wheat straw, corn stalks etc. are mostly co- composted using animal manures. Preparation of compost by adding 20 per cent cow dung slurry (w/w) to the recyclable wastes material (rice straw) was found ideal for achieving desirable C:N ratio, nutrient content and survival of beneficial microorganisms (Yadukumar and Nandan, 2005). Li *et al.* (2008) opined that co-composting of rice straw with livestock manure is a suitable treatment method for waste and discarded rice straw. As the C:N ratio (80:1) of rice straw is very high, it is essential to bring down the C:N ratio by supplying an exogenous nitrogen source. Devi *et al.* (2010) reported that poultry droppings is a good supplement due to its high nitrogen content, and therefore amendment of rice straw with poultry dropping is a desirable option to bring down the C:N ratio. Co-composting of cattle manure with rice straw produced an organic manure having total nitrogen and C:N ratio suitable for soil amendment (Goyal and Sindhu, 2011). This practice brings about substantial loss of heavy metals and maximum retention of plant nutrients (Anwar *et al.*, 2015).

Composting of rice straw is the best alternative to manage this resource, in addition to restoration of soil health (Gaind *et al.,* 2008). Co-composting of rice straw with 10 per cent rock phosphate and soyabean residues was identified as a good alternative for agri-waste management and generating safe and stable compost (Saludes *et al.*, 2008). Co-composting of rice straw and goat manure slurry makes the final compost more porous due to well decomposition of organic inputs. This also indicates that the lignin content was significantly reduced in the final compost (Lim and Wue, 2016). Composting of rice straw with goat manure improves the decomposition rate as reported by Sanusi *et al.* (2018).

2.2.1 Time Taken for co-composting

Compost maturity can be evaluated based on several parameters like pH, electrical conductivity (EC), cation exchange capacity (CEC), C:N ratio, moisture content and nutrient status. In order to promote compost maturation, environmental factors such as temperature, moisture, and aeration should be appropriately controlled (Eipstein, 1997; Aparna *et al.* 2007). Rashad *et al.* (2010) found that co- composting of rice straw with 10 per cent rock phosphate and soyabean residue is a good method for generating safe and stable composts useful as soil amendment within a period of 84 days. Jusoh *et al.* (2013) reported that composting of rice straw was completed within 90 days when mixed with goat manure and green wastes. Rice straw when co-composted with swine manure (4:6 w/w), produced quality end product within a period of 90 days (Qian *et al.*, 2014).

Amendment of rice straw with cattle dung produced good quality compost within a time period of 90 days (Goyal *et al.,* 2011). Composting of rice straw, cowdung, poultry waste and rock phosphate produced mature composts within 150 days (Raj and Antil, 2011). Mixing of poultry droppings with chopped rice straw produced mature compost within a period of 50 days (Manna *et al.,* 2013). Qian *et al.* (2014) reported that co-composting of rice straw and dairy manure generated quality compost within 90 days. Sharma *et al.* (2014) reported that co-composting of rice straw and poultry droppings produced good quality compost within a period of 60 days. According to Omar *et al.* (2020) compost prepared from rice straw, animal manure, biochar and rock dusts results in faster composting and generation of composts within 42 days.

Co-composting of barley wastes with poultry manure recorded a composting period of 103 days as reported by Guerra-Rodriguez *et al.* (2003). Amanullah (2007) reported that composting of sorghum straw and poultry manure in the ratio 10:1 could generate mature composts within 60 days. Addition of agricultural green wastes having high nitrogen content *viz.*, alfalfa and water hyacinth to rice straw considerably reduced the time required for composting (Salman *et al.*, 2011). When rice chaff was co-composted using dairy manure reported a slightly higher composting period of 112 days (Tian *et al.*, 2012).

2.2.2 Recovery of compost

Alten and Erdin (2005) reported 50 per cent recovery from a composting experiment having solid wastes and sludge as composting material. Verma *et al.* (2014) assessed the potential of different composting methods in wheat straw composting. Wheat straw mixed with cowdung slurry and composted in pits for 175 days recorded a recovery of 40 per cent. Shrivastava and Arya (2018) experimented composting of rice straw and reported that about 50 per cent weight reduction occurs with the formation of stable compost.

2.2.3 Chemical properties

Chemical properties including pH, EC, C:N ratio and nutrient content are the major determinants deciding quality of compost. Nolan *et al.* (2011) claimed that the quality of the final compost cannot be determined based on a single parameter. The influence of different composting methods on these quality parameters are reviewed here.

2.2.3.1 pH

Rice straw was co-composted with chicken slurry and the pH of the composting lot was recorded at periodic intervals (Recycled Organics Unit, 2007). pH showed an increment from 6.1 to 7.6 from beginning to maturation. The lower pH at the initial stage of co-composting was attributed to the formation of organic acids. However, higher pH of compost at maturity was result of decomposition of organic acids Amendment of rice straw with poultry manure generated composts within a period of 2 months and recorded a neutral pH value of 7.18 as compared to that with natural composting (8.77) (Goyal *et al.*, 2010). A stable pH value of 7.7 was obtained when rice straw was co-composted with swine manure for 90 days (Qian *et al.*, 2014).

Mixing of rice straw, poultry manure and oilseed rape cake in the ratio 5:2:3 on weight basis could produce mature compost having a neutral pH range of 7.0 (Abdelhamid *et al.*, 2004). Hu *et al.* (2009) reported that composting rice straw with goat manure could produce mature composts with a pH of 7.54. Composting rice chaff with dairy manure produced good quality end product with slightly alkaline pH of 8.15 (Liu *et al*., 2011).

2.2.3.2 EC

Electrical conductivity reflects the degree of salinity in composts and is an indicator for phytotoxic risks (Lin, 2008). Co-composting of straw and poultry manure in the ratio 8:1 on volume basis recorded an EC value of 1.8 dSm^{-1} (Kumar *et al*., 2009). According to Hou *et al.* (2017) compost prepared by mixing rice straw and goat manure resulted in an EC value of 1.54 dSm^{-1}.

2.2.3.3 C:N ratio

C:N ratio is an important parameter that can affect the compost quality. C:N ratio must be less than 50:1 at the initiation stage (Madejon *et al*., 1998; Tuomela *et al*., 2000) for the composting process to proceed at a faster pace. As the C:N ratio of rice straw is very high, it is essential to bring down the C:N ratio by supplying an exogenous nitrogen source. Different organic manures added to composting material can have different influence on the C:N ratio of composts. The type and nutrient content of bulking agents also regulate the process of co-composting. The proportion of carbon and nitrogen (C:N) in the composting material is the factor that determines the maturation of compost. The ideal C:N ratio for composts ranges between 15:1 to 25:1. Reduction in C:N ratio is considered as a criterion of maturity of compost. Hence, maintaining the correct C:N ratio is important to obtain good quality compost (Jhorar *et al*., 2009). The lowering of C:N ratio of rice straw by the addition of animal manures proved to be a reliable composting method to generate quality compost (Cayuela *et al*., 2009).

Qian *et al.* (2014) studied rice straw compost using swine manure and diary manure. The C:N ratio decreased faster in the swine manure- rice straw composts than dairy manure-rice straw compost, especially during the first 30 days of the composting process. In both the composting methods C:N ratios almost reached <25 after 60 days of composting. Before composting, the C:N ratio of rice straw was 71.72 and the final compost had a C:N ratio of 22.24 for rice straw and dairy manure and 22.20 for rice straw and swine manure compost.

Frederick *et al.* (2004) reported that amendment of rice straw with dairy manure could reduce the initial C:N ratio of rice straw from 40 to 19. Salman *et al.* (2011) conducted an experiment on co-composting of rice straw with animal manures and green wastes in three different vessels as three different mixtures. They studied mixture 1 as rice straw and cattle manure, mixture 2 as rice straw, cattle manure and water hyacinth, mixture 3 as rice straw, cattle manure and alfalfa and found that the initial C:N ratios of respective mixtures *ie.*, 58.51, 40.96 and 49.20 declined to 16.34, 14.59 and 14.77 in the finished composts. Considerable narrowing down of C:N ratios was thus reported.

Guerra-Rodriguez *et al.* (2000) explored the possibility of co-composting of barley waste with poultry droppings and recorded a drop in total carbon content from 36.20 to 23.70 per cent, which contributed to a narrower C:N ratio of 6:1. Likewise when rice straw was co-composted with cowdung, distillery effluent and microbial consortia, the C:N ratio dropped from 49.09 to 16.25 within 90 days of composting (Kumari *et al.*, 2018). Amanullah, (2007) composted sorghum straw with poultry manure in the ratio 10:1 on (volume basis) and reported a decline in C:N ratio upto 18 in 60 days' time. Kumar *et al.* (2009) concluded from a composting trial that lower C:N ratio of 8.15 could be achieved when rice straw was amended with poultry manure. Goyal *et al.* (2010) reported that inoculation of rice straw with cattle dung lowered the C:N ratio from 41.7 to 17.0 within 90 days of composting. According to Sharma *et al.* (2014), Co-composting of poultry droppings and rice straw could bring down the C:N of straw from 32.47 to 19.03 within a composting period of 60 days.

Co-composting of rice straw, poultry manure and oilseed rape cake with 5:2:3 ratio could lower the C: N of the compost from 12.1 to 9.8 within a period of 60 days of composting. (Abdelhamid *et al.*, 2004). According to Brady and Weil (2010), a compost is considered as stable when the C:N ratio of the compost is within the recommended range of 14-20. C:N ratio is a good indicator of compost maturity. The C: N ratio decreased from 28.16 to 19.92 with co- composting of rice straw using goat manure (Kausar *et al*., 2014 and Harshita *et al.* 2016). Omar *et al.* (2016), reported that mixing rice straw with chicken manure in composting could bring down the C:N ratio of the straw from 33.8 to 15.

2.2.3.2 Nutrient status of compost

Nutrient status of compost can vary with the composting methods adopted. Rice straw co - composted using poultry manure resulted in compost having a potassium content of 4 per cent (Guerra-Rodriguez *et al*., 2003). According to Rashad *et al.* (2010), P and K nutrients increased in the final product on co-composting rice straw using buffalo manure. The compost had a P content of 1.47 per cent and K content of 1 per cent, which were much higher compared to the initial P and K content of rice straw.

Salman *et al.* (2011) reported that addition of agricultural green wastes having high content of N such as alfalfa to rice straw-cattle dung mixture could increase the total nitrogen content of compost upto 2.39 per cent. The total P content and total K content increased upto 0.36 and 3.7 per cent respectively. Similarly, addition of nitrogen rich water hyacinth to rice straw-cattle manure mixture could increase the total N content upto 2.5 per cent, total P content upto 0.4 per cent and total K upto 4.9 per cent. Thus considerable enrichment was noticed in the compost compared to composting materials.

Composting generated by mixing of rice straw with cattle dung registered 78 per cent increase in nitrogen content compared to uninoculated rice straw. The total nitrogen content varied from 1.15 per cent in rice straw alone to 2.7 per cent in rice straw amended with cattle dung after 90 days of decomposition (Kumar *et al*., 2004). 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 when rice husk was co-composted using poultry manure.

Co-composting of rice straw and dairy manure could result in compost with total nitrogen content of 1.64 per cent and total phosphorous content of 2.14 per cent, which were considerably higher compared to rice straw (0.54 % N and 0.08 % P). Similarly, rice straw and swine manure under co-composting could result in increase in total N content up to 1.63 per cent and total P content up to 2.09 per cent (Qian *et al.,* 2014).

According to Kumar *et al.*, 2009, co-composting of rice straw and poultry manure results in increased total phosphorous content 2.13 mg g^{-1} compared to natural composting (1.23 mg g^{-1}). Goyal and Sindhu (2011) reported that inoculation of rice straw with cattle dung recorded richness of N, P and K nutrients compared to uninoculated rice straw. Total N content of 2.17 per cent, total P content of 0.16 per cent and total K content of 3.5 per cent was registered for compost generated experiment.

Co-composting of fresh poultry droppings with rice straw could produce mature compost with 1.89 per cent total nitrogen, 1.83 per cent total phosphorus and 1.34 per cent total potassium (Manna *et al*., 2013). According to Sharma *et al*. (2014) supplementation of rice straw with poultry droppings in composting could produce good quality compost having N content of 1.89 per cent which was very much higher than rice straw (1.20 % N).

Co-composting of rice straw, poultry manure and rape seed cake (3:1:1) produced a nutrient rich compost having total N content of 3.68 per cent. The same raw materials mixed in 5:2:3 ratios on volume basis could produce compost with total N content of 3.75 per cent (Abdelhamid *et al.*, 2004). Omar *et al*. (2016) reported that the total N content of compost generated from rice straw and chicken manure was high as 0.90 per cent. Co-composting of rice straw and goat manure could generate compost with total N content upto 2.14 per cent, total P content upto 0.34 per cent and total K content upto 5.96 per cent respectively. Micronutrients also were rich in the end product (Sanusi *et al.,* 2018). This indicates that the finished compost contained primary as well as micronutrients.

2.3 Effect of compost on growth characters

Wang *et al*. (2004) investigated the co-composting process of dairy manure with wheat straw and sawdust, and concluded that the finished compost as nutrient source could well enhance plant growth. Roca-Perez *et al.* (2009) reported improved growth of barley when rice straw compost was used as a soil amendment. Li-li *et al*. (2013) conducted co-composting of rice straw with rabbit manure and reported that the compost was a good quality organic manure for the growth of chinese cabbage.

According to Omar *et al*. (2015) application of compost generated by co-composting rice straw with and chicken slurry could well improve the shoot and root growth of fodder maize.

Addition of composts generated by co-composting of of rice straw with poultry manure and rape seed cake could increase the dry matter yield of faba bean plants. The dry weight per plant increased from 16.70 g to 25.80 g with the application of 200g compost per pot (Abdelhameed *et al*., 2004).

2.4 Effect of compost on yield and yield attributes

D'Hose *et al*. (2015) reported that compost generated on farm using crop residues and animal manures could significantly increase the yield of fodder maize.

Barus (2012), reported significant yield advantage in rice upto 26 per cent with the application of rice straw compost. Rice straw compost added as a nutrient source for rice crop could result in considerable yield enhancement (Mahmoud *et al*., 2014). Sannathimmappa *et al*. (2015) reported yield advantage in rice upto 100 per cent with the application of rice straw compost. Rice straw compost applied along with 50 per cent of the recommended dose of fertilizers could record yield increase of 23 per cent in pearl millet (Meena *et al.,* 2016).

2.5 Effect of compost on quality parameters of crops

Naikwade (2014) reported that the crude protein content of fodder maize increased with compost application compared to nutrition using chemical fertilizers alone. Abdelhamid *et al.* (2004) reported that application of compost generated by co-composting rice straw with poultry manure and rape seed cake could enhance the crude protein content of faba bean compared to application of chemical fertilizers. Protein content of french bean was significantly improved with the application of rice straw compost compared to the application of chemical fertilizers (Ansari and Jaikishun, 2011).

2.6 Effect of compost on physiological parameters

According to Shigeru *et al.* (2003) continuous application of rice straw compost promote the growth rate of both maize and rice plants under flooded and upland conditions. Sarangi *et al.* (2010) reported that application of compost generated from rice straw could well improve the leaf area index of rapeseed. Sarangi and Lama, (2013) reported that compost generated from rice straw could significantly improve the growth rate of rice and groundnut in rice- groundnut cropping system.

2.7 Effect of compost on soil properties

The principle requirement for a compost to be safely used in soil is its degree of stability or maturity, which implies stable organic matter content and the absence of phytotoxic compounds. Immature compost when applied to soils, may retard plant growth due to nitrogen starvation and production of some organic acids (Mathur *et al.*, 1993). According to Gaind and Nain (2010), recycling of crop biomass to generate compost is a good alternative to restore the productivity of soil. Dahshan *et al.* (2013) reported the addition of a bulking agent rice straw to cattle manure, produced compost with high in organic matter, total nitrogen, and C:N ratio suitable for use as soil amendment.

Rice 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 per cent to 0.65 per cent (Gaind and Nain, 2010). According to Lekshmi, (2011) soil physical, chemical and biological properties were favorably influenced by the addition of compost prepared from rice straw wastes. The pH of the compost increased from 5.47 to 5.87 by the application rice straw wastes (D'Hose *et al.*, 2015). Wantanabe *et al.* (2017) observed significant increase in the carbon content of soil with the application of rice straw compost along with moderate doses of chemical fertilizers, suggesting the positive influence of rice straw compost in INM schedule.

According to Samra *et al.* (2003), rice straw is one of the most abundant lignocellulosic waste material generated in fields. Hence recycling rice straw to soils is of great concern in improving the soil properties especially soil organic matter. Integrated use of rice straw compost with inorganic fertilizers could result in improved structure of soil, better aeration, water-holding capacity, increased fertility and less acidity of soils (Battacharyya *et al.*, 2012). Ng *et al.* (2016) reported that application of microbially enriched rice straw compost significantly improved the soil microbial activity.

Gaind *et al*. (2006) conducted an experiment on composting of wheat straw and the compost had the potential to supply plant nutrients in adequate quantities. Application of this compost to soil could improve the organic carbon, available P as well as enzymatic activity of the soil. The compost generated by co-composting plant residues and animal manures greatly influenced the biochemical and structural properties of soil (Mondini *et al*., 2010). Natsheh and Mousa (2014) found that compost application is the best management practice for increasing the soil fertility. Compost application is a promising measure for enhancing soil fertility (Scotti *et al.* 2015; Solomon and Jafer, 2015).

Incorporated mature composts also become part of the soil humus and employ their influence on long-term basis. Such inclusions of soil amendments are particularly important where the soils are poor enough in terms of organic matter content (Tiquia and Tam, 2002). Addition of organic amendments such as composts significantly influenced reducing exchangeable acidity, exchangeable Al and exchangeable Fe that altered soil chemical properties in a way to enhance the availability of phosphorus (Schulz *et al*., 2014; Ch'ng *et al*., 2014).

2.8 Effect of compost on nutrient uptake

Shigeru *et al*. (2003) reported an increased N uptake by maize and rice crop with the continuous application of rice straw compost. The N derived from rice straw contributed to higher uptake of nitrogen for maize and rice in both upland and flooded conditions. Velthof *et al*. (2003) supported this, they opinioned that the application of organic amendments to soil could stimulate N uptake by plants.

Nishanth and Biswas (2008) recorded a significant increase in the uptake of P and K while studying the effect of compost application on growth and yield of wheat. Maize plants when nourished with combined use of rice straw compost and inorganic fertilizers were found to increase the soil available N, available P and exchangeable K, contributed to higher uptake of nutrients (Yuan *et al.,* 2019). They also observed higher N, P and K content in leaf, stem and root of maize plant under rice straw compost application.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Rice based cropping system generate large amount of crop residue mainly straw. Considering this, a study entitled “Crop residue recycling for organic production of fodder maize in a rice based integrated farming system” was taken up. The major objectives were to generate nutrient rich manures from rice straw through co-composting and to evaluate their efficacy in influencing the growth, yield, quality and economics of fodder maize. The research work was conducted at IFSRS, Karamana during the period of July 2019 to May 2020. The work was carried out as two experiments. In the first experiment rice straw was co-composted by using different organic manures as nitrogen sources. The compost generated from experiment I was used as nitrogen equivalent component in experiment II. The materials used and the methodology adopted for the studies are discussed in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Experiment I – Co-composting of rice straw using different organic manures as nitrogen sources.

3.1.1.1 Location

The experiment was undertaken at the Integrated Farming System Research Station (IFSRS), Karamana, utilising the existing facilities of composting yard.

3.1.1.2 Time of experiment

The composting process was initiated during July 2019 and was completed by November 2019.

3.1.2 Experiment II - Evaluation of composts for organic production of fodder maize

3.1.2.1 Location

The experiment was conducted at IFSRS, Karamana, Thiruvananthapuram, Kerala, located at 8^0 28’ 28” N latitude and 76^0 57’47” E longitude, at an altitude of 5 m above mean sea level.

3.1.2.2 Climate and season

The field experiment with fodder maize as test crop was carried out during summer, 2020. Data on various weather parameters such as mean temperature, relative humidity and rainfall during the cropping period were collected from class B Agrometeorology Observatory maintained at IFSRS, Karamana and are given in Appendix I and illustrated in Fig.1.

3.1.2.3. Soil

Sample was collected before the commencement of present study. The samples were analysed for its mechanical composition and chemical properties. The soil properties were rated as per the Package of Practices of the KAU.

The soil in the site of experiment was sandy clay loam in texture, moderately acidic with normal electrical conductivity, high in organic carbon and available P, low in available N and medium in available K (Table 1).

3.2 MATERIALS

3.2.1 Experiment I – Co-composting of rice straw using different organic manures as nitrogen sources.

3.2.1.1 Composting materials

Partially shredded rice straw of variety Uma obtained from rice harvest at IFSRS, Karamana and stored for one month was used for compost preparation.

3.2.2 Experiment II - Evaluation of composts for organic production of fodder maize

2.2.1 Crop and variety

Fodder maize variety African tall was the test crop. This is reported to have herbage yield upto 40 t ha^{-1} and is suitable to Kerala conditions.

3.2.2.2 Source of seed

Seeds of fodder maize variety African tall were collected from certified supplier of fodder seeds of Kanyakumari district, Tamil Nadu.

Table 1. Chemical properties of soil before experiment

Parameter	Content	Rating
pH	5.9	Moderately acidic
Electrical conductivity (dS m^{-1})	0.24	Normal
Organic carbon (%)	1.70	High
Available nitrogen (kg ha^{-1})	259.24	Low
Available phosphorus (kg ha^{-1})	32.26	High
Available potassium (kg ha^{-1})	125.15	Medium

3.2.2.3 Manures and fertilizers

Dried and well rotten FYM (1.52 % N, 0.72 % P and 0.40 % K) was applied @ 10 t ha-1as basal uniformly to all the treatments. For the control treatment T8, an integrated nutrient management was followed by supplying N, P and K nutrients through urea (46 % N), rock phosphate (18 % P_2O_5) and muriate of potash (60 % K_2O). For treatments 1 to 7, respective composts prepared using rice straw and different organic manures were applied as nitrogen equivalent basis to substitute the recommended dose required.

3.3 METHODS

3.3.1 Experiment I – Co-composting of rice straw using different organic manures as nitrogen sources.

3.3.1.1 Design and Layout

Design : CRD

Treatments : 8

Replications : 3

Period of study: July 2019 - November 2019

3.3.1.2 Treatments

Co - composting

T_1 - Rice straw + cow dung (4:1)

T_2 - Rice straw + goat manure (4:1)

T_3 - Rice straw + poultry manure (4:1)

T_4 - Rice straw + cow dung + goat manure (4:1:1)

T_5 - Rice straw + cow dung + poultry manure (4:1:1)

T_6 - Rice straw + goat manure + poultry manure (4:1:1)

T_7 - Rice straw + cow dung + glyricidia leaves (4:1:1)

T_8 - Natural composting (Rice straw alone as control)

Rice straw was collected, sprinkled with water and stalked overnight. Further, it was mixed with different organic manures in 4:1 or 4:1:1 ratios on volume basis and was filled in concrete pits of size 1 m^3 as per the treatments described above. Sufficient moisture levels were maintained in the composting material by periodic sprinkling of water for 15 weeks. The materials were turned twice 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 Vigneswaran *et al*. (2016). Sampling to ensure maturity of compost was initiated at 10 weeks of start of composting. Mature composts were sieved, shade dried and stored as per the treatments for field evaluation.

3.3.2 Experiment II - Evaluation of composts for organic production of fodder maize

3.3.2.1 Design and layout

Design : RBD

Treatments : 8

Replications : 3

Plot size : 3m x 3m

3.3.2.2 Treatments

T_1- T_7 : Crop nutrition using composts 1 to 7 respectively

T_8 : Soil test data based application of chemical fertilizers as per KAU Recommendation (120 : 60 : 40 kg ha^{-1})

* FYM @ 10 t ha^{-1} was applied as basal organic dose uniformly for all the treatments. For treatments 1 to 7, respective composts were applied on N equivalent basis to substitute inorganic N requirement. This was sufficient to meet the P and K requirements as well.

3.3.2.3 Crop production

3.3.2.3.1. Land preparation

The land was ploughed twice and beds and channels were formed. Then the land was levelled and the plots were laid out according to the layout plan.

3.3.2.3.2. Seeds and sowing

Healthy seeds of African tall were dibbled at 5-6 cm depth with 2 seeds per hole at a spacing of 30 cm between rows and 15 cm between plants as per KAU POP recommendation. Sowing done on 01-03-2020.

3.3.2.3.3 Application of manures and fertilizers

The basal dose of organic manure was supplied through FYM @ 10 t ha^{-1} at the time of last ploughing. Based on soil test data the nutrient dose was finalised as 85: 15: 38 kg ha^{-1}. 71 per cent of the recommended dose of N (120 kg ha^{-1}), 25 per cent of recommended dose of P (60 kg ha^{-1}) and 94 per cent of recommended dose of K (40 kg ha^{-1}) were provided through chemical fertilizers in T_8. In treatments T_1- T_7, respective composts generated from experiment I were supplied on nitrogen equivalent basis. This quantity was sufficient to meet the P and K requirement also. Top dressing was done 30 DAS and 45 DAS.

3.3.2.3.4 Gap filling and thinning

Gap filling was done at 8 days after sowing to maintain optimum plant population. Thinning was done at 12-15 DAS.

3.3.2.3.5 Weed management

Hand hoeing and weeding were done on the 21st and 45th DAS.

3.3.2.3.6. Irrigation schedule

Irrigation was provided immediately after sowing and on 3rd day. Further irrigation was limited to once in every 5 days.

3.3.2.3.7 Harvest

Harvesting was done at 70 DAS at lush green stage of crop.

Fig.1 Weather data during cropping period (March to May, 2020)

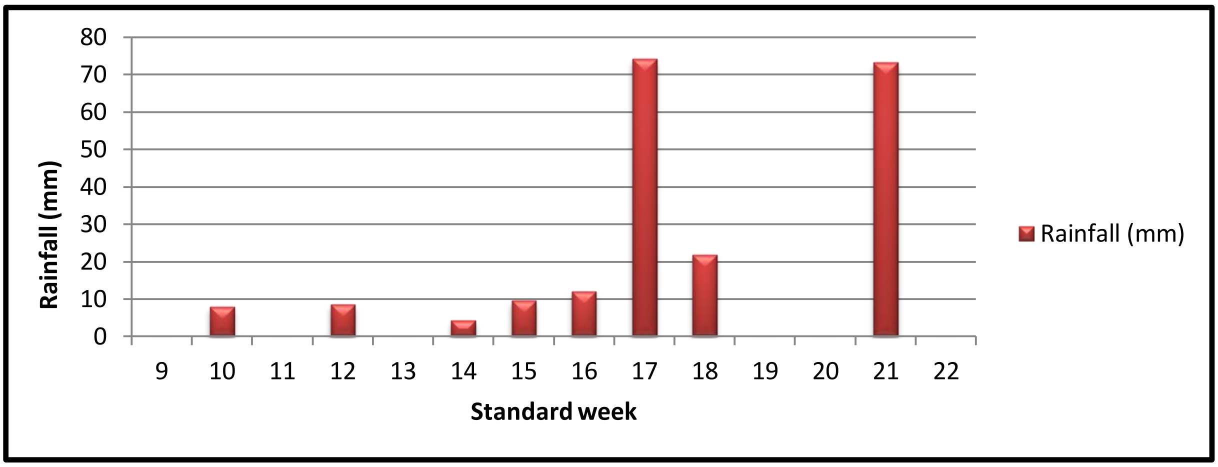

Fig.1.1 Rainfall during the cropping period (March to May, 2020)

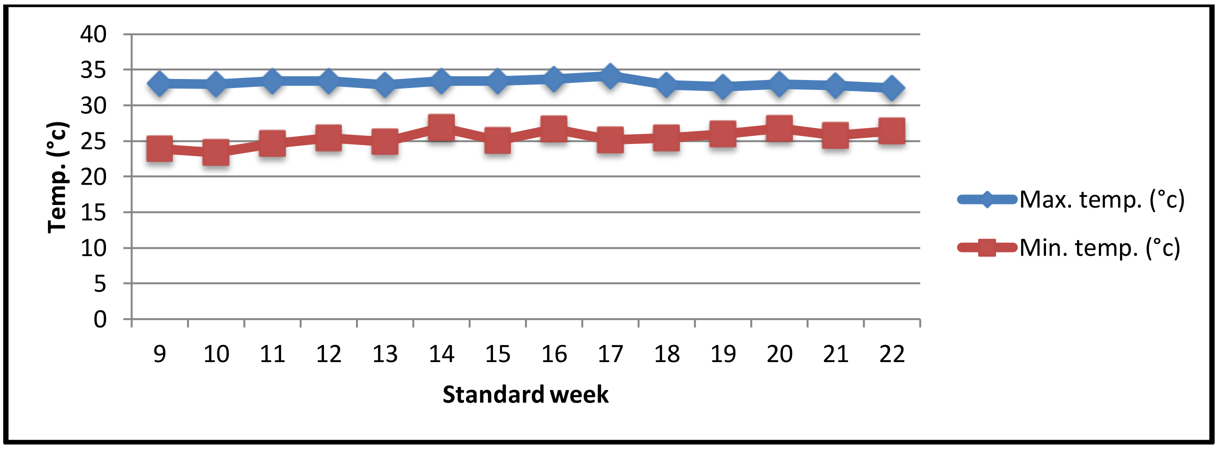

Fig.1.2 Temperature during the cropping period (March to May, 2020)

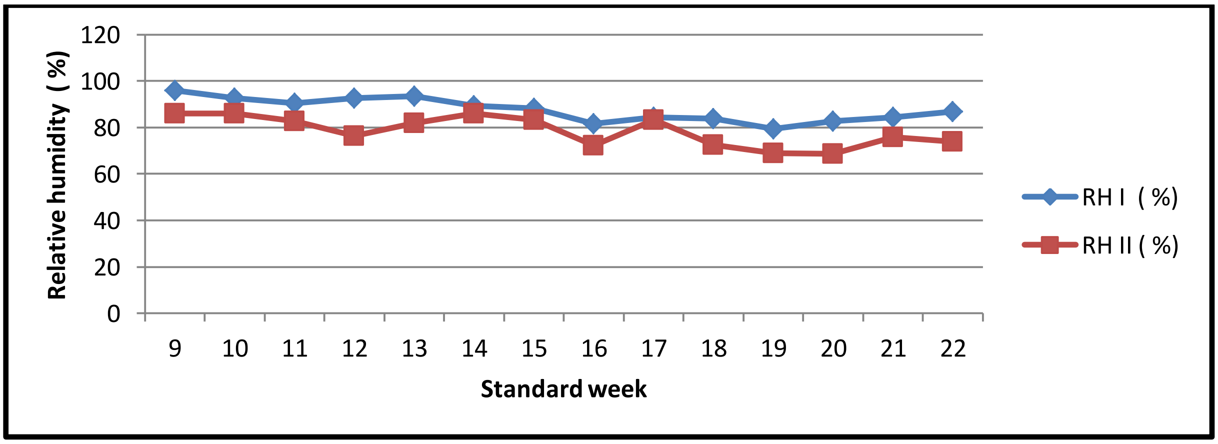

Fig.1.3 Relative humidity during the cropping period (March to May, 2020

R_1	R_2	R_3
T_1	T_4	T_2
T_2	T_6	T_1
T_3	T_8	T_5
T_4	T_7	T_4
T_5	T_2	T_6
T_6	T_2	T_7
T_7	T_1	T_8
T_8	T_5	T_3

Fig. 2 Lay out of the field

3.4 OBSERVATIONS

3.4.1 Experiment I - Co-composting of rice straw using different organic manures as nitrogen sources.

3.4.1.1 Composition of rice straw

Samples of rice 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 rice straw used for the study are listed in Table 2.

3.4.1.2 Nutrient content of organic manures

The content of N, P and K in cow dung, poultry manure, goat manure and glyricidia leaves were determined by the standard procedures as mentioned in Table 2. and presented in Table 4.

Table 2. Analytical methods followed for analysis of rice 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)

Table 3. Composition of rice straw before composting

Parameters	Content
Lignin (%)	19
Cellulose (%)	30
Major nutrients (%)	
N	0.22
P	0.15
K	1.38
Micronutrients (mg kg^{-1})	
Fe	262.75
Cu	27.05
Mn	637.5
Zn	31.05
B	4.24
C: N ratio	39:1

Table 4. Nutrient contents of organic manures

Manure	Nutrient content (%)		
	N	P	K
Cow dung	1.45	0.35	0.34
Poultry manure	2.57	0.24	0.95
Goat manure	3.75	0.34	1.22
Glyricidia leaves	2.80	0.12	1.18

3.4.1.4 Time taken for composting

Maturity of composts was determined based on visual observation and confirmed upon C:N ratio. The time taken for composting was recorded in days. The composts were visually observed to mark the end of compost. A powdery appearance of the material was observed as an indicator for well decomposition. Such visual observation were made from 10 weeks of initial of composting. Further such samples were tested for C:N ratios and those ones falling within the range of 20:1 were rated as mature composts.

3.4.1.5 Recovery of compost

The quantity of compost generated from each treatment was recorded at maturity on fresh weight basis and the recovery in percentage was worked out. At the time of filling of composting pits, the individual weights of each of the composting material were noted and the total quantity of composting material used in each of the treatments were recorded. Once the composting process was over the weight of compost generated from each of these treatments were recorded and the recovery percentage was worked out based on the following formula.

$$\text{Recovery} = \frac{\text{Weight of the compost}}{\text{Total weight of the composting material}} \times 100$$

3.4.1.6 Chemical properties of compost

3.4.1.6.1 pH

Samples obtained from each treatment on maturity were mixed with water in the ratio 1:5 and pH was measured using pH meter with glass electrode (Jackson, 1973).

3.4.1.6.2 Electrical conductivity

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

3.4.1.6.3 C: N ratio

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

3.4.1.6.4 Nutrient content

Composts were analysed for major (N, P and K) and micronutrients (Fe, Cu, Mn, Zn and B) as per the procedures outlined in Table 2.

Plate 1. General view of experimental area

3.4.2 Experiment II - Evaluation of composts for organic production of fodder maize

3.4.2.1 Growth characters

3.4.2.1.1 Plant height

Five plants were selected randomly from net plot area and labelled. Their heights were measured from the base of the plant to the tip of the fully opened youngest leaf at 20, 40 DAS and up to tassel at harvest and was expressed in cm.

3.4.2.1.2 Number of leaves plant^{-1}

Five plants were selected randomly and labelled in each treatment and their fully opened leaves were counted at 20, 40 DAS and at harvest. Leaves plant^{-1} were worked out as average values.

3.4.2.1.3 Leaf area index

Five plants were collected from each replication by leaving the extreme border row were used to calculate LAI at 20, 40 DAS and at harvest. The following formula prescribed by Lenvill *et al*. (1978) was followed in calculating LAI.

Leaf area = L × W × N × K

Where,

L = Length of the leaf (cm)

W = Maximum width of leaf (cm)

N = Number of leaves plant^{-1}

K = Constant factor – (0.75 for maize)

The LAI was calculated by using the following formula as suggested by Watson (1947).

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area (m}^2\text{)}}{\text{Land area (m}^2\text{)}}$$

3.4.2.1.4 Dry matter production

The five plants used for estimating leaf area index were separately sun dried and later oven dried at 65°C, till constant weight was obtained and their final dry weight was recorded at 20 and 40 DAS and at harvest and expressed as kg ha^{-1}.

3.4.2.2 Yield

3.4.2.2.1 Green fodder Yield

The plants were cut at a height of 5 cm from the base and the green fodder from each treatment was recorded as kg per plot. Further, per hectare yields were also computed from this data.

3.4.2.3 Quality parameters

3.4.2.3.1 Crude protein content

The nitrogen content of the plant sample was estimated by modified microkjeldhal method and expressed in percentage. The crude protein content of forage was worked out by multiplying the nitrogen percentage with a factor 6.25. (Simpson *et al*., 1965)

3.4.2.4 Physiological parameters

3.4.2.4.1 Crop growth rate (At 20 and 40 DAS and at final harvest)

Five sample plants uprooted randomly from net plot area of each treatment plots were and were oven dried at 75°C for 72 hours until attainment of constant weight. The individual dry weights of these samples were recorded and average dry weight of a plant was arrived. This data was used to work out the average dry weight from one square metre area attained and then the dry weight per metre square were recorded. CGR (g m $^{-2}$ day^{-1}) was calculated by the formula given by Hunt (1989).

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{\text{Ga}}$$

W_1 = Dry weight of plants (g) grown in one square metre at a given point of time t_1 (days)

W_2 = Dry weight of plants (g) grown in one square metre at a given point of time t_2 (days)

Ga = Ground area (1 square metre)

3.4.2.4.2 Relative growth rate (At 20 and 40 DAS and at final harvest)

Relative growth rate (g g^{-1} day^{-1}) was calculated by the formula given by Hunt (1989).

$$RGR = \frac{\ln w_2 - \ln w_1}{t_2 - t_1}$$

$\ln W_1$ = Natural logarithm of dry weight of plant m^{-2} recorded at time t_1 (days)

$\ln W_2$ = Natural logarithm of dry weight of plant m^{-2} recorded at time t_2 (days)

3.4.2.4.3 SCMR (**SPAD chlorophyll meter reading**) (60 DAS)

SPAD stands for Soil Plant Analysis Development. “Chlorophyll meter SPAD 502 plus” manufactured by Spectrum Technologies, USA (Model 2900P) was used for recording the readings. SCMR reading is an indication of chlorophyll content present in the fresh leaves. From each observational plant, three leaves were selected and readings were noted from three different points of each leaf. The average values were worked out for observational plants and thereafter for each treatment.

3.4.2.5 Analysis of soil (Chemical properties of soil)

Soil samples were drawn from each plot of different treatment and analysed for the following properties before and after the experiment.

3.4.2.5.1 pH

Soil samples were mixed with water in 1:2.5 ratio and pH was measured by using pH meter with glass electrode (Jackson , 1973).

Plate 2.1. Land preparation

Plate 2.2. FYM application

Plate 2.3. Sowing

Plate 2.4.Crop stand at 20 DAS

Plate 2.5.Crop stand at 40 DAS

Plate 2.6.Crop stand at 60 DAS

Plate 2. Different stages of fodder maize cultivation

3.4.2.5.2 Organic carbon

Organic carbon was determined by Chromic acid wet digestion method (Walkley and Black, 1934).

3.4.2.5.3 Available N

Available nitrogen was determined by Alkaline potassium permanganate method (Subbiah and Asija, 1956) and recorded in kg ha^{-1}.

3.4.2.5.4 Available P

Available phosphorus was determined by Bray No.1 extraction and spectrophotometry method (Jackson, 1973) and expressed in kg ha^{-1}.

3.4.2.5.5 Available K

Available potassium was determined by Neutral normal ammonium acetate extraction and flame photometry method (Jackson, 1973) and expressed in kg ha^{-1}.

3.4.2.6 Content and uptake of major nutrients

Plant samples were separately chopped, oven dried at 75°C for 72 hours until attainment constant weight oven dried and were analysed for N, P and K contents at final harvest as per the procedures described in Table 2. Uptake of N, P and K were calculated as the product of N, P and K content of plant samples (expressed in percentage) and their respective dry weights.

3.4.2.6.1 Uptake of nitrogen

Nitrogen content in plant samples was estimated using modified microkjeldhal method (Jackson, 1973) and the uptake of nitrogen was calculated by multiplying the nitrogen content of plants sample with dry weight of plant. Uptake values were expressed in kg ha^{-1}.

3.4.2.6.2 Uptake of phosphorus

Phosphorus content in plant samples was calorimetrically determined by wet digestion of the sample and developing colour using ascorbic acid method and read in spectrophotometer (Bray and Kurtz 1945). Uptake of phosphorus was calculated by multiplying the phosphorus content of plant sample with the dry weight of plant. Uptake values were expressed in kg ha^{-1}.

3.4.2.6.3 Uptake of potassium

Potassium content of plant samples was determined by flame photometer method and the uptake of potassium was calculated by multiplying the potassium content of plant sample with the dry weight of plant. Uptake values were expressed in kg ha^{-1}.

3.4.2.7 Economic analysis

Economics of cultivation was worked out by taking into account the cost of inputs, labour and the prevailing market price of fodder maize 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 Rs. ha^{-1}.

Net returns (Rs) = Gross returns (Rs) - Total cost of cultivation (Rs)

3.4.2.7.2 Benefit - Cost Ratio

Benefit: Cost Ratio was calculated as follows.

$$\text{BCR} \quad \frac{\text{Gross returns (Rs)}}{\text{Total cost of cultivation (Rs)}}$$

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 “Crop residue recycling for organic production of fodder maize in rice based integrated farming system.” conducted at Integrated Farming System Research Station, Karamana during July 2019 to May 2020 are presented in this chapter.

4.1 EXPERIMENT I - CO COMPOSTING OF RICE STRAW USING DIFFERENT ORGANIC MANURES AS NITROGEN SOURCES.

4.1.1 Time taken for composting

Various treatments of the study in influencing the time taken for compost production is presented in Table 5. It could be learnt from the data that different treatments had a significant influence on the time taken for production of mature compost. Rice straw co- composted with goat manure and poultry manure in the ratio of 4:1:1 (T_6) was superior among all the treatments in generating mature compost in the most speedy manner (74.33 days). This was followed by treatments T_4 (80.00 days) and T_5 (85.00 days) registering comparable time for compost maturation. Natural composting of rice straw (T_8) took the longest time (128.33 days) for composting.

4.1.2 Recovery of compost

Data pertaining to the recovery of different composts produced in this experiment are presented in Table 5. Different organic manures added in varying amounts as nitrogen sources for co-composting could significantly influence the recovery of compost. All the co-composting treatments could record higher recovery compared to natural composting of rice straw. The recovery of rice straw composts from different treatments under this study ranged from 23.87 to 55.33 percentage. Co-composting of rice straw with organic manures poultry manure and goat manure in the ratio 4:1:1 (T_6) on volume basis recorded significantly higher recovery of 55.33 per cent and was comparable to that from T_5 (52.4%) wherein co-composting of rice straw was carried out using poultry manure and cowdung in the ratio 4:1:1.

Table 5. Effect of different composting methods on time taken for composting (days) and per centage recovery of compost (%)

Treatments	Time taken for composting	Recovery of compost
T_1 - Rice straw + cow dung (4:1)	110.00	35.5
T_2 - Rice straw + goat manure (4:1)	91.33	40.16
T_3 - Rice straw + poultry manure (4:1)	97.67	45.27
T_4 - Rice straw + cow dung + goat manure (4:1:1)	80.00	48.03
T_5 - Rice straw + cow dung + poultry manure (4:1:1)	85.00	52.4
T_6 - Rice straw + goat manure + poultry manure (4:1:1)	74.33	55.33
T_7 - Rice straw + cow dung + glyricidia leaves (4:1:1)	87.67	45.37
T_8 - Natural composting (Rice straw alone as control)	128.33	23.87
SE m (±)	1.86	1.034
CD (0.05)	5.612	3.128

These were followed by treatments T_3, T_7 and T_2 registering comparable recoveries of 48.03 per cent, 45.37 per cent and 45.27 per cent respectively. Among co-composting treatments, T_1 (Rice straw + cow dung in 4:1 ratio) recorded the lowest recovery of 35.5 per cent.

Under natural composting of rice straw, (T_8), recovery of compost was the least; significantly lower than all the co-composting treatments (23.87%).

4.1.3. Major chemical properties of rice straw compost

Major chemical properties *viz.*, pH, EC and C: N ratio of rice straw composts were studied and details are presented in Table 6.

4.1.3.1 pH

Different co-composting methods were found to have no significant influence on the pH of rice straw composts. All the composts generated had a slightly alkaline pH ranging from 7.78 to 8.16.

4.1.3.2 Electrical conductivity

No significant influence of different co-composting methods was recorded with regard to EC of composts. The EC values ranged from 0.63 to 0.90 dS m^{-1}.

4.1.3.3. C:N ratio

C:N ratio of rice straw used for composting was 39:1. This was considerably narrowed down in the end product by way of co-composting using different N rich organic manures, thus making them useful as organic manures. Different treatments had significant influence on the C:N ratios of mature composts. Rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 on volume basis (T_6) registered a significantly lower C:N ratio of 10.23 after 74 days and was comparable to treatments T_4 (10.67) and T_5 (10.69). Under natural composting (T_8), a wider C:N ratio of 19.50 was recorded.

Table 6. Major chemical properties of composts as influenced by different composting methods

Treatments	pH	EC (dS m^{-1})	C: N ratio
T_1	8.08	0.80	12.90
T_2	8.16	0.80	11.43
T_3	7.83	0.77	11.69
T_4	8.03	0.67	10.67
T_5	7.78	0.73	10.69
T_6	7.78	0.63	10.23
T_7	7.98	0.67	11.16
T_8	8.04	0.90	19.50
SE m (±)	0.15	0.06	0.27
CD (0.05)	NS	NS	0.79

However, all the composts generated in the study had C: N ratios within the acceptable limit of 20:1.

4.1.4 Nutrient status of rice straw compost

Data pertaining to the content of major nutrients N, P and K of different rice straw composts produced through co-composting in the present study are presented in Table 7.

4.1.4.1 Major nutrients

Co-composting methods using, different organic manures as nitrogen source could significantly influence the total N, P and K content of rice straw composts. Rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 on volume basis (T_6) had the maximum content of major nutrients and showed in Table 7. This treatment recorded the highest N content of 3.30 per cent and was statistically on par with treatments T_4 (3.04 %) and T_5 (2.99 %). Treatment T_8 *i.e.* rice straw compost generated through natural composting recorded the significantly lowest N content of 1.2 per cent.

As noticed with nitrogen, T_6 itself recorded the highest P content (0.98 %) and was comparable to T_5 (0.93 %) and T_4 (0.88 %). Composting of rice straw without any addition of organic manures (T_8) recorded the significantly lowest P content of 0.35 per cent.

Significantly higher potassium content of 3.22 per cent was recorded with treatment T_6 and it was comparable to T_7 (3.00 %) *i.e.*, co-composting of rice straw with cowdung and glyricidia leaves. As noticed with N and P nutrients, significantly lowest K content also was recorded under natural composting of straw (T_8).

4.1.4.2 Micronutrients

Statistical analysis of the data generated on the content of micronutrients in different composts revealed that co-composting methods had a significant influence on the content of Fe, Cu, Mn, Zn and B micronutrients.

Treatment T_6 (rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 on volume basis) had a distinct advantage with regard to micronutrient content.T_6 recorded significantly higher Fe content of 3201.66 mg kg^{-1}, however comparable to treatments T_5 (3187.00 mg kg^{-1}) and T_4 (3031.83 mg kg^{-1}). T_6 could also record the highest content of Cu (45.58 mg kg^{-1}), superior to all other treatments. Content of Mn also was significantly higher for T_6 (1096.17 mg kg^{-1}), but on a par with treatment T_5 (1053.75 mg kg^{-1}). With respect to Zn, T_6 registered higher content (280.40 mg kg^{-1}) comparable to treatments T_4 (244.85 mg kg^{-1}), T_5 (244.67 mg kg^{-1}) and T_7 (211.85 mg kg^{-1}). T_6 could also record significantly superior B content of 19.97 mg kg^{-1}. It could thus be generalized that T_6 performed better with regard to content of all the micronutrients, comparable or closely followed by treatments T_5 and T_4 mostly. T_8 (natural composting of rice straw) had lower content of micronutrients and was comparable to T_1 and T_2 mostly. Fe content was much low with T_8 (807.16 mg kg^{-1}) and was on par with T_1 (1239.83 mg kg^{-1}) and T_2 (1299.50 mg kg^{-1}). Similarly, Cu content was lower for T_8 (12.65 mg kg^{-1}) comparable to T_1 (18.17 mg kg^{-1}) and T_2 (19.62 mg kg^{-1}).T_8 also registered lower Mn content (413.75 mg kg^{-1}), comparable to T_1 (447.08 mg kg^{-1}). Significantly lowest Zn (43.10 mg kg^{-1}) and B (12.97 mg kg^{-1}) contents were also noticed with $T_{8.}$

Table 7. Nutrient status of composts prepared under different treatments

Treatments	Major nutrients (%)			Micronutrients (mg kg^{-1})				
	N	P	K	Fe	Cu	Mn	Zn	B
T_1	2.59	0.55	2.39	1239.83	18.17	447.08	148.47	14.10
T_2	2.88	0.73	2.60	1299.50	19.62	645.73	161.50	16.83
T_3	2.78	0.79	2.45	1875.17	22.52	834.17	177.40	17.63
T_4	3.04	0.89	2.94	3031.83	31.90	908.75	244.85	17.93
T_5	2.99	0.93	2.86	3187.00	35.25	1053.75	244.67	18.77
T_6	3.30	0.98	3.22	3201.66	45.58	1096.17	280.40	19.97
T_7	2.93	0.82	3.00	1788.33	24.48	900.00	211.85	17.53
T_8	1.2	0.35	1.95	807.16	12.65	413.75	43.10	12.97
SE m (±)	0.08	0.03	0.05	257.58	2.79	58.59	23.54	0.30
CD (0.05)	0.230	0.090	0.160	778.873	8.452	177.160	71.190	0.904

T_1 - Rice straw + cow dung (4:1)
T_2 - Rice straw + goat manure (4:1)
T_3 - Rice straw + poultry manure (4:1)
T_4 - Rice straw + cow dung + goat manure (4:1:1)
T_5 - Rice straw + cow dung + poultry manure (4:1:1)
T_6 - Rice straw + goat manure + poultry manure (4:1:1)
T_7 - Rice straw + cow dung + glyricidia leaves (4:1:1)
T_8 - Natural composting (Rice straw alone as control)

4.2 EXPERIMENT II - EVALUATION OF COMPOSTS FOR ORGANIC PRODUCTION OF FODDER MAIZE

4.2.1 Growth characters

Composts prepared using rice straw and different organic manures were evaluated in field for organic production of fodder maize and the growth characters in terms of plant height, number of leaves and dry matter production were assessed, the details of which are as follows.

4.2.1.1 Plant height

Plant height recorded at different stages of crop growth (20, 40 DAS and at final harvest) is presented in Table 8. Significant influence of different treatments on plant height was noticed at 40 DAS and at final harvest. T_8 (soil test data based application of chemical fertilizers given in addition to basal FYM) could result in taller plants in both these stages and was comparable to treatments T_6 (Basal FYM + compost prepared by co - composting rice straw with goat manure and poultry manure in the ratio 4:1:1, supplied on N equivalent basis), T_4 and $T_{5.}$

At 40 DAS, T_8 recorded a higher plant height of 119.34 cm whereas $T_{6,}$ T_4 and T_5 recorded comparable plant heights of 115.15 cm, 113.30 cm and 113.05 cm respectively. Plant height was found lower and comparable for T_7 (105.94 cm), T_2 (100.94 cm) T_3 (98.81 cm) and T_1 (94.57 cm). At harvest stage, T_8 recorded higher plant height (180.87cm) and was comparable to treatments T_6 (176.74 cm), T_4 (174.81 cm), T_5 (172.15 cm). This was closely followed by T_7 (168.21 cm). Plant height was comparable and lower for treatments T_2 (165.81 cm) and T_3 (158.04 cm) at this stage. Significantly lowest plant height was recorded under T_1 (145.95 cm).

4.2.1.2 Number of leaves per plant

Data generated on the number of leaves per plant at different growth stages are presented in Table 9. Significant influence of different treatments on the number of leaves was noticed at 40 DAS and at final harvest. Soil test data based application

Table 8. Influence of different treatments on plant height of fodder maize at various growth stages (cm)

Treatments	Plant height		
	20 DAS	40 DAS	At harvest
T_1	53.93	94.57	145.95
T_2	53.25	100.94	165.81
T_3	55.94	98.81	158.04
T_4	59.37	113.30	176.74
T_5	57.95	113.05	172.15
T_6	59.62	115.15	174.81
T_7	56.41	105.94	168.21
T_8	59.65	118.34	180.87
SE m (±)	0.24	1.84	4.18
CD (0.05)	0.700	5.380	12.240

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based integrated nutrient management as per KAU recommendation

of chemical fertilizers given in addition to basal FYM (T_8) could record more number of leaves in both these stages and was comparable to treatments T_6 ,T_4 and $T_{5.}$

At 40 DAS, T_8 could record a leaf count of 9.33 and treatments $T_{6,}$ T_4 and T_5 recorded comparable leaf counts of 9.22, 9.11 and 9.00 respectively. Leaf count was found lower for T_7 and T_2 (8.11), T_3 (7.78) and T_1 (7.67).

At harvest stage, T_8 recorded more number of leaves (12.67) and was comparable with treatments T_6 (12.56), T_4 (12.45), T_5 (12.22). Leaf number was significantly lower for treatments $T_{7,}$ T_2, T_3 and T_1 at this stage. T_1 could record a leaf count of 10.78 only at harvest stage.

4.2.1.3 Total dry matter production

The dry matter production of fodder maize increased progressively from 20 DAS to harvest (Table 10). The effect of treatments and plants response was statistically traceable at two stages *i.e.*, 40 DAS and at harvest. At 40 DAS, T_8 (Basal dose of FYM followed by soil test data based application of chemical fertilizers) recorded higher dry matter accumulation (5393 kg ha^{-1}) and was comparable to T_6 (5243 kg ha^{-1}). This was followed by treatments T_4 (5133 kg ha^{-1}) and T_5 (5001 kg ha^{-1}). Dry matter production was lower and comparable with treatments T_1 and T_2 which recorded respective values of 4196 and 4370 kg ha^{-1}.

At harvest also, T_8 (13580 kg ha^{-1}) and T_6 (13309 kg ha^{-1}) recorded higher and comparable DMP, similar to that at 40 DAS. This was again followed by the comparable performance of T_4 and T_5.

Treatment T_1 (co-composting of rice straw with cowdung in the ratio 4:1) had lower drymatter content in all growth stages. At 40 DAS, T_1 recorded drymatter content of 4196 kg ha^{-1} comparable to T_3 (4230 kg ha^{-1}) and T_2 (4370 kg ha^{-1}). Similarly, at harvest drymatter content was 9988 kg ha^{-1}for $T_{1,}$ which was on par with T_3 (100345 kg ha^{-1}) and T_2 (10116 kg ha^{-1}) respectively. Similar to 40 DAS, T_1 and T_3 recorded lower and comparable values for DMP at harvest stage.

Table 9. Influence of different treatments on number of leaves per plant of fodder maize at various growth stages

Treatments	No. of leaves per plant		
	20 DAS	40 DAS	At harvest
T_1	5.44	7.67	10.78
T_2	6.33	8.11	11.11
T_3	5.66	7.78	11.00
T_4	5.99	9.11	12.45
T_5	5.66	9.00	12.22
T_6	6.77	9.22	12.56
T_7	5.66	8.11	11.55
T_8	6.55	9.33	12.67
SE m (±)	0.41	0.41	0.35
CD (0.05)	NS	1.200	1.030

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

Table 10. Influence of different treatments on dry matter production of fodder maize at various growth stages (kg ha^{-1})

Treatments	Dry matter production		
	20 DAS	40 DAS	At harvest
T_1	726	4196	9988
T_2	733	4370	10116
T_3	733	4230	10035
T_4	748	5133	13111
T_5	741	5001	13024
T_6	756	5243	13309
T_7	726	4898	11037
T_8	763	5393	13580
SE m (±)	17.06	60.85	104.520
CD (0.05)	NS	178.0	305.7

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

4.2.2 Yield and yield attributes

Data pertaining to the green fodder yield of fodder maize expressed in t ha^{-1} is presented in Table 11. It could be learnt from the data that different treatments had a significant influence on green fodder yield. Significantly higher yield of 33.56 t ha^{-1} was recorded with the treatment T_8 (basal dose of 10 t ha^{-1} FYM followed by soil test based application of chemical fertilizers). As per KAU Package of Practices Recommendations, the nutrient dose for fodder maize is 120: 60:40 kg NPK ha^{-1}. Based on soil test data, this rate was reduced and NPK @ 85.2: 15: 37.6 kg ha^{-1} were applied for the crop. Treatment T_8 which was thus based on integrated nutrient management was however found comparable to organic nutrition treatments T_6 (33.11 t ha^{-1}), T_4 (32.67 t ha^{-1}), T_5 (32.23 t ha^{-1}) and T_7 (32.20 t ha^{-1}) wherein different rice straw composts were supplied on N equivalent basis to meet the inorganic N dose. This was closely followed by T_2 (31.05 t ha^{-1}). Significantly lower yields were recorded in treatments T_1 (29.89 t ha^{-1}) and T_3 (29.94 t ha^{-1}).

4.2.3 Quality parameters

Different treatments could significantly influence the crude protein content of fodder maize at harvest stage, the details of which are presented in Table 12.

4.2.3.1 Crude protein content

Among different treatments, T_8 (KAU POP recommendation combining organic and inorganic nutrients) recorded a higher crude protein content (8.26 per cent) and was comparable to T_6 (8.19 %) and T_4 (8.17 %) followed by T_5 (8.11 %) *i.e.* plants nourished under organic nutrition using rice straw composts. The treatments T_1 (7.94 %), T_3 (8.0 %), T_2 and T_7 (8.08 %) recorded lower and comparable crude protein content.

Table 11. Influence of different treatments on yield of fodder maize at harvest (t ha^{-1})

Treatments	Green fodder yield
T_1	29.89
T_2	31.05
T_3	29.94
T_4	32.67
T_5	32.23
T_6	33.11
T_7	32.20
T_8	33.56
SE m (±)	0.70
CD (0.05)	2.030

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I.

*T_8 - Soil test data based INM as per KAU recommendation

Table 12. Influence of different treatments on crude protein contents of fodder maize (%)

Treatments	Crude protein
T_1	7.94
T_2	8.08
T_3	8.00
T_4	8.17
T_5	8.11
T_6	8.19
T_7	8.08
T_8	8.26
SE m (±)	0.15
CD (0.05)	0.140

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

4.2.3 Physiological parameters

4.2.3.1 Leaf area index

Leaf area index of fodder maize was recorded at three crop stages and found significantly influenced by different treatments at 40 DAS and at harvest (Table 13). At 20 DAS, LAI was found unaffected by any of the treatments applied.

At 40 DAS, LAI was higher with treatment T_8 (3.67) and it was comparable with T_6 (3.45) and T_4 (3.36). These were closely followed by T_5 (3.25). LAI was lower and comparable in treatments T_1 (2.02) and (2.23) at this stage.

At harvest, LAI was significantly higher (5.91) with T_8 and it was comparable to treatments T_6 (5.88), T_4 (5.76) and T_5 (5.71). Lowest leaf area index was recorded with T_1 (5.23).

4.2.3.2 Crop growth rate (CGR)

Different treatments on crop nutrition including INM (T_8) and organic nutrition using rice straw composts (T_1 - T_7) were found to have a significant influence on the crop growth rate of fodder maize at 40 DAS and at harvest (Table 14).

CGR recorded at 20 to 40 DAS was significantly higher for treatment T_8 (23.15 g m^{-2} day^{-1}) and was comparable to T_6 (22.44 g m^{-2} day^{-1}). This was followed by T_4 (21.93 g m^{-2} day^{-1}) and T_5 (21.31 g m^{-2} day^{-1}). T_1 could register a significantly lower CGR of 17.35 g m^{-2} day^{-1} and it was on par with T_3 (17.48 g m^{-2} day^{-1}) and T_2 (18.19 g m^{-2} day^{-1}).

During 40 DAS to harvest stage, T_8 registered a higher CGR (40.94 g m^{-2} day^{-1}) and was comparable to T_6 (40.33 g m^{-2} day^{-1}), T_5 (40.12 g m^{-2} day^{-1}) and T_4 (39.89 g m^{-2} day^{-1}). CGR was the least (19.30 g m^{-2} day^{-1}) in T_1.

4.2.3.3 Relative growth rate (RGR)

Relative growth rate of fodder maize was worked out at different stages of crop growth *i.*e., 20 - 40 DAS and at 40 DAS- harvest and the results of the same are presented in Table 15. Different treatments on crop nutrition had a significant

Table 13. Influence of different treatments on the leaf area index of fodder maize at various growth stages

Treatments	Leaf area index		
	20 DAS	40 DAS	At harvest
T_1	0.95	2.02	5.03
T_2	0.94	2.53	5.31
T_3	0.99	2.23	5.26
T_4	0.96	3.36	5.76
T_5	1.04	3.25	5.71
T_6	0.94	3.45	5.88
T_7	1.01	2.81	5.32
T_8	0.95	3.67	5.91
SE m (±)	0.023	0.12	0.07
CD (0.05)	NS	0.358	0.200

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

influence on the relative growth rate of test crop fodder maize at 40 DAS and at harvest. At 40 DAS, plants nourished under integrated nutrient management (T_8) registered higher relative growth rate (0.0978 g $g^{-1}day^{-1}$) and was comparable to T_6 (0.0969 g g^{-1} day^{-1}), T_4 (0.0963 g g^{-1} day^{-1}), T_5 (0.0955 g g^{-1} day^{-1}) and T_7 (0.0949 g g^{-1} day^{-1}). Lower and comparable RGR were registered in treatments T_1 and T_3 (0.0877 g g^{-1} day^{-1}) and T_2 (0.0893 g g^{-1} day^{-1}).

At crop harvest, T_5 (0.0319 g g^{-1} day^{-1}) registered higher RGR however comparable to T_4 (0.0313 g g^{-1} day^{-1} and T_6 (0.0310 g g^{-1} day^{-1}). This was followed by T_8 (0.0308 g g^{-1} day^{-1}). Lower and comparable RGR were observed with T_7 (0.0271 g g^{-1} day^{-1}) and T_2 (0.0280 g g^{-1} day^{-1}). Organic treatments have performed better than INM here.

4.2.3.4 SPAD chlorophyll meter reading

Application of different rice straw composts could produce a significant influence on the chlorophyll content of fodder maize at 60 DAS and the data on SCMR are presented in Table 16. The data reveals that at 60 DAS, significantly higher SCMR of 48.70 was recorded in fodder maize with treatment T_8 (basal FYM, followed by soil test based application of chemical fertilizers according to KAU Package of Practices Recommendations) and which was on par with treatments T_6 (46.12) and T_4 (45.09) followed by T_5 (44.84). Significantly, lower SCMR of 37.08 was recorded in plants under T_1 compost application comparable to T_3 (39.12) and T_2 (40.49).

4.2.4 Analysis of soil

Properties of soil like pH and organic carbon are given in Table 16 and available nutrient status in Table 17.

4.2.4.1 pH

It is clear from the data that different treatments failed to produce a significant effect on pH of the soil after the crop harvest. The initial pH of the soil was 5.9 that indicate the soil is moderately acidic in nature. After the experiment it ranged from 5.71 to 6.23.

Table 14. Influence of different treatments on the crop growth rate of fodder maize at various growth stages (g m^{-2} day^{-1})

Treatments	20 to 40 DAS	40 DAS to harvest
T_1	17.35	19.30
T_2	18.19	28.73
T_3	17.48	29.03
T_4	21.93	39.89
T_5	21.31	40.12
T_6	22.44	40.33
T_7	20.82	30.70
T_8	23.15	40.94
SE m (±)	0.29	0.54
CD (0.05)	0.909	1.656

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

Table 15. Influence of different treatments on the relative growth rate of fodder maize at various growth stages (g g^{-1} day^{-1})

Treatments	20 to 40 DAS	40 DAS to harvest
T_1	0.0877	0.0289
T_2	0.0893	0.0280
T_3	0.0877	0.0288
T_4	0.0963	0.0313
T_5	0.0955	0.0319
T_6	0.0969	0.0310
T_7	0.0949	0.0271
T_8	0.0978	0.0308
SE m (±)	0.001	0.00
CD (0.05)	0.0040	0.0010

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

Table 16. Influence of different treatments on SPAD chlorophyll meter reading of leaves at 60 DAS

Treatments	SPAD chlorophyll meter reading (SCMR)
T_1	37.08
T_2	40.49
T_3	39.12
T_4	45.09
T_5	44.84
T_6	46.12
T_7	41.10
T_8	48.70
SE m (±)	1.26
CD (0.05)	3.846

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

4.2.4.2 Organic carbon

The data revealed that the organic carbon content of the soil after the field experiment could not significantly influenced by different treatments. The initial organic carbon content of the soil was 1.7 per cent and the final organic carbon content of the soil varied from 1.7 per cent to 1.76 per cent.

4.2.4.3 Available nitrogen

The data on available N after the experiment is shown in Table 18. The result revealed that different treatments have no significant influence on the availability of N. The initial available N status of the soil was 259.24 kg ha^{-1}. After the experiment the available N was unaffected by different treatments and it ranged from 267.33 kg ha^{-1} to 287.5 kg ha^{-1}.

4.2.4.4 Available phosphorus

Different rice straw composts as N equivalent component have significant influence on the available P content of the soil (Table 18). The initial available P content of the soil was 32.26 kg ha^{-1}. After the experiment treatment T_6 (rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1) recorded the higher P content of 34.19 kg ha^{-1} comparable to T_4 (co-composted rice straw, goat manure and cowdung in the ratio 4:1:1) recording a value of 33.56 kg ha^{-1} and significantly superior to other treatments. The treatment T_1 (rice straw and cow dung in the ratio 4:1) recorded the lowest available P content of 29.19 kg ha^{-1}.

4.2.4.5 Available potassium

The data on available potassium in soil as influenced by various treatments are given in the Table 18. Initially the soil contains an available potassium content of 125.15 kg ha^{-1}. After the experiment treatment T_6 (rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1) registered higher available potassium content of 132.42 kg ha^{-1} comparable to T_4 (132.08 kg ha^{-1}). And the lowest potassium content was recorded in T_8 (121.83 kg ha^{-1}).

Table 17. Influence of different treatments on pH and organic carbon content of soil (%) before and after the experiment

Treatments	pH	Organic carbon
T_1	5.92	1.76
T_2	6.20	1.75
T_3	5.86	1.75
T_4	5.91	1.74
T_5	6.05	1.74
T_6	5.93	1.73
T_7	6.23	1.72
T_8	5.71	1.70
SE m (±)	0.15	0.01
CD (0.05)	NS	NS

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

Table 18. Influence of different treatments on available nutrient status of soil before and after the experiment (kg ha^{-1})

Treatments	Available nutrient status of soil		
	N	P	K
T_1	275.00	29.19	129.57
T_2	271.11	30.86	129.70
T_3	275.33	31.69	129.63
T_4	283.33	33.56	132.08
T_5	283.33	32.53	131.38
T_6	287.50	34.19	132.42
T_7	279.17	31.69	131.98
T_8	267.33	30.02	121.83
SE m (±)	7.75	0.22	0.69
CD (0.05)	NS	0.669	0.430

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

4.2.5 Content of major nutrients

The results on effect of different treatments on the content of major plant nutrients by fodder maize are depicted in Table 19.

4.2.5.1 N content

Content of N was found higher (1.32 %) for treatment T_8 (basal FYM + soil test based application of chemical fertilizers) and was on par with treatments T_6 (1.31 %), T_4 (1.31%) and T_5 (1.30 %). The lower N content was recorded with treatment T_1 (1.27) comparable to T_3 (1.28 %), T_2 (1.29 %), and T_7 (1.29 %).

4.2.5.2 P content

Different treatments had a significant influence on the content of P of fodder maize. Plants with soil test data based application of chemical ferilizers (T_8) registered higher P content of 0.16 per cent which was on par with treatment T_6 (rice straw co - composted with goat manure and poultry manure in the ratio 4:1:1), with 0.15 per cent P content. Lower and comparable P content was observed in T_1 (0.12 %), T_3 (0.12 %), T_2 (0.13 %) and T_5 (0.13 %).

4.2.5.3 K content

Plants grown under integrated nutrient management (T_8) registered higher K content of 1.5 per cent and it was found comparable with the content of T_6 (1.49%) and T_4 (1.48 %). The K content was lower for treatment T_1 (1.4 %) *i.e.* rice straw co-composted with cowdung in the ratio 4:1 comparable to T_3 (1.41 %), T_2 (1.42 %) and T_7 (1.44 %).

4.2.5 Uptake of major nutrients

The results on effect of different treatments on the uptake of major plant nutrients by fodder maize are depicted in Table 20.

4.2.5.1 N uptake

Uptake of N was found higher (179.25 kg ha^{-1}) for treatment T_8 (basal FYM + soil test based application of chemical fertilizers) and was on par with T_6 (rice straw

Table 19. Influence of different treatments on the contents of major nutrients of fodder maize plants (%)

Treatments	Content of major nutrients		
	N	P	K
T_1	1.27	0.12	1.40
T_2	1.29	0.13	1.42
T_3	1.28	0.12	1.41
T_4	1.31	0.14	1.48
T_5	1.30	0.13	1.45
T_6	1.31	0.15	1.49
T_7	1.29	0.14	1.44
T_8	1.32	0.16	1.5
SE m (±)	0.01	0.003	0.01
CD (0.05)	0.020	0.008	0.040

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

Table 20. Influence of different treatments on uptake of major nutrients of fodder maize plants (kg ha^{-1})

Treatments	Uptake of major nutrients		
	N	P	K
T_1	126.83	11.99	142.17
T_2	130.85	13.14	145.32
T_3	128.45	12.37	143.48
T_4	171.29	18.78	190.56
T_5	169.29	17.38	189.26
T_6	174.34	20.41	195.19
T_7	142.75	15.46	163.68
T_8	179.25	21.28	198.04
SE m (±)	1.77	0.38	2.07
CD (0.05)	5.160	1.153	6.346

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

co-composted with goat manure and poultry manure in the ratio 4:1:1 as nutrient source) recording a value of 174.34 kg ha^{-1}. The lower N uptake was recorded with treatment T_1 (126.83 kg ha^{-1}) comparable to T_3 (128.45 kg ha^{-1}) and T_2 (130.85 kg ha^{-1}).

4.2.5.2 P uptake

Different treatments had a significant influence on the uptake of P by fodder maize plants. Plants grown under soil test based application of chemical ferilizers (T_8) registered higher P uptake of 21.28 kg ha^{-1} which was on par with treatment T_6 with an uptake of 20.41 kg ha^{-1}. The lower P uptake was observed in T_1 (11.99 kg ha^{-1}) comparable to T_3 (12.37 kg ha^{-1}) and T_2 (13.14 kg ha^{-1}).

4.2.5.3 K uptake

Plants grown under integrated nutrient management based on soil test data (T_8) registered higher uptake of K (198.04 kg ha^{-1}) and it was found comparable with the uptake of T_6 (195.19 kg ha^{-1}). The uptake of K was lower for treatment T_1 (142.17 kg ha^{-1}) *i.e.* rice straw co-composted with cowdung in the ratio 4:1 comparable to T_3 (143.48 kg ha^{-1}) and T_2 (145.32 kg ha^{-1}).

4.2.7 Economics of cultivation

Economics of cultivation of fodder maize was worked out in terms of net returns and B:C ratio and are given in Table 21.

4.2.7.1 Net returns

Net returns was found highest for treatment T_8 (₹39814 ha^{-1}) followed by T_6 (₹27661 ha^{-1}). The lowest net returns were recorded in T_1 (₹4320 ha^{-1}), where rice straw co-composted with cow dung in the ratio 4:1 was used as the nitrogen source.

4.2.7.2 B:C ratio

The treatment T_8 registered the highest BCR of 1.31, followed by T_6 (1.20). The lower BCR of 1.03 was recorded with the treatment T_1 comparable to T_3 (1.08), and T_2 (1.09).

Table 21. Influence of different treatments on net returns (Rs. ha^{-1}) and BCR of fodder maize

Treatments	Net returns	B:C ratio
T_1	4320	1.03
T_2	12349	1.09
T_3	10823	1.08
T_4	20510	1.14
T_5	21246	1.15
T_6	27661	1.20
T_7	20665	1.15
T_8	39814	1.31
SE m (±)	513.43	0.02
CD (0.05)	1502.0	0.050

*From T_1 to T_7, organic nutrition of crop using composts 1 to 7 generated in Experiment I

*T_8 - Soil test data based INM as per KAU recommendation

DISCUSSION

5. DISCUSSION

The research work entitled "Crop residue recycling for organic production of fodder maize in a rice based integrated farming system" was conducted at IFSRS, Karamana with the objectives to generate nutrient rich manures from rice straw through co-composting and to evaluate their efficacy in influencing the growth, yield, quality and economics of fodder maize. The results obtained from this experiment are discussed in this chapter.

5.1 EXPERIMENT I - CO COMPOSTING OF RICE STRAW USING DIFFERENT ORGANIC MANURES AS NITROGEN SOURCES.

5.1.1 Time taken for composting

From the experimental results, it is revealed that different methods of co-composting could significantly influence the time taken for maturation of rice straw compost. Fig. 3 illustrates the influence of different co-composting methods on the maturation of compost. Co-composting of rice straw with goat manure and poultry manure (T_6) in the ratio 4:1:1 (on volume basis) was the most effective treatment in terms of significant earliness in maturation of compost. This could be related with the addition of nitrogen rich organic inputs viz., goat manure and poultry manure to rice straw.

Being an essential component of proteins and amino acids, nitrogen is required for the growth of the microbial biomass involved in any composting process. It is recommended that, to maintain an active microbial population in composting, the available carbon to nitrogen ratio should be kept at appropriate levels. Under treatment $T_{6,}$ rice straw with wider C: N ratio was well mixed with organic inputs goat manure and poultry manure, which had higher N content. Release of nitrogen from these sources could possibly support microbial activity in a better manner, thereby hastening composting and in faster attainment of compost maturity. There are several reports in support of this observation. Devi *et al.* (2010) reported that poultry manure as an organic input in rice straw composting underwent rapid mineralization with most of the inorganic N released within 28 days. This rapid release of N could support build up of microbial population resulting in enhanced microbial activity and faster decomposition of straw. Sanusi *et al.* (2018) reported that mixing of carbonaceous rice straw with nitrogen rich goat manure resulted in microbial build up leading to quicker composting.

In general, co-composting in 4:1:1 ratio, performed better than 4:1 ratio, which could be attributed to the presence of more organic matter in 4:1:1 combination, which might have in turn supported higher microbial population. Treatments T_4 (80 days) and T_5 (85 days) were comparable and took lesser time for compost maturation next to $T_{6.}$ These treatments had N rich poultry manure/goat manure added as N sources in addition to cow dung (Table.3). Time taken for composting was significantly prolonged (128.33days) in treatment T_8 (natural composting of rice straw). This could be related to the fact that no nitrogen inputs were added to the carbonaceous and lignin rich rice straw, which was difficult to be decomposed. In support of this, Jusoh *et al.* (2013) reported that non-addition of N inputs to carbon rich substrates slows down degradation resulting in prolonged composting period.

5.1.2 Recovery of compost

The effect of different composting methods on the recovery of composts was very prominent as depicted in Fig. 4. The recovery of compost was significantly higher with treatments T_6 (Rice straw + goat manure + poultry manure in 4:1:1 ratio) and T_5 (Rice straw + cowdung + poultry manure in 4:1:1 ratio). This could generally be related with the addition of nitrogen sources in higher quantities (4:1:1) compared to 4:1 treatments. In particular, poultry manure was a common ingredient for both these treatments. Being low in moisture content, poultry manure added more of dry matter to the composting lot, naturally contributing to higher recovery. Among these two best treatments, the advantage for T_6 (55.33%) could be related with the ingredient goat manure which had a lower moisture content compared to cowdung added in T_5 (52.4%). Also, the higher nitrogen content noticed with goat manure and poultry manure (Table 3) compared to cow dung could be yet another factor which led to higher recovery in T_6 by way of better decomposition of the composting material.

There are similar research reports well supporting the above findings. Guerra-Rodriguez *et al.* (2000) had established the advantage of poultry manure in complete decomposition of composting material thereby avoiding wastage and hence better recovery. Yadav (2005) reported that, poultry manure added to the composting material in higher quantities could enhance the recovery of compost. Gaind and Nain (2010) reported that mixing of rice straw with poultry droppings could result in complete decomposition leading to higher recovery.

Goat manure is rich in nitrogen due to the addition of urine to droppings. Nitrogen in turn supports growth and reproduction of microbes and as a result, the manure is abundant in microorganisms. Microorganisms in turn, enhance the composting process by way of microbial degradation (Koki *et al.*, 2011). Based on these reasons, the efficacy of goat manure as a co- composting material for rice straw was well proven by Sanusi *et al.* (2018).

Natural composting of rice straw with no addition of organic manure (T_8) could result in significantly lowest recovery (23.87%). Organic residues with wide C: N ratios as rice straw could be better decomposed with the addition of N rich co-composting inputs. Unlike all other treatments, this was not followed under T_8 which explains a lower decomposition rate and hence poor recovery. Abdel *et al.* (2011) reported that natural decomposition of rice straw is slower due to components cellulose and lignin which are difficult to be decomposed. According to Balasubramanian (2013), natural composting of rice straw is much slow. Addition of nitrogen rich organic manures as co-composting materials can improve the nutritional value of compost as well as accelerate the degradation process (Sanchez-Garcia *et al.*, 2015).

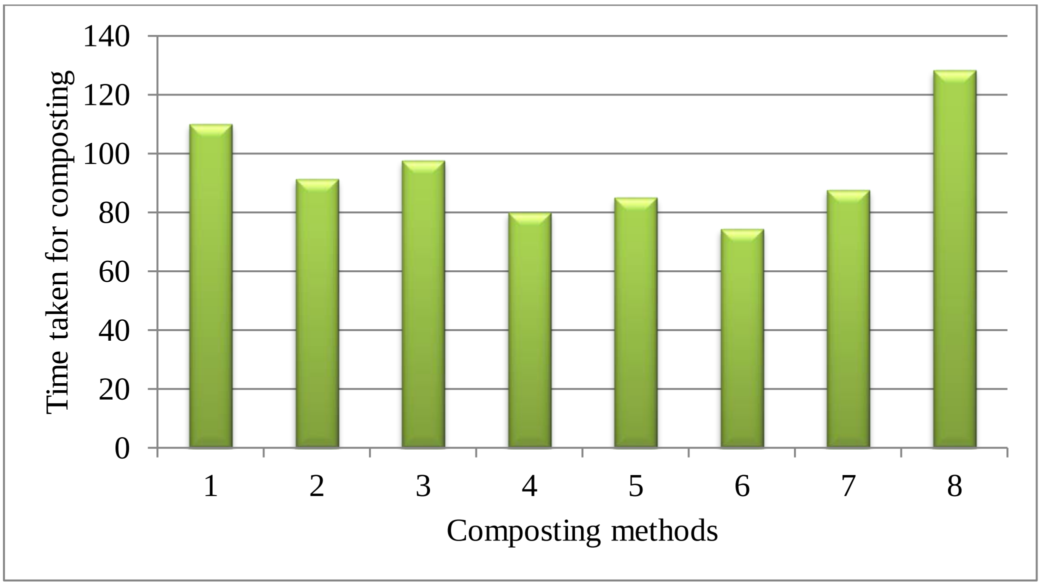

Fig. 3 Influence of different composting methods on maturation of compost (days)

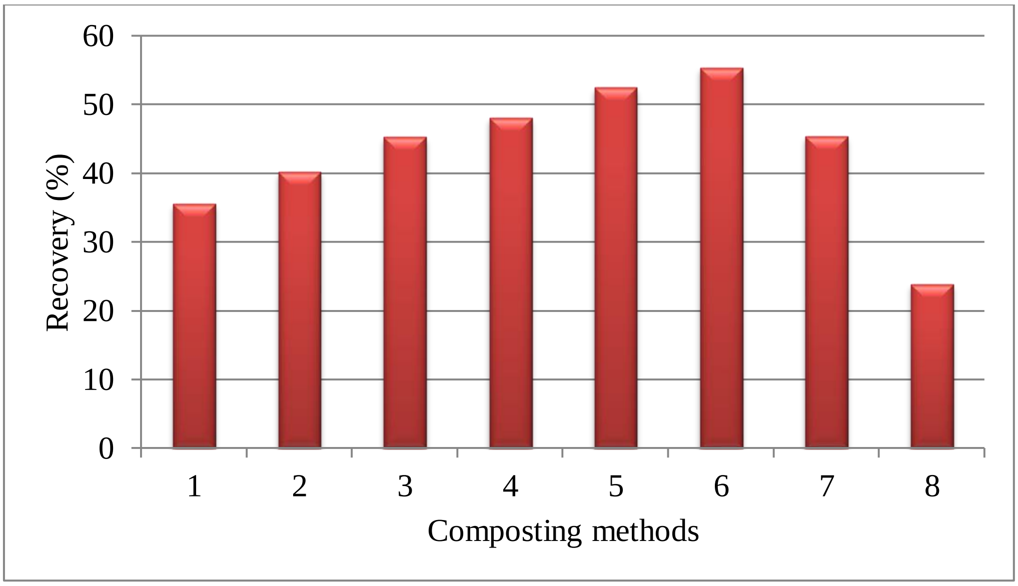

Fig. 4 Effect of different composting methods on recovery of compost

5.1.3.2 Electrical conductivity

Electrical conductivity, an indicator of salinity of a substrate, varies depending on the release of mineral ions during decomposition. This can be influenced by the different N sources added to the composting substrate. Higher EC causes phytotoxicity and hence EC values of < 4 dS m^{-1} are preferred for composts (Yadav and Garg, 2013). The EC values of different composts generated in the present study were in safe limits (0.63-0.90 dS m^{-1}) and hence suitable for soil application. However, different composting methods could not significantly influence the EC of composts. This suggests the similar influence of different N sources on EC. George, (2019) studied composting of rice straw using vermicomposting, microbial composting and co-composting strategies and recorded similar acceptable range of EC for the different rice straw composts generated.

5.1.3.3 C: N ratio

C: N ratio of rice straw used for composting was 39:1 and it was considerably narrowed down in the end product through co-composting. This could be related with the fact that during co-composting, carbon is used up as an energy source for microbial metabolism and the intense microbial activity results in a decrease in carbon content of the composting material. Simultaneous addition of N rich organic manures increases the N level as well as the activity of N fixing bacteria (Raj and Antil, 2011). Because of these reasons C: N ratio narrows down.

Rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 (T_6) registered a significantly lower C:N ratio of 10.23, comparable to treatments T_4 (10.67) and T_5 (10.69). This could be related with the N content of these organic manures which followed the descending order- goat manure (3.75 %), poultry manure (2.57%) and cow dung (1.45 %), with regard to N content (Table 3). T_6 had a mix of N rich sources goat manure and poultry manure which could be well related to the considerable narrowing down of C: N ratio. Jusoh *et al*. (2013) reported that co-composting of rice straw with goat manure in the ratio 5:1 (volume basis) could narrow down the C: N ratio of straw from 34 to 16. Qian *et al*. (2014) experimented with co-composting of rice straw using organic sources goat manure and green leaves and arrived at narrowing down of C:N ratio in a speedy manner. Nandni (2017) reported that co-composting of rice straw and poultry manure in the ratio 5:1 (volume basis) along with cattle dung @ 10 per cent of the mixture resulted in good quality compost with a favourable C:N ratio of 16.0. In a trial conducted on rice straw composting at Kerala Agricultural University, George, (2019) observed that compost with narrow C:N ratio (10.32) could be obtained from fresh rice straw which had a wider C:N ratio (60:1). Here co-composting of rice straw was carried out using two organic sources *viz.*, poultry manure and cow dung.

Under natural composting (T_8), a wider C: N ratio of 19.5 was recorded which could be attributed to the non addition of N sources. However, all the composts generated in the present study had C: N ratios within 20:1, the acceptable limit for use as manures as suggested by Vigneswaran *et al.* (2016). The effect of different co-composting methods on the C:N ratio of the composts is illustrated in Fig. 5.

5.1.4 Nutrient status of rice straw compost

5.1.4.1 Major nutrients

With the progress of composting, plant nutrients get concentrated such that the end product is rich in major nutrients compared to the initial substrate (Jusoh *et al.*, 2013a). Composts generated in the present study recorded an increase in N content compared to the initial N content (0.22 %) of rice straw. Compost generated with goat manure and poultry manure as N sources (T_6) recorded significantly higher N content, which could definitely be related with the higher N content of these two manures over cowdung (Table 3). Higher and comparable N content was recorded with treatments T_4 and T_5. In these treatments, also goat manure /poultry manure were included as one of the nitrogen sources along with cow dung. These results are in conformity with those of Jusoh *et al.* (2013b) and Qian *et al.* (2014) who obtained composts having higher nitrogen content using rice straw, goat manure and poultry manure. Treatment T_8 recorded the significantly lowest N content of 1.2 per cent. This is attributed to the non addition of nitrogen rich organic manure to rice straw. Similar to this result, Chan *et al.* (2016) reported that the non addition of organic manures to carbon rich composting substrates resulted in lower microbial activity and hence less mineralization of N.

Concentrations of primary nutrient P in rice straw composts were well above the initial content (0.15 %) in rice straw. Co-composting of rice straw with of goat manure and poultry manure (T_6) resulted in higher P content (0.98 %) comparable to treatments T_5 (0.93 %) and T_4 (0.89 %). This could be attributed to the richness of goat manure and poultry manure in P compared to cowdung (Table 3) and these three treatments made use of either goat manure, poultry manure or both. Naturally, when used as organic sources in composting, these manures enriched the P content of final product. This is in confirmity with the results obtained by Das *et al.*, (2011) and Sanusi *et al.* (2018) who obtained P rich composts from rice straw by way of co-composting with poultry manure and goat manure. Among these, natural composting of rice straw (T_8) recorded the significantly lowest P content of 0.35% per cent.

The total K content was found to be higher for treatment T_6 (3.22 %), but comparable to T_7 (3.00 %) *i.e.,* co-composting of rice straw with cowdung and glyricidia leaves in 4:1:1 ratio on volume basis. Higher K content registered in composts T_6 and T_7 could be attributed to the richness of K in goat manure (1.22%), poultry manure (0.95 %) and glyricidia leaves (1.18%). Apart from the above mentioned enriching effect, these manures might have contributed to the build up of microbial organisms thereby enhancing mineralization of K from the composting substrate. Shak *et al.* (2014) also arrived at such beneficial effects of K enrichment of composts on co-composting of rice straw with goat manure and poultry manure. Daphal (2018) reported similar enhancement in potassium content on co composting wheat straw with glyricidia leaves. Compost generated under treatment T_8 (natural composting of rice straw) recorded the significantly lowest K content of 1.95 per cent mainly attributed to the non addition of organic manures. The nutrient status of rice straw composts as influenced by different co- composting methods is depicted in Fig. 6.

5.1.4.2 Micronutrients

Rice straw samples at the start of experiment contained micronutrients including Fe (262.75 mg kg^{-1}), Cu (27.10 mg kg^{-1}), Mn (637.10 mg kg^{-1}), Zn (31.10 mg kg^{-1}) and B (4.24 mg kg^{-1}). An increase in the content of these micronutrients was observed in the final produce. Several authors (Jusoh *et al.*, 2013; Sanusi *et al.*, 2018) have reported such similar results of increased micronutrient content with the progress of composting. In general, these micronutrients were higher in T_6 (rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1

on volume basis) and lower in T_8 (natural composting of straw). T_4 (rice straw co-composted with cow dung and goat manure in 4:1:1 ratio) and T_5 (rice straw co-composted with cow dung and poultry manure in 4:1:1 ratio) recorded comparable contents or closely followed T_6 mostly.

Organic manures like goat manure and poultry manure are rich in plant nutrients including micronutrients (Azeeze and Averbeke, 2010), and when co-composted with rice straw could enhance the content of micronutrients in the final product (Table.6). Also, the N rich nature of these composts could be related to the flourishment of microbes which could accelerate the rate of mineralization of nutrients from the composting substratum (Jusoh *et al*., 2013).

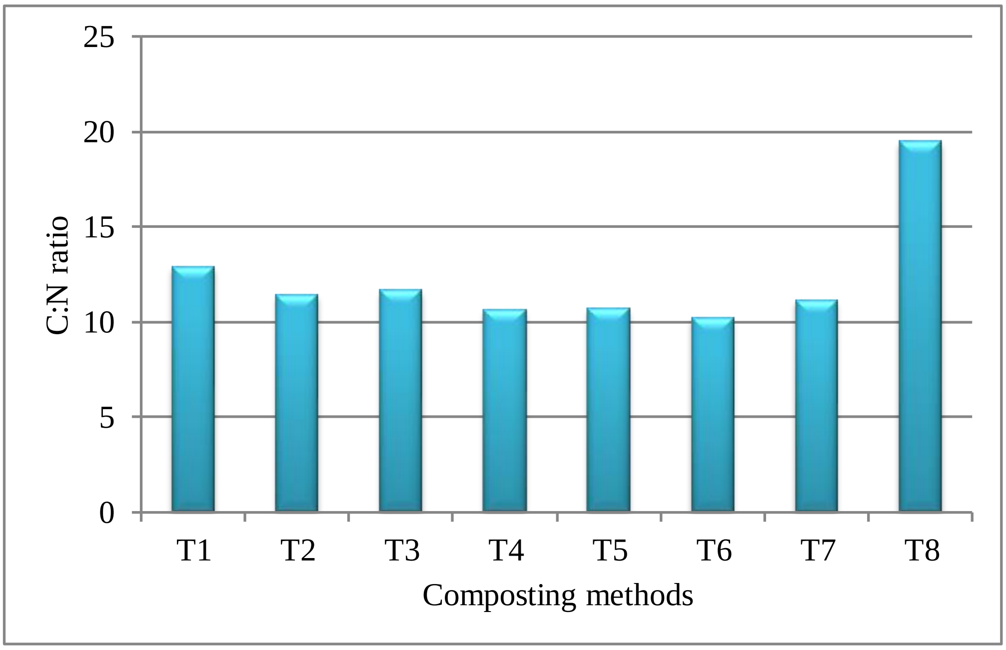

Fig. 5 Effect of different composting methods on C: N ratio of compost

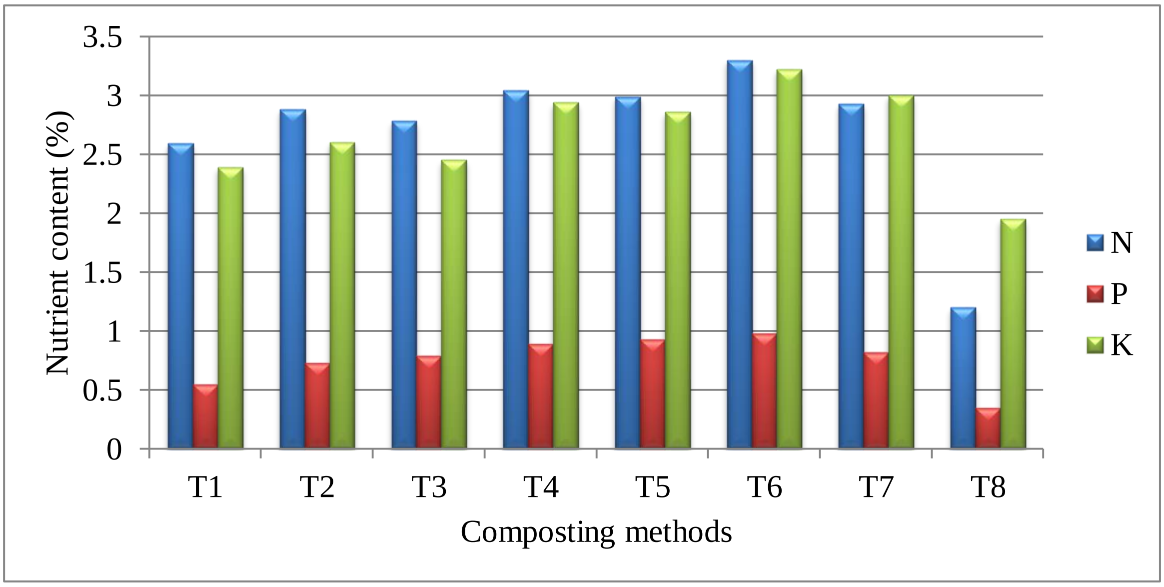

Fig. 6 Influence of different composting methods on nutrient status of compost

5.2. EXPERIMENT II- EVALUATION OF COMPOSTS FOR ORGANIC PRODUCTION OF FODDER MAIZE

5.2.1 Growth characters

5.2.1.1 Plant height

Plant height is an index of the general growth of a plant. Different rice straw composts used as manures for organic production of fodder maize could significantly influence plant height at two stages of crop growth. This could be attributed to the difference in micronutrients contained in different composts (Table 6) and the C: N ratio of composts (Table 5) which determine mineralization of plant nutrients, which in turn decide crop uptake of nutrients reflecting in growth parameters of crop including plant height.

Plants nourished with basal dose of FYM @ 10 t ha^{-1} and N, P and K fertilizers on the basis of soil test (T_8), recorded higher plant height however comparable to organic nutrition followed under T_6, T_4 and T_5. Composts applied under these organic nutrition treatments had favourably narrower C:N ratios (Table 5). Hence it could be assumed that rapid mineralisation of nutrients resulted in these treatments leading to nutrient availability and hence better nutrient uptake resulting in improved plant height. Similar to this result, improved plant height was recorded on fodder maize (Coulibaly *et al.* (2016)) by the application of compost. Also, the micronutrient content of composts generated under T_6, T_4 and T_5 were more (Table 6). This might have positively contributed to plant physiological reactions leading to better plant height. This was in conformity with the results of Borase *et al.* (2018) who reported that the plant height of fodder maize was highly influenced by the application of micronutrients like Zn and B.

5.2.1.2 Number of leaves per plant

Different rice straw composts could not produce any significant influence on the number of leaves per plant of fodder maize at 20 DAS. However significant influence of treatments on leaf number of plant was recorded at 40 DAS and at final harvest.

The improvement in leaf number of crop is a reflection of enhancement in crop growth as brought about by better crop nourishment. It could be assumed that integrated nutrient management as provided by T_8 as well as organic nutrition using composts prepared under treatments $T_{6,}$ T_4 and T_5 were equally effective in well nourishing the crop. The composts mentioned above had favourable C: N ratios and higher content of micronutrients. Speedy mineralisation of nutrients from these composts might have provided nutrients in time for better crop growth. Coupled with adequate micronutrients, this could provide a well balanced nutrient package resulting in better growth which was reflected as more number of leaves. This agrees with the findings of Zhou *et al.* (2015), who reported that composts are rich in micro and macronutrients (Table 6) that might have positively contributed to mean number of leaves per plant in fodder maize. Other rice straw composts including $T_{1,}$ T_2 and T_3 had relatively wider C:N ratios and lower content of micronutrients. Hence it could be assumed that the mineralisation of nutrients took more time and the crop physiology wasn't perfectly benefitted with lesser supply of micronutrients. Moreover the crop span was short (70 days) and a speedy mineralisation of nutrients could definitely influence crop growth. This was supported by the findings of Alade *et al.* (2019).

5.2.1.3 Dry matter production

Dry matter production, an important character contributing to fodder yield was found highly influenced by different treatments in the present study. Different rice straw composts generated under the study and used for organic production of fodder maize could produce a significant impact on the total dry matter production (Table 9) of the test crop fodder maize. Dry matter accumulation increased progressively with advance in crop stages till final harvest.

Higher and comparable DMP was recorded in treatments T_8 and T_6. This could be attributed to the enhancement in growth in terms of plant height and leaf count (Tables 7 and 8) which naturally reflected in higher DMP. The enhanced growth effected under these two treatments could be related with the ready availability of nutrients for crop. It could be inferred that chemical fertilizers included in the nutrition schedule (T_8) and rice straw compost with narrower C: N ratio supplied under T_6 favoured easy mineralization of nutrients for enhanced crop growth.

There are many research documents in support of the above. Taller plants with more leaves having increased photosynthetic area could produce more dry matter (Mahdi, 2012). Similarly Bharat *et al.* (2017) found an increase in drymatter accumulation in fodder maize under integrated nutrient management.

The results also suggest that certain rice straw composts (T_1 and T_2) prepared with lower addition of organic manure to rice straw (4:1), couldn't perform well as $T_{6,}$ wherein organic manures were added at higher rates (4:2). T_1 and T_2 had wider C: N ratios compared to T_6 suggesting more time for nutrient mineralization. Also these composts were not as enriched with micronutrients (Table 6) compared to T_6 and this can be related with their relatively poor performance in influencing growth and DMP.

5.2.2 Yield and yield attributes

Fodder maize is an ideal forage crop for dairy animals and it can be fed as green, dry or in the form of silage. In the present study, organic crop nutrition of fodder maize var. African tall was experimented. Integrated nutrient management as recommended by KAU and based on soil test data (T_8) was compared with organic nutrition using different rice straw composts generated from the study. It was noticed that different treatments on crop nutrition had a significant influence on the green fodder yield of the crop (Fig.7).

Among different treatments, T_8 (Basal dose of 10 t ha^{-1} of FYM followed by 85.20:15: 37.60 kg NPK ha^{-1}) registered higher yield of 35.56 t ha^{-1}comparable to completely organic treatments T_6 (33.11 t ha^{-1}), T_4 (32.67 t ha^{-1}), T_5 (32.23 t ha^{-1}) and T_7 (32.20 t ha^{-1}). The relative advantage of these treatments with regard to supply of composts with narrower C:N ratio (Table 5) could be related with their improved performance leading to higher crop yields. Composts with narrow C: N ratios readily undergo mineralization making available plant nutrients in a speedy manner. This could especially benefit crops with shorter duration including the test crop fodder maize which had a shorter crop span of 70 days. Siddaram *et al.* (2010) also supported this, who reported that this enhanced yield attributes could be due to the better availability of soil nutrients, water and improvement in other soil physico-chemical characters due to the application of compost. Also, the micronutrient content was more in composts supplied in treatments T_6, T_4 and T_5 (Table 6) which also could have influenced the plant physiology in a better manner leading to better yield performance. In the present study, growth parameters including plant height, leaf number, dry matter production etc. were significantly improved under treatments T_6, T_4 and T_5 (Tables 7, 8 and 9). Also, physiological parameters including LAI, CGR and RGR

(Table 12, 13 and 14) also recorded significant improvement under the above treatments. Hence all these could be related with the better crop growth leading to enhanced yields. In support to this, Mithare *et al.*(2019) reported that leaf area influences interception and utilization of solar radiation by crops which in turn could influence dry matter accumulation and ultimately fodder yield.

Also, it could be assumed that the microbial load could have been more in these composts leading to better mineralization of nutrients from the soils of cropped field. In these treatments organic manure was applied at a higher rate (4 parts of rice straw: 2 parts of organic manure) compared to treatments T_1, T_2 and T_3 (4 parts of rice straw: 1 parts of organic manure). This is in conformity with the results obtained by Hariz *et al.* (2013) who reported that addition of higher quantities of organic manure to the composting substrate could enhance the microbial load in composts.

Lower yields recorded under T_1 (29.89 t ha^{-1}) and T_3 (29.94 t ha^{-1}) could be well related with the comparatively wider C: N ratio and lower content of micronutrients. Also, in these treatments, only one part of organic manure was added to four parts of cow dung and it could therefore be assumed that the microbial build up in these composts could have been less in influencing many reactions including enzymatic changes in soil which could lead to better nutrient release. Growth and physiological parameters recorded were also comparatively poor with regard to these treatments.

5.2.3 Quality Parameters

5.2.3.1 Crude protein content

Crude protein content of fodder maize estimated at harvest stage of crop was significantly influenced by different treatments (Fig.8) and the data pertaining to which is presented in Table 11.

Significantly higher crude protein content was recorded in the treatment T_8 (8.26%), the treatment based on INM principles and it was found comparable to T_6 (8.19 %), T_4 (8.17 %) and T_5 (8.11 %) maintained under complete organic nutrition. This improvement in crude protein content could be attributed to the increased uptake of major nutrient N. Being a structural component of amino acids, nitrogen plays a direct role in protein synthesis thereby influencing the quality of fodder (Aslam *et al.*, 2011). Rice straw composts generated under T_6, T_4 and T_5 had higher amount of micronutrients *viz.*, Fe and Zn (Table 6). The composts are rich in micronutrients. These micronutrients have a very important role to play in the uptake of major nutrients especially N. Among the micronutrients B and Zn helps in the uptake of N while Fe helps in the uptake of P and substantially increase the translocation of absorbed nitrogen into protein. This way, organic crop nutrition performed in a comparable manner to the well balanced INM provided by $T_{8.}$ Similar findings were reported by Milkha *et al*. (2005); Black, (2019).

According to Sharifi *et al*. (2016) there exist a balance between micronutrient and uptake of macronutrients. Application of Fe and Zn, increase the crude protein content of fodder maize by improving the bioavailability and uptake of nutrients especially nitrogen.

5.2.4 Physiological parameters

5.2.4.1 Leaf Area Index

Leaf Area Index, a vital photosynthetic character recorded a discernible increase with advance in crop growth. Observations on LAI were recorded at three crop stages. Crop nutrition followed under different treatments could significantly influence the LAI of test crop at 40 DAS and at harvest. At both these stages, plants nourished under integrated nutrient management (T_8) recorded significantly higher leaf area index and was comparable to certain treatments based on organic nutrition (T_6, T_4 and T_5). This was supported by Elfeel and Abohssan, (2016). Who reported higher leaf area index in leguminous tree (*Acacia tortilis*) with the addition of NPK fertilizers but it was comparable to plants under compost application at the rate of 7.5 kg/tree.

Performance of T_6, T_4 and T_5 in manner comparable to INM could be related with the narrower C:N ratios and higher content of micronutrients in the composts supplied under these treatments (Table 5 and 6). The data reveals micronutrients like Fe, Zn, Mn and B were found higher in these composts. Narrower C:N ratios suggest faster mineralization of plant nutrients thereby ensuring timely nutrient availability to crops resulting in improved growth. Also it could be assumed that, higher micronutrient contents in these composts had a favourable influence on various physiological reactions within plants leading to better growth which reflected in

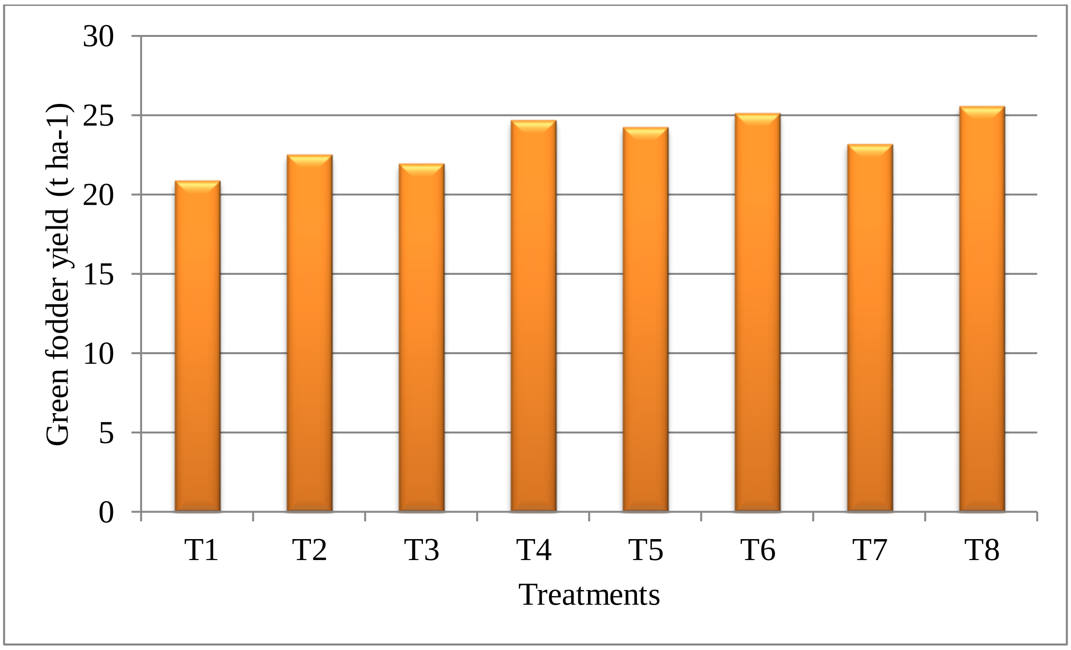

Fig. 7 Influence of different treatments on green fodder yield of fodder maize

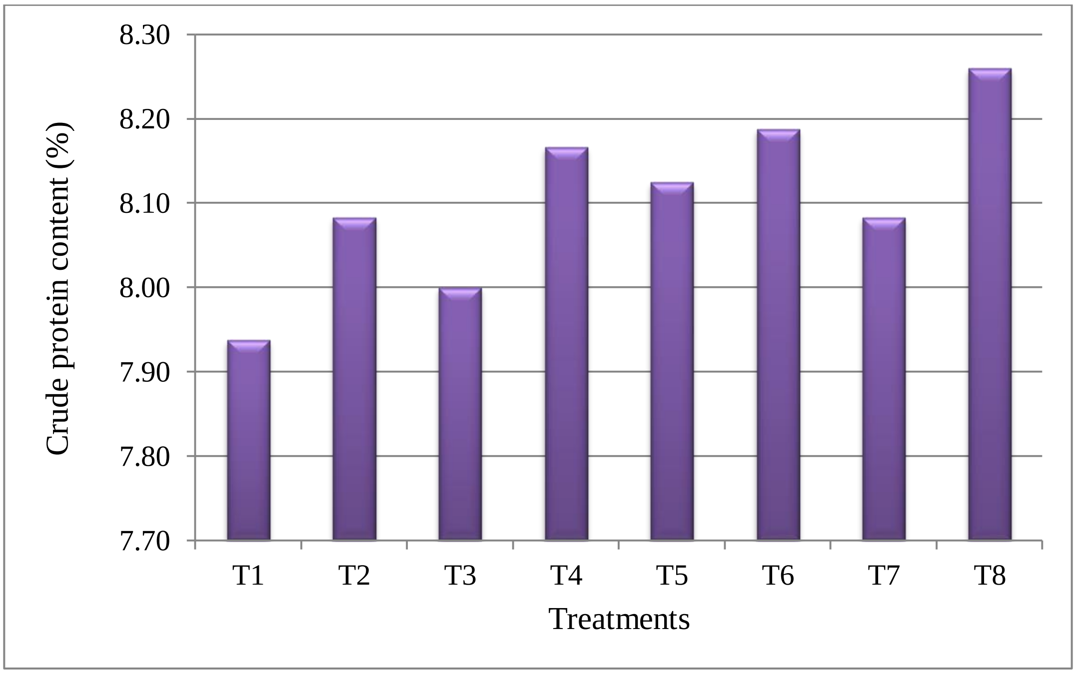

Fig.8 Influence of different treatments on crude protein content of fodder maize

improved LAI. Borase *et al*. (2018) reported increased LAI of maize with the supply of micronutrients like Zn, Fe and B in addition to RDF.

5.2.4.1 Crop growth rate

Crop growth rate is an important parameter that measures plant growth in terms of dry matter accumulation per unit area in a specific time (Azarpour *et al*., 2011). CGR showed an increasing trend from seedling stage to harvest. At 40 DAS and at harvest the plants managed under integrated nutrient management practice as per KAU POP recommendations (T_8) exhibited significantly higher CGR compared to those under organic nutrient management. Treatment T_1 recorded significantly lower CGR throughout the growth period (Table 13).

CGR has a direct relationship with no. of leaves per plant and LAI. Towards the later phase of plant growth, more no. of leaves developed and LAI was more (Table.12) justifying the higher CGR values. Also, during the peak vegetative phase the plant height (Table.7) and stem girth increased with accumulation more of dry matter which could also related to increase in CGR. This was in similar lines with the results obtained by Bindhya, (2019).

5.2.4.3 Relative growth rate

Relative growth rate represents the relative increase in dry matter over time and it decreased linearly towards maturity. This is highly correlated with the nutrient content available to the plants. Therefore, compost addition as nutrient package significantly influence the relative growth rate of maize plants (20 to 40 DAS and 40 DAS to harvest). Plants under integrated nutrient management recorded higher RGR comparable to plants under organic nutrient management (T_6, T_4, T_5 and T_7) in all growth stages. This was highly correlated to nutrient availability to the plants and build up of new photosynthetic tissues. Singh *et al*. (2009) and Azarpour *et al*. (2014) could also reported the similar result about RGR under different nutrient availability.

Among all treatments, it was observed that the RGR value was highest at early growth stage and then it tends to decrease until harvest. This is because the newly formed leaves at the top of the plant will begin to shade lower leaves and therefore average photosynthesis per unit area will go down. Beyond that, over the time structural component of plant tissue is not considered metabolic and does not share in the growth and therefore the relative growth rate decreases with time. These results are in conformity with the findings of Hokmalipour and Darbandi (2011) who reported that relative growth rate was significantly different among different treatments and observed a declining trend as the crop proceeds towards maturity.

5.2.4.4 SPAD chlorophyll meter reading

SPAD chlorophyll meter reading is a measure of greenness of the leaves. The results indicated that crop nutrition using different rice straw composts could significantly increase SCMR reading in fodder maize. This reading was significantly higher in plants treated under integrated nutrient management (T_8) and it was comparable to treatments T_6 and T_4. This could be attributed to the higher nutrient availability and better nutrient uptake by plants. It could be assured that the higher micronutrient status of composts (Table. 6) helped to improve the chlorophyll content of crop. Among micronutrients Fe, Mn and Zn play a significant role in influencing chlorophyll content. Fe has definite role in the biosynthesis of chlorophyll and it's precursors, while Mn and Zn support chlorophyll production through the activation of certain enzymes. This has been supported by James *et al.* (2008) also.

5.2.5 Soil analysis

5.2.5.1 pH and organic carbon

The pH of soil of experimental plot before the experiment was 5.9 and the organic carbon content was 1.7 percent. Analysis of soil after the experiment revealed that the different treatments failed to produce a significant influence on the pH and organic carbon content of the soil after the experiment (Table 16). All the treatments registered a moderately acidic pH and it ranged from 5.71 to 6.23 after the experiment. This indicates a slight increase in pH after the experiment, which is due to the buffering action of the compost. Compost addition provide relatively higher amount of basic cations to the soil, which reduce the exchangeable acidity and thereby raise the pH. These findings agree with those of Albert and Frimpong (2016) who attributed increase in pH of soil with the addition of compost. In the case of organic carbon a very minor increase was observed to the addition of composts to soil which served as carbon inputs. This might be due to the increased organic matter present in the compost. This was well supported by Frimpong *et al.* (2016) and Trupiano *et al.* (2017). Moreover the basal application of FYM at the time of ploughing could also increase the organic carbon content of soil, supported by Hussain *et al.* (2019).

5.2.5.2 Available soil nutrients

Different treatments could significantly influence the available nutrient status of the soil. Plants nourished with rice straw compost generated through co-composting of rice straw with goat manure and poultry manure (T_6) recorded greater availability of N, P as well as K, compared to plants under integrated nutrient management based on soil test data (T_8). This could attributed to the release of nutrients by the compost over a prolonged period and is agreement with with the findings of Ch’ng *et al.* (2014). According to Vo-Van-Binh *et al.* (2014) the addition of composted organic inputs to an agricultural soil increased the content of nutrients available for plants. Zhen *et al.* (2014) reported that compost application encourages the soil microbial population. Diverse microbes are maintained, which further helps in making available plant nutrients from the soil. Moreover the compost application decrease the possibility of nutrient losses in soils and enhances nutrient build up. Albert and Frimpong (2018) experimented with compost application in maize crop and confined slow release of nutrients in maintaining soil fertility.

5.2.6 Plant analysis

5.2.6.1 Content of major nutrients

Content of major nutrients N, P and K) was significantly influenced by different treatments. Plants nourished under integrated nutrient management (T_8) recorded higher NPK content and was comparable to T_6. The higher nutrient status of plants managed under organic nutrition could be due to the significant increase in the available nutrients in the soil (or easy mineralization because of narrower C:N ratio). These are responsible for enhancing plant establishment and their improved growth and nutritional status. In support to this, Clemente *et al.* (2012) and Pardo *et al*. (2014) reported the positive influence of compost and biochar amendments on the mobility and availability of nutrients to the plants (*Solanum lycopersicum* L.).

5.2.6.2 Uptake of major nutrients

Uptake of major nutrients (N, P and K) was significantly influenced by different treatments. Among those higher and comparable uptake of N, P as well as K were recorded in treatments T_8 (basal FYM followed by application of chemical fertilizers based on soil test data) and T_6 (plants under organic nutrition). Compared to the same amount of nutrients added to the soil the plant uptake from compost was lower than that from inorganic N fertiliser, because the organic N in the compost has to be mineralised before the plants can take it up. Odlare and Pell, (2009) supported these findings. Among the organic treatments T_6 performed better *i.e.*, the application of compost prepared from rice straw, poultry manure and goat manure. The higher organic matter content in the composts could improve root and shoot development which thus increase nutrient uptake. Lazcano *et al.* (2009) obtained the similar results on tomato plant by the application of compost. Compost addition increased microbial activity, improved soil structure or nutrient and water retention. This improved microbial activity can increase nutrient mobilisation and the improved soil structure and water retention will promote root growth and thus the nutrient uptake. This was similar to the results obtained by Oworu *et al.* (2010) by the application of compost prepared from fruit residues, manure and kitchen waste on amaranthus plant. Moreover the compost was rich in micronutrients like Fe, Mn, Zn, Cu and B which helps to improve the uptake of major nutrients. This was in conformity with the results of Amal *et al.* (2015), who reported that application of micronutrients are helpful for improving nutrient content and uptake in fenugreek.

5.2.7 Economics of cultivation

Economics of fodder maize cultivation using different rice straw compost as nitrogen source was worked out in terms of net returns and BCR. Higher net returns and B:C ratio was obtained with the treatments T_8 and $T_{6.}$ This could be attributed to the higher yield obtained from plants grown under these treatments. Furthermore, the cost of cultivation associated with these treatments was also less. This is because cheap price of chemical fertilizers used for crop nutrition in T_8 and more recovery of compost from treatment $T_{6.}$ With more recovery, 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 fodder maize was less when composts with low production cost were used as nutrient source. Significantly lowest net returns and B:C ratio was recorded in the treatment T_1, in which rice straw co-composted with cowdung in the ratio 4:1 was used as nutrient source. 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 *i.e.,* the lower recovery recorded with the treatment T_1 resulted in higher cost of production for unit compost material.

The economics of cultivation concluded that treatment T_8 *i.e.* based on INM recorded more lucrative in phrase of net returns (39814 $Rs.ha^{-1}$) and B:C ratio (1.31) followed by T_6 (based on organic nutrition).

SUMMARY

6. SUMMARY

The study entitled “Crop residue recycling for organic production of fodder maize in a rice based integrated farming system” was conducted during 2019-2020, at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, with the objectives to generate nutrient rich manures from rice straw through co-composting and to evaluate their efficacy in influencing the growth, yield, quality and economics of fodder maize.

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 co-composting were tried to generate nutrient rich organic manures from rice straw. The experiment was laid out in Completely Randomized Block design with eight treatments and three replications, where rice straw was mixed with cow dung (T_1), goat manure (T_2) and poultry manure (T_3) in the ratio 4:1 on volume basis. In treatments T_4, T_5, T_6 and $T_{7,}$ a ratio of 4:1:1 was followed. These treatments were rice straw + cow dung + goat manure (T_4), rice straw+ cow dung + poultry manure (T_5), rice straw + goat manure + poultry manure (T_6) and rice straw+ cow dung + glyricidia leaves (T_7). Natural composting of rice straw was followed in T_8 with no addition of organic manures.

Different rice straw composts generated from Experiment I were used as nitrogen equivalent component in Experiment II. The field experiment was laid out in Randomized Block Design with eight treatments and three replications during summer 2020. In this experiment FYM was applied uniformly for all treatments as basal dose at the time of ploughing. After that the compost prepared from experiment I was used as nitrogen equivalent component for treatments 1 to 7 at 15, 30 and 45 DAS as topdressing. In treatment T_8 (control), instead of compost integrated nutrient management based on soil test data according to KAU Package of Practices recommendations was followed. Fodder maize variety African tall, was used as the test crop.

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

Different methods of co-composting had a significant influence on the time taken for maturation of composts. Among different methods of co- composting tested, rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 (T_6) recorded significantly lowest time for composting (74.33 days).

Percentage recovery of composts varied significantly with different methods of co-composting. In general, co-composting treatments with combination of goat manure and poultry manure as N source recorded higher recovery compared to other methods of composting. Rice straw co-composted with the highest quantity of poultry manure and goat manure (T_6) recorded the highest recovery of 55.33 per cent.

Different composting methods were found to have no significant influence on the pH and EC of rice straw composts. All the composts generated had a slightly alkaline pH ranging from 7.78 to 8.16. The EC values ranged from 0.63 to 0.90 dS m^{-1} and were within the acceptable limit of < 4 dS m^{-1}. Composting could significantly narrow down the initial wide C: N ratio (39:1) of rice straw. Rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 (T_6) recorded a lower C: N ratio of 10.23:1 and was comparable to treatments T_4 (10.67) and T_5 (10.69).

Different composting methods could significantly influence the major and micronutrient status of rice straw composts. Nutrient content of the composting material was found to increase with the progress of composting. The compost obtained from rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 (T_6) was found rich in plant nutrients and recorded higher N (3.30 %), P (0.98 %) and K (3.22 %) contents and was comparable with the treatments T_4 and T_5 (N). But in case of K, the composts obtained from co-composting of rice straw with cowdung and glyricidia leaves in the ratio 4:1:1 (T_7) was found comparable with treatment T_6.

With respect to micronutrient status Fe, Mn, Zn, Cu and B content of different composts were significantly influenced by composting methods. In general, co-composting treatments T_6, T_4 and T_5 recorded higher micronutrient status. Rice straw co-composted with poultry manure and goat manure in the ratio 4:1:1 (T_6) recorded the higher iron content (3201.66 mg kg^{-1}) and was comparable to treatments T_5 (3187.00 mg kg^{-1}) and T_4 (3031.83 mg kg^{-1}). T_6 could also record the highest content of copper (45.58 mg kg^{-1}), superior to all other treatments. Content of manganese also was significantly higher for T_6 (1096.17 mg kg^{-1}), but on a par with treatment T_5 (1053.75 mg kg^{-1}). With respect to zinc, T_6 recorded higher content (280.40 mg kg^{-1}) comparable to treatments T_4 (244.85 mg kg^{-1}), T_5 (244.67 mg kg^{-1}) and T_7 (211.85 mg kg^{-1}). T_6 could also record significantly superior boron content of 19.97 mg kg^{-1}. It could thus be generalized that T_6 performed better with regard to content of all the micronutrients, comparable or closely followed by treatments T_5 and T_4 mostly.

The results of field experiment study indicated that rice straw composts as nitrogen equivalent component had significant influence on growth, yield attributes, physiology and quality attributes of fodder maize. Plants under integrated nutrient management based on soil test data (T_8) produced taller plants at all stages of crop growth comparable to T_6, T_4 and T_5. At 40 DAS, T_8 recorded a higher plant height of 119.34 cm whereas $T_{6,}$ T_4 and T_5 recorded comparable plant heights of 115.15 cm, 113.30 cm and 113.05 cm respectively. Towards the later stages of crop growth plant height was found higher and comparable for the treatments where co - composted rice straw was made used as nitrogen equivalent component (T_6, T_4 and T_5). At final harvest (70 DAS), T_8 recorded higher plant height (180.87cm) and was comparable to treatments T_6 (176.74 cm), T_4 (174.81 cm), T_5 (172.15 cm).

Significant influence of different treatments on the number of leaves was noticed at 40 DAS and at final harvest. Soil test data based application of chemical fertilizers given in addition to basal FYM (T_8) could record more number of leaves in both these stages and was comparable to treatments T_6 ,T_4 and $T_{5.}$ At 40 DAS, T_8 could record a leaf count of 9.33 and treatments $T_{6,}$ T_4 and T_5 recorded comparable leaf counts of 9.22, 9,11 and 9.00 respectively. At harvest stage, T_8 recorded more number of leaves (12.67) and was comparable with treatments T_6 (12.56), T_4 (12.45), T_5 (12.22).

The dry matter production of fodder maize increased progressively from 20 DAS to harvest. The effect of treatments and plants response was statistically traceable at two stages *i.e.* 20-40 DAS and 40 DAS to harvest. At 40 DAS, T_8 (Basal dose of FYM followed by soil test data based application of chemical fertilizers) recorded higher dry matter production (5393 kg ha^{-1}) and was comparable to T_6 (5243 kg ha^{-1}). At harvest also, T_8 (13580 kg ha^{-1}) and T_6 (13309 kg ha^{-1}) recorded higher and comparable DMP, similar to that at 40 DAS. This was again followed by the comparable performance of T_4 and T_5.

Different treatments had a significant influence on green fodder yield. Significantly higher yield of 33.56 t ha^{-1} was recorded with the treatment T_8 (basal dose of 10 t ha^{-1} FYM followed by soil test based application of chemical fertilizers). As per KAU Package of Practices Recommendations, the nutrient dose for fodder maize is 120:60:40 kg NPK ha^{-1}. Based on soil test data, this rate was reduced and NPK nutrients @ 85.2:15:37.6 kg ha^{-1} were applied to test crop. Treatment T_8 which was based on integrated nutrient management was however found comparable to organic nutrition treatments T_6 (33.11 t ha^{-1}), T_4 (32.67 t ha^{-1}), T_5 (32.23 t ha^{-1}) and T_7 (32.20 t ha^{-1}) wherein different rice straw composts were supplied on organic nutrition basis to meet the inorganic N dose.

Among different treatments, T_8 (KAU POP recommendation combining organic and inorganic nutrients) recorded a higher crude protein content 8.26 per cent and was comparable to T_6 (8.19%), T_4 (8.17 %) and T_5 (8.11 %) *i.e.* plants nourished under organic nutrition using rice straw composts.

Leaf area index of fodder maize was recorded at three crop stages and found significantly influenced by different treatments at 40 DAS and at harvest (Table 12). At 40 DAS, LAI was higher with treatment T_8 (3.67) and it was comparable with T_6 (3.45) and T_4 (3.36). At harvest T_8 (5.91) recorded higher LAI comparable to T_6, T_4 and T_5.

Different treatments on crop nutrition including INM (T_8) and organic nutrition using rice straw composts (T_1-T_7) were found to have a significant influence on the crop growth rate of fodder maize at 40 DAS and at harvest. CGR recorded at 40 DAS was significantly higher for treatment T_8 (23.15 g m^{-2} day^{-1}) and was comparable to T_6 (22.44 g m^{-2} day^{-1}). During harvest stage, T_8 registered a higher CGR (40.94 g m^{-2} day^{-1}) and was comparable to T_6 (40.33 g m^{-2} day^{-1}), T_5 (40.12 g m^{-2} day^{-1}) and T_4 (39.89 g m^{-2} day^{-1}). Relative growth rate of fodder maize was worked out at different stages of crop growth *i.*e., 20 to 40 DAS and at 40 DAS to harvest. At 40 DAS, plants nourished under integrated nutrient management (T_8) registered higher relative growth rate (0.0978 g g^{-1}day^{-1}) and was comparable to T_6 (0.0969 g g^{-1}day^{-1}), T_4 (0.0963 g g^{-1}day^{-1}), T_5 (0.0955 g g^{-1}day^{-1}) and T_7 (0.0949 g g^{-1}day^{-1}). At crop harvest, T_5 (0.0319 g

g^{-1} day^{-1}) registered higher RGR however comparable to T_4 (0.0313 g $g^{-1}day^{-1}$) and T_6 (0.0310 g $g^{-1}day^{-1}$). In the case of chlorophyll content significantly higher SCMR of 48.70 was recorded in fodder maize with treatment T_8 (basal FYM, followed by soil test based application of chemical fertilizers according to KAU Package of Practices Recommendations) and which was on par with treatments T_6 (46.12) and T_4 (45.09).

Different treatments failed to produce a significant effect on pH and organic carbon of the soil after the crop harvest. The pH ranged from 5.71 to 6.23 and the organic carbon content varied from 1.7 per cent to 1.76 per cent. Soil nutrient status was found to be better maintained than the initial status after crop harvest in all treatments. Available P and K content were higher for organic nutrition treatments T_6 and T_4. The uptake of major nutrients was higher for T_8 and T_6 followed by T_4 and T_5.

Treatment T8 was identified as most remunerative in terms of highest net returns (Rs.39814 ha^{-1}) and B:C ratio (1.31) followed by T_6.

The results of the present study revealed that co-composting is an efficient technology for producing quality organic manure from rice straw and different organic manures. Co-composting at the ratio 4:1:1 performed better in terms of generating compost rich in plant nutrients, narrower C:N ratio, earliness in maturity and better recovery ($T_{6,}$ $T_{4,}$ T_5 and T_7). Among these treatments, T_6 (rice straw + goat manure + poultry manure in 4:1:1 ratio) could be rated as most superior based on the time taken for composting (74.33 days). When utilized for organic crop nutrition of fodder maize African Tall, could result in comparable growth and yield as that with the integrated nutrient management package recommended by KAU.

Future line of work

- Repeat the experiment in the fields of integrated rice farmers and to work out the extent of cost reduction possible by accounting family labour and cost free resources especially rice straw and organic manures.
- Studies on in situ composting of left over rice straw in crop fields.
- Explore the efficacy of rice straw compost for vegetables and pulses grown in summer rice fallows.

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APPENDIX I

Weather data during the cropping period in (March 2020 to May, 2020)

Standard week	Temperature (^{o}C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	RH I	RH II	
09	33.10	23.90	95.90	86.00	0
10	33.00	23.40	92.70	86.00	8
11	33.40	24.60	90.40	82.60	0
12	33.40	25.40	92.70	76.40	8.6
13	32.90	24.90	93.60	81.90	0
14	33.40	26.90	89.30	86.10	4.3
15	33.40	25.10	88.20	83.40	9.6
16	33.70	26.70	81.60	72.20	12
17	34.10	25.20	84.40	83.30	74.1
18	32.90	25.40	83.90	72.40	21.8
19	32.60	26.00	79.40	69.00	0
20	33.00	26.80	82.70	68.70	0
21	32.80	25.80	84.40	75.90	73.2
22	32.40	26.40	86.80	73.80	0

APPENDIX II

Average input cost and market price of produce

Sl. No	Items	Cost (₹)
	INPUT	
A	Seed	80 per kg
B	Labour	780 per day
C	Cost of manures, fertilizers	
1	FYM	5 per kg
2	Lime	15 per kg
3	Urea	8 per kg
4	Rock phosphate	15 per kg
5	Muriate of potash	23 per kg
9	OUTPUT	
A	Market price of fresh fodder	5 per kg

ABSTRACT

CROP RESIDUE RECYCLING FOR ORGANIC PRODUCTION OF FODDER MAIZE IN A RICE BASED INTEGRATED FARMING SYSTEM

By

ATHIRA KV
(2018-11-108)

ABSTRACT

Submitted in partial fulfilment of the
requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

ABSTRACT

The study entitled "Crop residue recycling for organic production of fodder maize in a rice based integrated farming system" was undertaken during 2018-2020, at College of Agriculture,Vellayani, Thiruvananthapuram, Kerala, with the objectives to generate nutrient rich manures from rice straw through co-composting and to evaluate their efficacy in influencing the growth, yield, quality and economics of fodder maize.

The research work was carried out as two experiments at the Integrated Farming System Research Station (IFSRS), Karamana. Co-composting of rice straw was studied in Experiment I, wherein rice straw was mixed with organic manures including cow dung (T_1), goat manure (T_2) and poultry manure (T_3) the ratio 4:1 on volume basis. In treatments T_4, T_5, T_6 and $T_{7,}$ a ratio of 4:1:1 was followed. These treatments were rice straw + cow dung + goat manure (T_4), rice straw+ cow dung + poultry manure (T_5), rice straw + goat manure + poultry manure (T_6) and rice straw+ cow dung + glyricidia leaves (T_7). Natural composting of rice straw was followed in T_8 with no addition of organic manures.

The time taken for maturation of composts, percentage recovery of composts and quality parameters of different composts were found to vary significantly with different co-composting methods. Rice straw co-composted with goat manure and poultry manure in the ratio 4:1:1 (T_6) recorded significant earliness in maturity (74.33 days) and recovery (55.33 %) of compost. Treatment T_6 registered a narrower C: N ratio (10.23:1) and was comparable to treatments T_4 (10.67) and T_5 (10.69). Compost generated from T_6 recorded higher N (3.30 %) and P (0.90 %) content and was comparable to T_4 and $T_{5.}$ Higher K (3.22 %) content, was also noticed with $T_{6,}$ comparable to treatment T_7 (3.00 %). Micronutrient content was higher for treatments T_6, T_4 and T_5.

Different rice straw composts generated from Experiment I were used for organic production of fodder maize var. African Tall grown in summer rice fallows. The field experiment was conducted from March to May, 2020 and was laid out in Randomized Block Design with eight treatments and three replications. FYM @ 10 t ha^{-1} was applied uniformly for all treatments as basal dose at the time of ploughing.

The recommended dose of nutrients for fodder maize is 120: 60: 40 kg ha^{-1}. As per soil test data, the NPK dose required for the experimental field was 85.2: 15: 37.6 kg ha^{-1}. In treatments T_1 to T_7, respective composts prepared under Experiment I were supplied on nitrogen equivalent basis to substitute for the recommended dose of inorganic N and this was sufficient in providing the recommended P and K nutrients also. For treatment T_8 (control), KAU Package of Practices Recommendation was followed on soil test data basis. The results revealed that different treatments had significant influence on the growth, yield, physiological as well as quality parameters of fodder maize. Basal dose of 10 t ha^{-1} of FYM followed by chemical fertilizers (T_8) recorded taller plants at all stages of crop growth but was comparable to treatments $T_{6,}$ T_4 and T_5. These treatments could also record higher and comparable leaf number per plant as well as higher dry matter production at 40 DAS and at harvest stages of crop. Physiological parameters like leaf area index, crop growth rate, relative growth rate and chlorophyll content were observed to vary significantly under different treatments. Treatment T_8 recorded higher green fodder yield (33.56 t ha^{-1}) and crude protein content (8.26%) and was comparable to organic nutrition treatments $T_{6,}$ T_4 and T_5.

Soil nutrient status of the cropped field in terms of available nitrogen, phosphorus and potassium was found to be better maintained than initial status after crop harvest, in all treatments. Available P and K content were higher for organic nutrition treatments T_6 and $T_{4,}$ whereas available N remained unaffected by treatments. Different treatments could not significantly influence the final soil pH and organic carbon status of soil. Uptake of major plant nutrients was significantly higher for treatments T_8 and T_6. Treatment T_8 was identified as most remunerative in terms of higher net returns (Rs. 39814 ha^{-1}) and benefit: cost ratio (1.31). This was followed by $T_{6,}$ registering net returns of Rs. 27661 ha^{-1}and B: C ratio 1.20.

The present study revealed that co-composting of rice straw using nutrient rich organic inputs could generate quality composts. When utilized for organic crop nutrition of fodder maize African Tall, compost could result in comparable growth and yield as that with the integrated nutrient management package recommended by KAU. The study confirms that, rice straw which is lacking in quality for use as cattle feed due to improper drying and which is often accumulated as a bio waste in fields could efficiently be recycled for crop production and the technology is quite promising for rice based integrated farmers for efficient recycling of farm resources.

സംഗ്രഹം

നെല്ലധിഷ്ഠിത സംയോജിത കൃഷി സമ്പ്രദായത്തിലെ ഒരു പ്രധാന ഉല്പന്നമാണ് വൈക്കോൽ. മഴക്കാലത്തെ വിളവെടുപ്പ്, കൃത്യമായി ഉണക്കുന്നതിലുള്ള സൗകര്യക്കുറവ് എന്നിവയെല്ലാം കാരണം ഉല്പാദിപ്പിക്കപ്പെടുന്ന വൈക്കോലിന്റെ നല്ലൊരു ഭാഗം കാലിത്തീറ്റയായി ഉപയുക്തമാകാതെ നഷ്ടമായി പോകുന്നു. ഇത്തരത്തിൽ കൃഷിയിടങ്ങളിൽ ജൈവമാലിന്യമായി നിക്ഷേപിക്കപ്പെടുന്ന വൈക്കോൽ കമ്പോസ്റ്റിംഗിലൂടെ മികച്ച ജൈവവളമായി മാറ്റാനാകും. ഈ വിഷയത്തെ അടിസ്ഥാനമാക്കിയുള്ള ഒരു ശാസ്ത്രീയ പഠനം കേരള കാർഷിക സർവകലാശാലയുടെ കീഴിൽ തിരുവനന്തപുരം വെള്ളായണി കാർഷിക കോളേജിൽ 2018-2020 കാലഘട്ടത്തിൽ നടത്തുകയുണ്ടായി.

വൈക്കോൽ പലതരം ജൈവ വസ്തുക്കളുമായി കൂട്ടി കലർത്തി (കോ - കമ്പോസ്റ്റിംഗ്) വിഘടിപ്പിച്ചിട്ടാണ് മികച്ച ജൈവവളങ്ങളാക്കി മാറ്റിയത്. ഈ പരീക്ഷണത്തിൽ ചാണകം, കോഴിക്കാരം, ആട്ടിന്കാഷ്ഠം, ശീമക്കൊന്നയില എന്നിങ്ങനെ പല ജൈവവസ്തുക്കൾ കോ-കമ്പോസ്റ്റിംഗിനായി ഉപയോഗപ്പെടുത്തി. വൈക്കോൽ, ജൈവവവസ്തുക്കൾ എന്നിവ 4:1, 4:1:1 എന്നീ അനുപാതങ്ങളിൽ (വ്യാപ്തി അളവാക്കി) ആണ് കോ - കമ്പോസ്റ്റിംഗിന് ഉപയോഗിച്ചത്. 4:1 അനുപാതത്തിൽ വൈക്കോലിനൊപ്പം ചാണകം/ആട്ടിന്കാഷ്ഠം/കോഴിക്കാരം എന്നിവയും 4:1:1 അനുപാതത്തിൽ വൈക്കോൽ, ചാണകം, ആട്ടിന്കാഷ്ഠം / വൈക്കോൽ, ചാണകം, കോഴിക്കാരം /വൈക്കോൽ, ചാണകം, ശീമക്കൊന്നയില എന്നിങ്ങനെ ആയിരുന്നു പരീക്ഷണങ്ങൾ.

മേൽപറഞ്ഞ പഠനത്തിൽ നിന്നും 4:1:1 എന്ന അനുപാതത്തിൽ (വ്യാപ്തത്തിന്റെ അടിസ്ഥാനത്തിൽ) വൈക്കോൽ, ആട്ടിന്കാഷ്ഠം, കോഴിക്കാരം എന്നിവ യോജിപ്പിച്ചുള്ള കമ്പോസ്റ്റിംഗിലൂടെ 74 ദിവസത്തിനുള്ളിൽ കമ്പോസ്റ്റ് തയ്യാറായി. കമ്പോസ്റ്റിംഗിനായി ഉപയോഗിച്ച ജൈവവസ്തുക്കളുടെ 55.33 ശതമാനം അളവിൽ കമ്പോസ്റ്റ് ലഭ്യമാകുകയും ചെയ്തു. ഈ കമ്പോസ്റ്റിലെ കാർബൺ: നൈട്രജൻ അനുപാതം 10.23:1 എന്ന നിലയിൽ മികച്ചതായി കണ്ടു. കൂടാതെ സസ്യമൂലകങ്ങളുടെ അളവിലും ഇത്

മികച്ചു നിന്നു. (3.3% പാകജന്യകം, 0.9% ഭാവഹം, 3.22% ക്ഷാരം). ഈ കമ്പോസ്റ്റിൽ സൂക്ഷ്മമൂലകങ്ങളുടെ അളവും മികച്ചതായിരുന്നു.

തുടർന്ന് നടത്തിയ വിള പരീക്ഷണത്തിൽ തീറ്റചോളം (ആഫ്രിക്കൻ ടോൾ ഇനം) നട്ടു വളർത്തുകയും പഠനം I ൽ ഉത്പാദിപ്പിച്ച വിവിധ കമ്പോസ്റ്റുകൾ ഇതിനു ജൈവവവളമായി ഉപയോഗപ്പെടുത്തുകയും ചെയ്തു. ജൈവവരീതിയിൽ വളർത്തിയ ചോളം T6 (4:1:1) എന്ന അനുപാതത്തിൽ വൈക്കോൽ, കോഴിവളം, ആട്ടിന്കാഷ്ഠം എന്നിവ ചേർത്ത് ഉത്പാദിപ്പിച്ച കമ്പോസ്റ്റ്) ജൈവ-രാസവസ്തുക്കൾ സമന്വയിപ്പിച്ച വിള പോഷണത്തിനു തത്തുല്യ നിലയിൽ മികച്ചതായി കണ്ടു. മേൽപറഞ്ഞ സസ്യപോഷണ രീതിയിൽ നിന്നും ഹെക്ടറൊന്നിനു 33 ടൺ കണക്കിൽ ഉത്പാദനം ലഭ്യമായി.

കൃത്യമായി ഉണങ്ങാത്തതുമൂലം കന്നുകാലിതീറ്റയായി ഉപയുക്തമല്ലാത്തതും വയലുകളിൽ ജൈവ മാലിന്യമായി അടിഞ്ഞു കൂടുന്നതുമായ വൈക്കോൽ, വിള ഉൽപാദനത്തിനായി പുനരുപയോഗം ചെയ്യാമെന്നും നെല്ല് അടിസ്ഥാനമാക്കിയുള്ള സംയോജിത കൃഷിക്കാർക്ക് ഈ സാങ്കേതികവിദ്യ വളരെ ഗുണം ചെയ്യമെന്നും ഈ പഠനം സ്ഥിരീകരിക്കുന്നു.