

**NUTRIENT RELEASE AND BIOLOGICAL
ACTIVITY OF SOILS INCORPORATED
WITH CEREAL CROP RESIDUES**

BY

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B.Sc. (Ag.)

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Place:

Date: Bapatla

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CERTIFICATE

This is to certify that the thesis entitled “**Nutrient release and biological activity of soils incorporated with cereal crop residues**” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the major field of **Soil Science and Agricultural Chemistry** of the Acharya N. G. Ranga Agricultural University, Guntur is a record of the *bonafide* original research work carried out by **Ms. KANITI S P CHOWDARY** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma or has been published. The published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Ms. S P CHOWDARY. KANITI has satisfactorily prosecuted the course of research and that the thesis entitled “**Nutrient release and biological activity of soils incorporated with cereal crop residues**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

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DECLARATION

I, S P CHOWDARY. KANITI, hereby declare that the thesis entitled **“Nutrient release and biological activity of soils incorporated with cereal crop residues”** submitted to the **Acharya N. G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** in the major field of **Soil Science and Agricultural Chemistry** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Bapatla

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ABSTRACT

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A green house experiment entitled **“Nutrient release and biological activity of soils incorporated with cereal crop residues”** was conducted at Department of Soil Science and Agricultural Chemistry, Agricultural College, Bapatla, during *kharif*, 2013 to study the influence of crop residues and their composts on soil properties and performance of rice in terms of yield and nutrient uptake. The test soil was non-saline, clay in texture and neutral in reaction. The soil was medium in organic carbon, low in available nitrogen, medium in phosphorus, high in potassium and sufficient in sulphur status. All the micronutrients were above the critical limit except zinc.

The experiment was laid out in CRD with nine treatments replicated thrice. The treatments comprised of **T₁** - 100% RDFN, **T₂** - 100% RDFN+ 25% N through paddy straw, **T₃** - 100% RDFN+ 25% N through paddy compost, **T₄** - 100% RDFN + 25% N through maize stalk, **T₅** - 100% RDFN+ 25% N through maize compost, **T₆** -75% RDFN+ 25% N through paddy straw, **T₇** -75% RDFN+ 25% N through paddy compost, **T₈** - 75% RDFN+ 25% N through maize stalk and **T₉** - 75% RDFN+ 25% N through maize compost. Crop residues and prepared composts were applied to soil as per the treatments based on their nitrogen content 15 days before transplanting of rice seedlings. Nitrogen was applied in three splits as per the treatments in the form of urea. Phosphorus (basal) and potassium (two equal splits) were applied in the form of SSP and muriate of potash, respectively to all the treatments.

The influence of various treatments on soil properties (physical, physico-chemical properties, available nutrients and biological activity) and performance of rice (yield and nutrient uptake) were determined by standard procedures at different stages.

Application of inorganics alone or in combination with crop residues or composts didn't show marked difference in bulk density, pH, EC and CEC of the soils. However, the treatments supplied with inorganic fertilizer in combination with crop residues or composts resulted in significant increase in organic carbon content and improved water holding capacity of the soil over no residue treatment (100% RDFN). Application of 100 % RDFN+ 25% N through maize compost was found to be superior in maintaining maximum mineral nitrogen and available nutrient contents.

The microbial population (bacteria, fungi and actinomycetes) and enzyme activity (dehydrogenase) of soil in treatments supplied with cereal crop residues and composts in all combinations (T₂ to T₉) were found to be statistically higher than only inorganic treatment at all crop growth stages. The treatments, which received 25% N through crop residue composts (T₃, T₅, T₇ and T₉) recorded relatively higher values than the raw crop residue treatments (T₂, T₄, T₆ and T₈).

The performance of rice in terms of drymatter production, grain and straw yields was significantly influenced by the treatments. The treatment supplied with 100% RDFN + 25% N through maize compost recorded maximum drymatter production, grain and straw yield. The same treatment resulted in significantly higher uptake of all nutrients and it was followed by treatment supplied with 100% RDFN + 25% N through paddy compost.

LIST OF CONTENTS

Chapter No.	Title	Page No.
I	INTRODUCTION	
II	REVIEW OF LITERATURE	
III	MATERIAL AND METHODS	
IV	RESULTS AND DISCUSSION	
V	SUMMARY AND CONCLUSIONS	
	LITERATURE CITED	

T ₁ R ₁	T ₉ R ₂	T ₁ R ₃
T ₂ R ₁	T ₈ R ₂	T ₂ R ₃
T ₃ R ₁	T ₇ R ₂	T ₃ R ₃
T ₄ R ₁	T ₆ R ₂	T ₄ R ₃
T ₅ R ₁	T ₅ R ₂	T ₅ R ₃
T ₆ R ₁	T ₄ R ₂	T ₆ R ₃
T ₇ R ₁	T ₃ R ₂	T ₇ R ₃
T ₈ R ₁	T ₂ R ₂	T ₈ R ₃
T ₉ R ₁	T ₁ R ₂	T ₉ R ₃

Treatments : 9 Treatments
 Replications : Three
 Design : CRD
 Season : *kharif*, 2013-14
 Variety : BPT 5204

Fig. 3.1. Layout of pots in greenhouse

Chapter I

INTRODUCTION

Rice is the staple food crop for more than half of the world's population. Rice is grown in an area of 161.42 M ha with an annual production of 678.688 M t and productivity of 4200 kg ha⁻¹ in the world. In India, it is grown in an area of 39.47 M ha with an annual production of 87.83 m t and productivity of 2284 kg ha⁻¹. In Andhra Pradesh, rice is grown in an area of 40.06 lakh ha with a production of 12.88 M t and productivity of 3217.17 kg ha⁻¹ (Ministry of Agriculture, 2011-12). The ministry of new and renewable energy (MNRE, 2009) government of India has estimated that about 500 Mt of crop residues are generated every year.

The increasing constraints of labour and time under intensive agriculture have led to the adoption of mechanized farming in rice based cropping systems, which leaves large amounts of crop residues in the fields. As crop residues interfere with field operations for the next crop, farmers often prefer to burn the residues. In addition to environmental pollution, burning results in large losses of organic carbon, plant nutrients and also harms beneficial soil organisms. Crop residue management is known to affect soil quality indicators either directly or indirectly.

Incorporation of crop residues alters the soil environment, which in turn influences the microbial population and activity in the soil and subsequent nutrient transformations. It is through this chain of events that management of crop residues regulates the efficiency with which fertilizer, water, and other reserves are used in a cropping system. Another feature of rice-based cropping system (RBCS) in the tropics is the inherent conflict between maximizing short term production at minimum cost versus providing sustainable health and long term productivity of the soil. One reason for this conflict is the general below average economic condition of the farmers practicing RBCS. In the tropics, crop residues have, in fact played a pivotal role in the maintenance of soil resources at acceptable levels because these are the major sources of carbon inputs.

In comparison with other organic materials, cereal residues are relatively poor with respect to nitrogen and phosphorus content. Thus, crops sown immediately after the incorporation of residues of cereal crops suffer due to deficiency of plant available nitrogen. Addition of fertilizer nitrogen to the decomposing residues only partially offsets the immobilization process. Therefore, a major problem encountered in the profitable utilization of cereal crop residues is the occurrence of microbial immobilization of soil and fertilizer N and possible release of phytotoxic compounds (Mary *et al.*, 1996). Allowing adequate time for decomposition of crop residues before planting the next crop can be beneficial in alleviating adverse effects due to nitrogen immobilization and phytotoxicity. Composting is an environment friendly and less energy consuming process. It is a biological process in which organic wastes are converted into humus through activities of complex soil micro organisms. This process can be hastened in an organized manner so as to make them available for plants.

In Krishna zone, rice-maize cropping system is a major one in which both crops leave considerable biomass. The knowledge on mineralization and nutrient release from rice straw and maize stalk and their influence on biological activity would be very much helpful in proper management of the crop residues. Keeping this in view, the present investigation was conducted using raw rice and maize residues and their composts with the following objectives:

OBJECTIVES

1. To study the nutrient availability in the soils.
2. To assess the changes in biological activity of the soils.
3. To estimate the drymatter production and uptake of nutrients by rice.

LIST OF SYMBOLS AND ABBREVIATIONS USED

@	:	At the rate of
a.i	:	Active ingredient
$^{\circ}\text{C}$:	Degree Celsius
CD @ 5%	:	Critical difference at 5 per cent probability level
CFU g^{-1}	:	Colony forming units per gram
cm	:	Centimetre
cmol (p^+) kg^{-1}	:	Centimole of unit positive charge per kilogram
CRD	:	Completely randomized design
Cu	:	Copper
CV	:	Coefficient of variation
DAT	:	Days after transplanting
dS m^{-1}	:	Deci Siemen per metre
EC	:	Electrical conductivity
<i>et al.</i>	:	And others
Fe	:	Iron
Fig.	:	Figure
g	:	Gram
g^{-1}	:	Per gram
g ha^{-1}	:	Gram per hectare
g kg^{-1}	:	Gram per kilogram
g pot^{-1}	:	Gram per pot
h^{-1}	:	Per hour
ha^{-1}	:	Per hectare
<i>i.e.</i>	:	That is
K	:	Potassium
K_2O	:	Potassium oxide
kg	:	Kilogram
kg^{-1}	:	Per kilogram
kg ha^{-1}	:	kilogram per hectare
L^{-1}	:	Per litre
Mgm^{-3}	:	Mega gram per metre cube

mg kg ⁻¹	:	Milligram per kilogram
mg pot ⁻¹	:	Milligram per pot
min	:	Minimum
mL	:	Millilitre
mm	:	Millimetre
Mn	:	Manganese
MOP	:	Muriate of potash
µg TPF g ⁻¹ soil day ⁻¹	:	Microgram of triphenyl formazon per gram of soil per day
µg g ⁻¹ soil	:	Microgram per gram soil
µg pot ⁻¹	:	Microgram per pot
N	:	Nitrogen
nm	:	Nanometer
No.	:	Number
NS	:	Non - significant
ppm	:	Parts per million
P	:	Phosphorus
pH	:	Potential of hydrogen ion concentration
P ₂ O ₅	:	Phosphorus pentoxide
PNP	:	Para nitrophenol
%	:	Percent
RDF	:	Recommended dose of fertilizers
SEm±	:	Standard error of mean
SSP	:	Single super phosphate
TPF	:	Triphenyl formazone
viz.	:	Namely
Zn	:	Zinc

LIST OF TABLES

Table No.	Title	Page
3.1	Weekly meteorological data during the crop growth period (03-10-2013 to 03-01-2014)	
3.2	Characteristics of the experimental soil.	
4.1	Chemical composition of the crop residues and composts (on dry weight basis)	
4.2	Soil properties at 15 days after incorporation of crop residues and composts	
4.3	Influence of crop residues and composts on soil physical and physico-chemical properties at harvest	
4.4	Influence of crop residues and composts on physico-chemical properties of soils	
4.5	Influence of crop residues and composts on soil organic carbon (g kg^{-1}) content	
4.6	Influence of crop residues and composts on ammonical nitrogen content (kg ha^{-1}) in soils	
4.7	Influence of crop residues and composts on nitrate nitrogen content (kg ha^{-1}) in soils	
4.8	Influence of crop residues and composts on available nitrogen content (kg ha^{-1}) in soils	
4.9	Influence of crop residues and composts on available phosphorus content (kg ha^{-1}) in soils	
4.10	Influence of crop residues and composts on available potassium content (kg ha^{-1}) in soils	
4.11	Influence of crop residues and composts on available sulphur content ($\mu\text{g g}^{-1}$) in soils	
4.12	Influence of crop residues and composts on available iron content ($\mu\text{g g}^{-1}$) in soils	

Table No.	Title	Page
4.13	Influence of crop residues and composts on available zinc content ($\mu\text{g g}^{-1}$) in soils	
4.14	Influence of crop residues and composts on available copper content ($\mu\text{g g}^{-1}$) in soils	
4.15	Influence of crop residues and composts on available manganese content ($\mu\text{g g}^{-1}$) in soils	
4.16	Influence of crop residues and composts on bacterial population ($\times 10^5$ CFU g^{-1} soil) of soils	
4.17	Influence of on crop residues and composts fungal population ($\times 10^3$ CFU g^{-1} soil) of soils	
4.18	Influence of crop residues and composts on actinomycetes population ($\times 10^3$ CFU g^{-1} soil) of soils	
4.19	Influence of crop residues and composts on soil dehydrogenase activity ($\mu\text{g TPF g}^{-1}$ soil h^{-1})	
4.20	Influence of crop residues and composts on drymatter production at 60 DAT, grain and straw yield of rice	
4.21	Influence of crop residues and composts on nitrogen and phosphorus uptake (mg pot^{-1}) by rice	
4.22	Influence of crop residues and composts on potassium and sulphur uptake (mg pot^{-1}) by rice	
4.23	Influence of crop residues and composts on uptake of iron and zinc (mg pot^{-1}) by rice	
4.24	Influence of crop residues and composts on uptake of manganese and copper (mg pot^{-1}) by rice	

LIST OF FIGURES

Fig. No.	Title	Page
3.1	Layout of pots in green house	
4.1	Influence of crop residues and composts on soil organic carbon content (g kg^{-1})	
4.2	Influence of crop residues and composts on ammonical nitrogen content (kg ha^{-1}) in soils	
4.3	Influence of crop residues and composts on nitrate nitrogen content (kg ha^{-1}) in soils	
4.4	Influence of crop residues and composts on available nitrogen content (kg ha^{-1}) in soils	
4.5	Influence of crop residues and composts on available phosphorus content (kg ha^{-1}) in soils	
4.6	Influence of crop residues and composts on available potassium content (kg ha^{-1}) in soils	
4.7	Influence of crop residues and composts on available sulphur content ($\mu\text{g g}^{-1}$) in soils	
4.8	Influence of crop residues and composts on available iron content ($\mu\text{g g}^{-1}$) in soils	
4.9	Influence of crop residues and composts on available zinc content ($\mu\text{g g}^{-1}$) in soils	
4.10	Influence of crop residues and composts on available copper content ($\mu\text{g g}^{-1}$) in soils	
4.11	Influence of crop residues and composts on available manganese content ($\mu\text{g g}^{-1}$) in soils	
4.12	Influence of crop residues and composts on soil dehydrogenase activity ($\mu\text{g TPF g}^{-1} \text{ soil day}^{-1}$)	
4.13	Influence of crop residues and composts on drymatter production at 60 DAT, grain and straw yield (mg pot^{-1}) of rice	

4.14	Influence of crop residues and composts on nitrogen uptake (mg pot^{-1}) by rice	
4.15	Influence of crop residues and composts on phosphorus uptake (mg pot^{-1}) by rice	
4.16	Influence of crop residues and composts on potassium uptake (mg pot^{-1}) by rice	
4.17	Influence of crop residues and composts on sulphur uptake (mg pot^{-1}) by rice	
4.18	Influence of crop residues and composts on iron uptake (mg pot^{-1}) by rice	
4.19	Influence of crop residues and composts on zinc uptake (mg pot^{-1}) by rice	
4.20	Influence of crop residues and composts on copper uptake (mg pot^{-1}) by rice	
4.21	Influence of crop residues and composts on manganese uptake (mg pot^{-1}) by rice	

LIST OF PLATES

Plate No.	Titles	Page
3.1	Composts prepared from paddy straw and maize stalk	
3.2	General view of layout of pots in green house	
4.1	Bacterial colonies in different treatments at 30 DAT	
4.2	Bacterial colonies in different treatments at 60 DAT	
4.3	Fungal colonies in different treatments at 30 DAT	
4.4	Fungal colonies in different treatments at 60 DAT	
4.5	Actinimycetes colonies in different treatments at 60 DAT	
4.6	Actinomycetes colonies in different treatments at 90 DAT	

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Note: The literature is cited following the guidelines given by Acharya N. G. Ranga Agricultural University, Guntur, Andhra Pradesh.

Chapter III

MATERIAL AND METHODS

The present investigation entitled “Nutrient release and biological activity of soils incorporated with cereal crop residues” was carried out during *kharif* 2013 in green house of Agricultural College, Bapatla. The details of materials used and experimental procedures followed during the course of investigation are described in this chapter.

3.1 LOCATION AND CLIMATE

The experiment was conducted at Agricultural College, Bapatla located in coastal region of Krishna Agro Climatic Zone of Andhra Pradesh. The data on weather parameters recorded during the period of experimentation (August 2013 to January 2014) are presented in table 3.1. The weekly mean maximum and minimum temperatures ranged from 28.1⁰C to 33.1⁰C and 17.3⁰C to 25.4⁰C respectively, while the average maximum and minimum temperatures during the crop period were 30.8 ⁰C and 20.9⁰C, respectively. The weekly mean relative humidity ranged from 75.6 to 90.1 per cent with an average of 82.96 per cent. A total rainfall of 560.3 mm was received during the period of experimentation with seventeen rainy days.

3.2 CROP RESIDUES

3.2.1. Collection and Preparation

Two types of crop residues namely paddy straw and maize stalk were collected from the Agricultural College Farm, Bapatla. The collected residues were air dried and chopped into small pieces.

3. 2. 2. Compost Preparation

Paddy straw and maize stalk each of 5 kg was kept for decomposition in 8 pots by adding fungal consortium for 45 days. They were covered with moist gunny bags and moistened every day to maintain optimum moisture conditions. Required turnings were done to hasten decomposition. The material was ready for use in 45 days.

**Table 3.1 Weekly meteorological data during the crop growth period
03-10-2013 to 03-01-2014)**

Standard week	Date and Month	Mean temperature (°C)		Mean relative humidity (%)	Rainfall (mm)	No. of rainy days
		Max	Min			
40	1 st Oct-7 th Oct, 2013	32.5	25.4	84.0	112.1	3
41	8 th Oct-14 th Oct, 2013	33.0	23.6	83.6	91.2	3
42	15 th Oct-21 st Oct, 2013	33.1	24.7	90.1	6.1	1
43	22 nd Oct-28 th Oct, 2013	28.1	24.1	90.0	288	5
44	29 th Oct-4 th Nov, 2013	32.0	24.1	86.3	6.9	2
45	5 th Nov-11 th Nov, 2013	31.2	21.3	82.4	0	0
46	12 th Nov-18 th Nov, 2013	30.1	19.5	80.2	1.3	0
47	19 th Nov-25 th Nov, 2013	30.7	22.1	84.2	39.3	2
48	26 th Nov-2 nd Dec, 2013	30.2	21.4	87.4	15.4	1
49	3 rd Dec -9 th Dec, 2013	29.9	18.4	80.2	0	0
50	10 th Dec-16 th Dec, 2013	30.7	17.7	75.6	0	0
51	17 th Dec – 23 rd Dec 2013	29.3	16.6	80.2	0	0
52	24 th Dec – 31 st Dec 2013	29.8	17.7	75.7	0	0
1	1 st Jan -7 th Jan 2014	29.9	17.3	81.6	0	0
Total		430.5	293.9	1161.5	560.3	17
Mean		30.8	20.9	82.96		

Rainy day= more than 2.5mm rainfall per day.

3.2.3 Analysis of Crop Residues and Compost

The carbon and nutrient contents of paddy straw, maize stalk and their composts used in this study were determined by using standard methods as described below.

3.2.3.1 Carbon

The total carbon content in crop residues and compost samples was estimated by wet oxidation method given by Chopra and Kanwar (1976).

3.2.3.2 Nitrogen

The nitrogen content in crop residues was estimated by micro Kjeldahl distillation method as given by Piper (1966). Whereas, in compost it was estimated by macro Kjeldahl distillation method as outlined by Chopra and Kanwar (1976).

3.2.3.3 Total Nutrients

One gram of powdered plant sample or compost was taken in 150 mL Erlenmeyer flask was digested with diacid mixture (HNO_3 : HClO_4 in 9:4 ratio). The sample digest was filtered through Whatman No.42 filter paper by washing with small quantities of double distilled water until it was chloride free and diluted to 100 mL. The clear extract obtained was used for the determination of P, K, Fe, Zn, Mn and Cu.

3.2.3.4 Phosphorus

The phosphorus content in the diacid digest was determined by vanadophosphomolybdate yellow colour method. The intensity of yellow colour was determined using spectrophotometer at 420 nm as given by Piper (1966).

3.2.3.5 Potassium

The potassium concentration in the diacid mixture was determined using flame photometer as described by Muhr *et al.* (1965).

3.2.3.6 Micronutrients

The procedure outlined by Lindsay and Norvell (1978) was followed for determining micronutrient cations viz., Fe, Zn, Mn and Cu by using atomic absorption spectrophotometer.

3.3 Experimental Soil

A representative sample was collected from the bulk of soil and analysed for physical, physico-chemical, chemical and biological properties before the experimentation by following standard procedures. The data on initial characteristics of the experimental soil are presented in table 3.2.

3.4 EXPERIMENTAL DETAILS

3.4.1 Experimental Design and layout

The experiment was conducted in green house of Agricultural College, Bapatla using rice (BPT-5204) as a test crop in completely randomized design. The experiment was designed with 9 treatments comprising of two types of crop residues (paddy straw and maize stalk) in combination with inorganic fertilizers as mentioned below. The arrangement of pots in greenhouse is depicted in figure 3.1.

Treatmental details:

T ₁	:	100% RDFN
T ₂	:	100% RDFN +25% N through paddy straw
T ₃	:	100% RDFN+25% N through paddy compost
T ₄	:	100%RDFN +25% N through maize stalk
T ₅	:	100% RDFN +25% N through maize compost
T ₆	:	75% RDFN +25% N through paddy straw
T ₇	:	75% RDFN +25% N through paddy compost
T ₈	:	75% RDFN +25% N through maize stalk
T ₉	:	75% RDFN +25% N through maize compost

RDFN - recommend dose of fertilizers

Recommended dose of P₂O₅ and K₂O were applied uniformly to all the treatments.

3.5 CONDUCT OF GREEN HOUSE EXPERIMENT

A cement pot of 20 kg capacity was selected to raise nursery. The pot was filled with soil and mixed with FYM. Required quantity of treated rice (BPT 5204) seed was soaked in water for 24 hours and incubated for 48 hours to induce germination. The sprouted seeds were broadcasted uniformly in pots to raise nursery. Nursery was irrigated whenever necessary and 2% urea solution and 0.5% FeSO₄ were sprayed for its healthy growth. Necessary quantities of compost prepared from rice straw and maize stalk were mixed up in 20 kg soil by considering their nitrogen content as per the treatments 15 days prior to transplanting of rice seedlings. A total of five treatments (no residue, 25% of N through paddy straw, maize stalk and their composts) were replicated six times for carrying out statistical analysis of samples at 15 days after addition of organics.

Nitrogen was applied in the form of urea as per the treatments in three equal splits viz., basal, maximum tillering (45 DAT) and panicle initiation (90 DAT). Recommended dose of phosphorus (60 kg P₂O₅ ha⁻¹) was applied at the time of transplanting through single super phosphate whereas half of recommended dose of potassium was applied at transplanting through muriate of potash and remaining half was at panicle initiation.

The soil in each pot was puddled manually and nine healthy seedlings of 28 days old were transplanted in 3 hills at the rate of 3 seedlings per hill in each pot. The soil in the pots was kept under submergence with water to a depth of 4 to 5 cm till ten days before harvest. Weeding was done time to time. To ensure even stand and to maintain optimum plant population, gap filling was done at 7 DAT.

During the experiment the incidence of blast and leaf folder were observed. So plant protection measures were taken up against blast and leaf folder using Tricyclazole @ 0.6 g L⁻¹ at 20 DAT and Monocrotophos @ 1.6 mL L⁻¹ at 50 DAT, respectively through hand sprayer with a spray volume of 1 L.

The crop was manually harvested on 3rd Jan, 2014 *i.e.* 120 days after transplanting. The produce of individual pot was then threshed manually and grain, straw and biological yields were recorded on per pot basis. Initial, 15 days after incorporation of crop residues and soil samples at 30, 60, 90 and 120 days after transplanting were collected from different treatments and the plant samples were collected at 60 and 120 DAT.

3.6 ESTIMATION OF YIELD PARAMETERS, YIELD AND NUTRIEN UPTAKE

3.6.1 Panicle Length

Randomly selected panicles were measured and their average length was reported on per panicle basis.

3.6.2 Number of Grains per Panicle

Total number of grains of randomly selected panicles was counted from each pot and average was reported per panicle.

3.6.3 Thousand Grain Weight (g)

The weight of thousand grains was recorded from the grain samples drawn randomly from each pot produce of each treatment and expressed in grams.

3.6.4 Grain Yield (g pot⁻¹)

The air dried panicles from each pot were threshed, cleaned and weight of the grain was recorded on the basis of grain yield per pot.

3.6.5 StrawYield (g pot⁻¹)

The weight of straw from each pot was recorded after complete sun drying until a constant weight.

3.6.6 Nutrient uptake

The uptake of nutrients at harvest was worked out by using the following formulae. Macronutrients uptake was expressed as mg pot^{-1} and micronutrient uptake was expressed in mg pot^{-1}

$$\text{Macronutrient Uptake (mg pot}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{Dry matter yield (mg pot}^{-1}\text{)}}{100}$$

$$\text{Micronutrient Uptake (mg pot}^{-1}\text{)} = \text{Nutrient concentration (\mu g/g)} \times \text{Dry matter yield (mg pot}^{-1}\text{)}$$

3.7 SOIL ANALYSIS

3.7.1 Collection and Preparation of Soil Samples

For microbial activity samples at initial, before imposing treatments and at 30, 60, 90 and 120 DAT up to a depth of 30 cm were collected and stored in polythene bags at 2 to 4⁰ C for as short time as possible until examination. To carryout enzyme activity, samples were collected at 15 days after addition of crop residues / compost and at 30, 60, 90 and 120 DAT.

Soil samples at initial and 15 days after incorporation of crop residues and at 30, 60, 90 and 120 days after transplanting were collected from different treatments, thoroughly mixed, air dried, ground with wooden pestle mortar taking care not to crush concretions and passed through 2 mm sieve for general soil analysis. The sieved soil samples were stored in clean poly bags with proper labels.

3.7.2 Biological Activity

3.7.2.1 Enumeration of microbial population

The microbial counts in fresh soil samples were taken out by following serial dilution plate count technique (Dhingra and Sinclair, 2000). Exactly 1g of soil was added to 9 mL of sterile water to dilute the population by 10 times, from which 1 mL was transferred to another 9mL of sterile water to make it 10^2 times dilution and it was continued till required dilution was obtained.

The nutrient agar medium was prepared by mixing agar agar-20 g; beef extract-3 g; peptone-5 g solution; water-1 litre for bacterial count (10^5 dilution) and pour into petri plate. Exactly 0.1 mL of the final diluted sample was transferred on to a petri plate with nutrient agar medium in laminar air flow chamber and spread with 'L' shaped glass rod and allowed to grow for one and half day after which colony counts were recorded.

Likewise fungal count was estimated at 10^3 dilution using Rose Bengal Agar medium treated with streptomycin. Selective medium like khusters agar was used for actinomycetes count (10^3 dilution).

3.7.2.2 Enzyme activity

Dehydrogenase activity

Dehydrogenase activity in the soil samples was determined by following the procedure as described by Klein *et al.* (1971). Exactly 5 grams of soil was taken in a screw cap test tube to which one mL of 3 per cent aqueous solution of 2,3,5- triphenyltetrazolium chloride (TTC), one mL of one per cent glucose solution and 2.5 mL of distilled water (sufficient to leave a thin film of water above the soil layer) were added. The test tubes were stoppered with rubber bands and incubated at 30°C for 24 hours. At the end of incubation, the contents of the tube were rinsed down into a small beaker and converted into slurry by adding 10 mL methanol, the slurry was filtered through Whatman No. 1 filter paper. Repeated rinsing of soil with methanol was continued till filtrate was free

of red colour. The intensity of red colour was measured at 485 nm wave length, against a methanol blank in a spectrophotometer. The concentration of Triphenylformazon (TPF) formed in the soil sample was determined using graded concentrations of formazon. The results were expressed in milligram of TPF formed per gram of soil per day.

3.7.3 Physical, Physico-chemical and Chemical Properties of Soil

3.7.3.1 Bulk density

Bulk density was determined in the soils by following clod method as suggested by Dastane, 1967.

3.7.3.2 Water holding capacity

Water holding capacity was determined by Keen Raczkowski brass cup method as described by Sankaram (1966).

3.7.3.3 Soil reaction (pH)

Soil pH was determined in the soil suspension (1: 2.5 soil: water) by a glass electrode pH meter after equilibrating the soil with water for 30 minutes with occasional stirring (Jackson, 1973).

3.7.3.4 Electrical conductivity (EC)

The soluble salt content of soil samples was determined in 1: 2.5 soil water suspension using electrical conductivity bridge (Jackson, 1973).

3.7.3.5 Organic carbon (O.C)

The OC was determined by following Walkley and Black's (1934) wet digestion method as reported by Jackson (1973) was followed.

3.7.3.6 Cation exchange capacity

It was determined by saturating the soil with 1N sodium acetate (pH 8.2) and excess of sodium was washed with 98% ethyl alcohol. The adsorbed sodium was then replaced by ammonium acetate (pH 7.0) solution and the sodium concentration in leachate was determined by flame photometer as outlined by Jackson (1967).

3.7.3.7 Mineral nitrogen

Ammonical nitrogen

Acidified NaCl extractable $\text{NH}_4^+\text{-N}$ was determined by Kjeldahl distillation method (Jackson, 1958).

Exactly 100g of fresh soil sample was treated with 200 ml of 10% NaCl in an Erlenmeyer flask. The flask was stoppered and shake for 30 minutes on a mechanical shaker. The suspension was filtered through a Buchner funnel lined with 11 cm dia Whatman no 42 filter paper and connected to a vacuum pump. The contents are transferred to round bottom flask for distillation and contents are distilled and the $\text{NH}_4^+\text{-N}$ is calculated on dry basis.

Nitrate nitrogen

The nitrate nitrogen content of the soils was determined by the procedure outlined by A.O.A.C. (1950).

3.7.3.8 Available nitrogen or Mineralizable nitrogen

Available nitrogen content in the soils was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956), where in both inorganic (ammonical and nitrate nitrogen) and part of organic nitrogen that can be mineralized are included.

3.7.3.9 Available phosphorus

Available phosphorus in the soil samples was extracted with 0.5 M NaHCO_3 of pH 8.5 (Olsen *et al.*, 1954) and the phosphorus in the extract was estimated colorimetrically by ascorbic acid method using spectrophotometer at 660 nm (Watanabe and Olsen, 1954).

3.7.3.10 Available potassium

Available potassium in soil was extracted using neutral normal ammonium acetate and potassium in the extract was determined flame photometrically (Muhr *et al.*, 1965).

3.7.3.11 Available sulphur

Available sulphur was determined by extracting with 0.15% calcium chloride dehydrate and sulphur in the extract was determined by turbidimetric method using spectrophotometer at 420 nm (Hesse, 1971).

3.7.3.12 DTPA extractable micronutrients

Available zinc, copper, manganese and iron in the soils were extracted using DTPA extract (Lindsay and Norvell, 1978) and determined using atomic absorption spectrophotometer .

3.8 COLLECTION, PREPARATION AND ANALYSIS OF PLANT SAMPLES

3.8.1 Collection and Preparation of Plant Samples

The plant samples collected at 60 and 120 DAT were washed with dilute HCl and then with distilled water. The samples were shade dried initially and then oven dried at 60⁰ C temperature and grinding was done with electrically operated grinder. The ground plant samples were stored in paper bags and used for analysis.

3.8.2 Plant Analysis

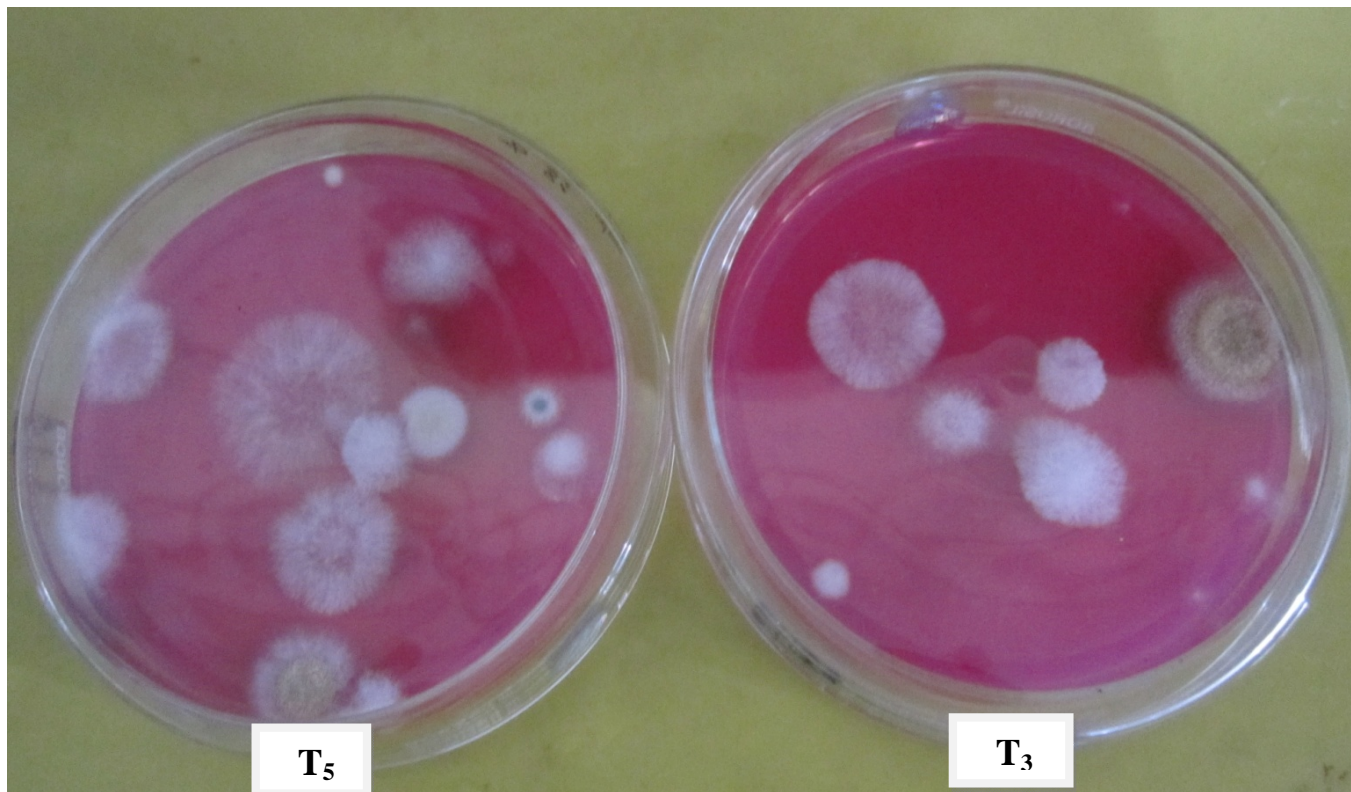
Nitrogen, phosphorus, potassium and micronutrients in plant samples were estimated by following standard procedures as mentioned in 3. 2. 3.

3.9 STATISTICAL ANALYSIS

The data obtained on chemical analysis and biometrical observations were analyzed statistically using Fisher's method of analysis of variance as suggested by Panse and Sukhatme (1978) following the completely randomized design. Statistical significance was tested by F value at p=0.05 level of significance. Relationship between soil properties and performance of rice crop was established with simple correlation.



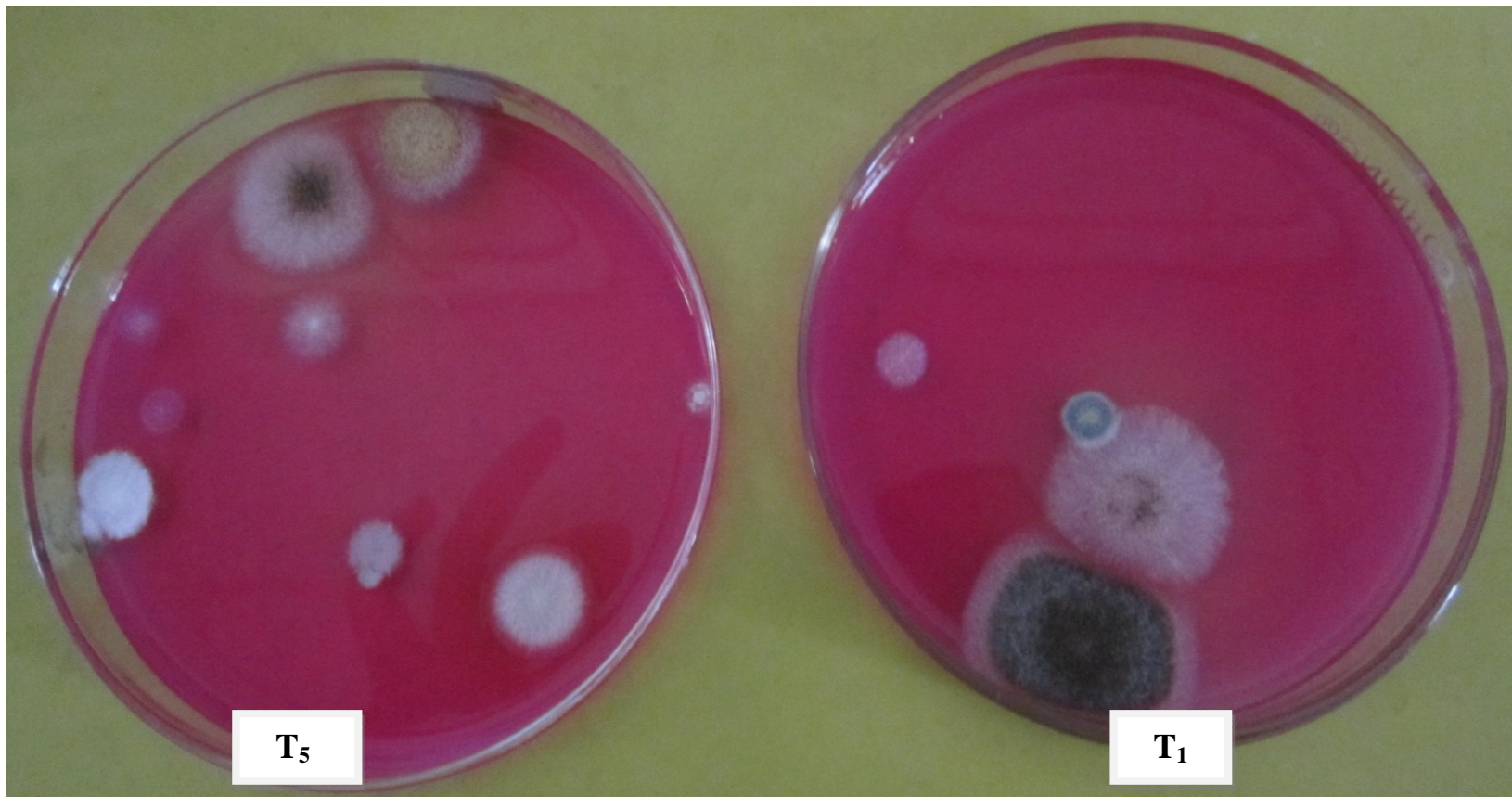
Plate 3.1. Composts prepared from paddy straw and maize stalk



100 % RDFN + 25% N through maize compost

100 % RDFN + 25% N through paddy compost

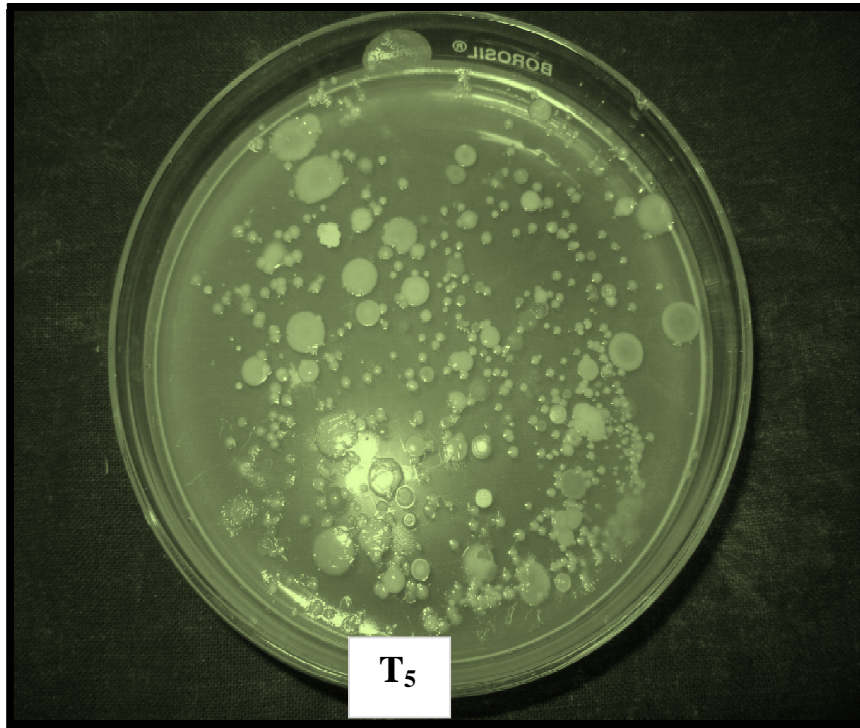
Plate 4.4. Fungal colonies in different treatments at 60 DAT



100 % RDFN + 25% N through maize compost

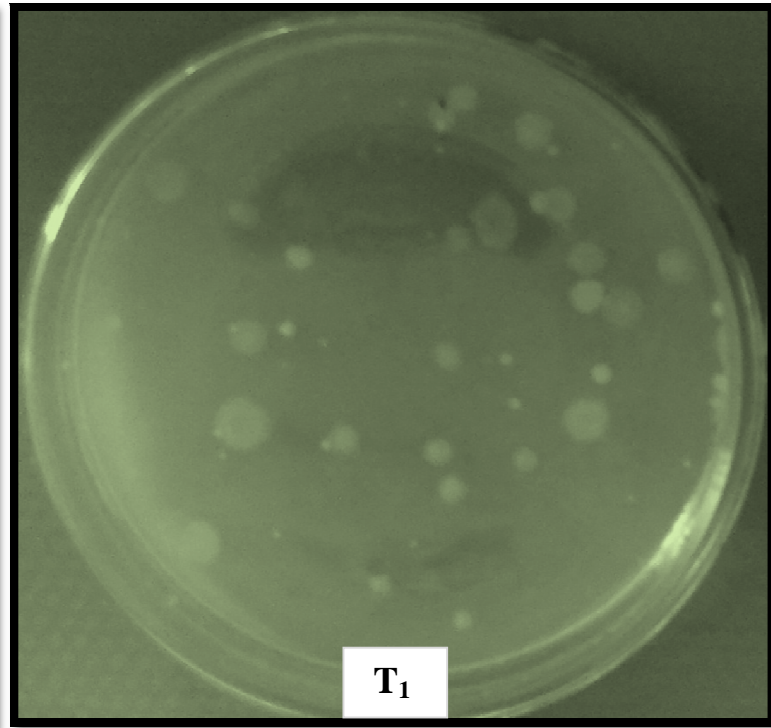
100 % RDFN

Plate 4.3. Fungal colonies in different treatments at 30 DAT



T₅

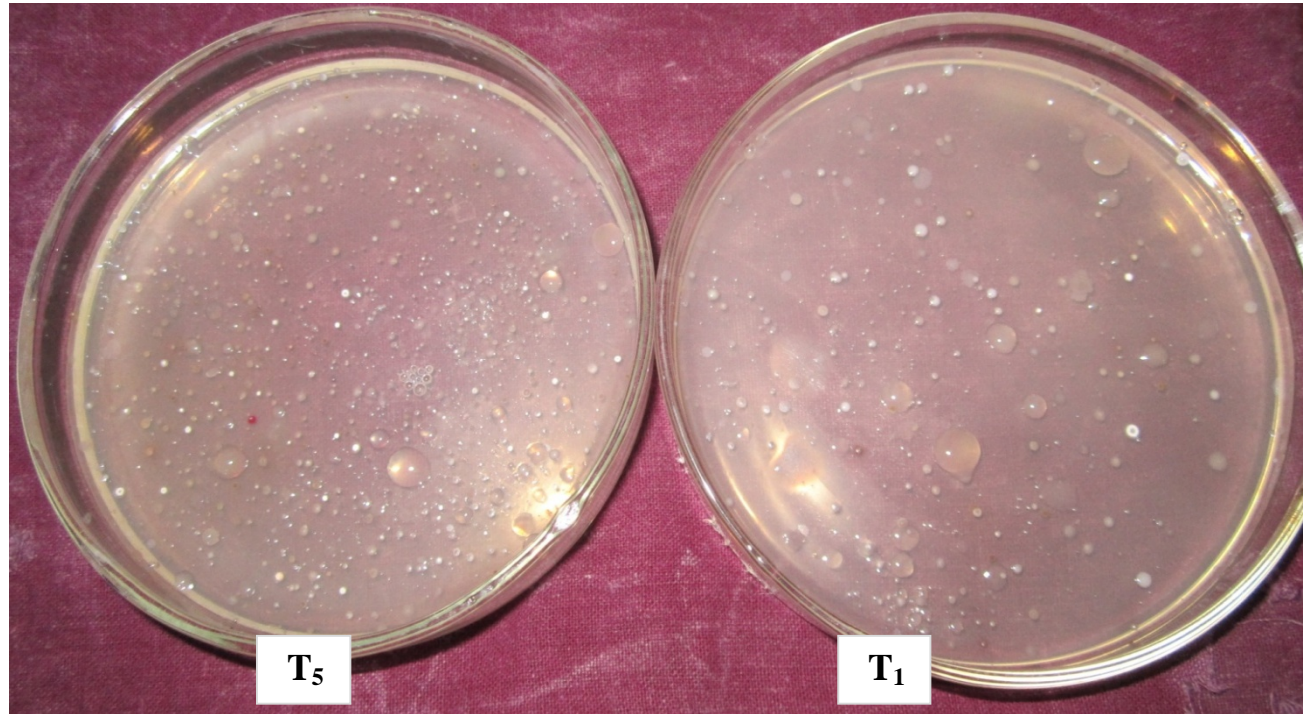
100 % RDFN + 25% N through maize compost



T₁

100 % RDFN

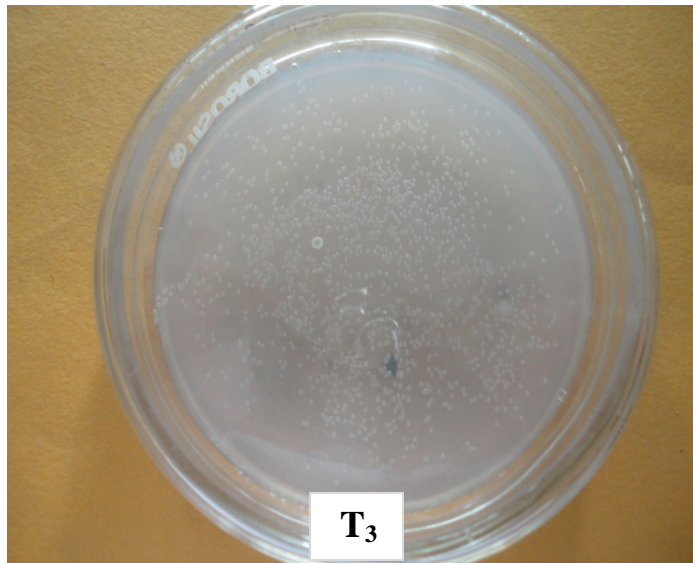
Plate 4.1. Bacterial colonies in different treatments at 30 DAT



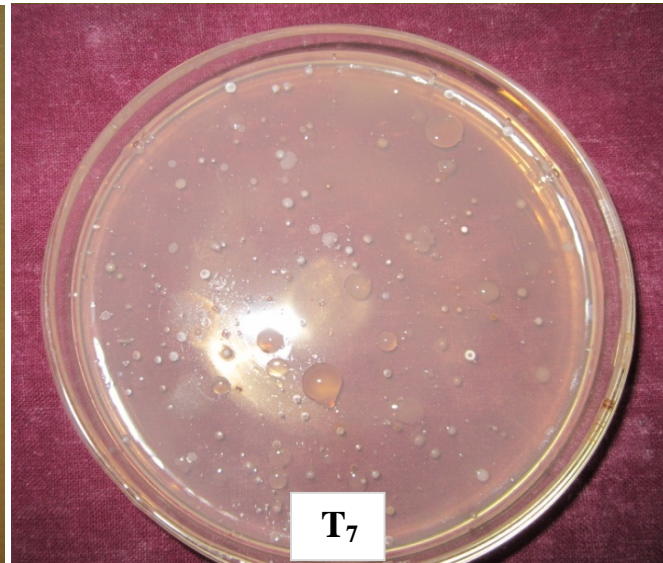
100 % RDFN + 25% N through maize compost

100 % RDFN

Plate 4.6. Actinomycetes colonies in different treatments at 90 DAT

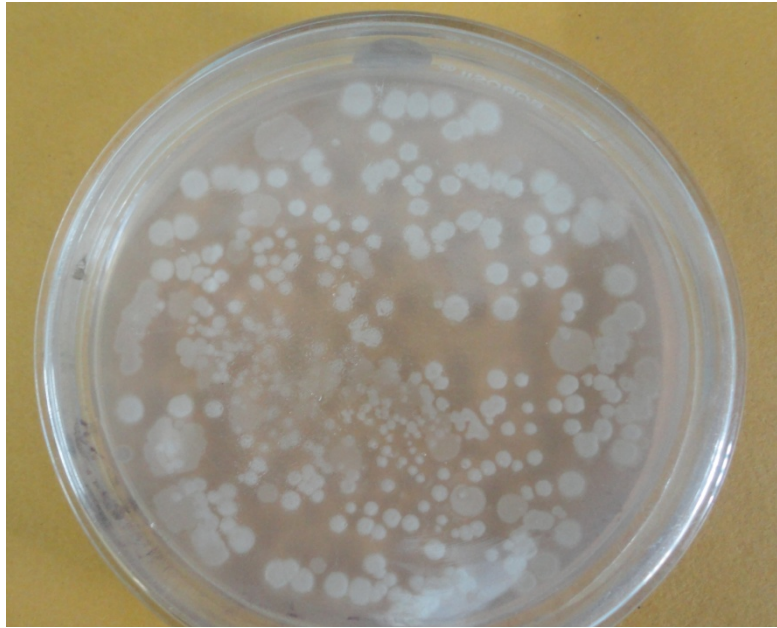


100 % RDFN + 25% N through paddy compost



100 % RDFN + 25% N through paddy straw

Plate 4.5. Actinomycetes colonies in different treatments at 60 DAT



T₅

100 % RDFN + 25% N through maize compost



T₃

75 % RDFN + 25% N through maize compost

Plate 4.2. Bacterial colonies in different treatments at 60 DAT



Plate. 3.2. General view of layout of pots in green house

Chapter IV

RESULTS AND DISCUSSION

A green house experiment entitled “Nutrient release and biological activity of soils incorporated with cereal crop residues” was conducted at Agricultural College, Bapatla during *kharif* 2013-2014 to find out the influence of crop residues and their composts on soil properties and performance of paddy at Department of Soil Science and Agricultural Chemistry, Agricultural College, Bapatla. The results obtained from the experiment were analysed statistically and are presented and discussed in this chapter with cause, effects and corroborative research findings under the following heads.

4.1 WEATHER CONDITIONS

The weather parameters *viz.*, temperature, relative humidity and rainfall presented in Table 3.1 revealed that the weekly mean maximum and minimum temperatures ranged from 28.1⁰C to 33.1⁰C and 17.3⁰C to 25.4⁰C respectively, while the average maximum and minimum temperatures during the crop period were 30.8⁰C and 20.9⁰C, respectively. The weekly mean relative humidity ranged from 75.6 to 90.1 per cent with an average of 82.96 per cent. A total rainfall of 560.3 mm was received during the period of experimentation with 17 rainy days.

4.2 CHEMICAL CHARACTERISATION OF CROP RESIDUES AND COMPOSTS

Composting is a controlled microbiological process where in several chemical and biochemical changes take place in crop residues. Chemical and biochemical changes during composting are important for the optimization process and the quality of the end product.

The chemical characteristics of crop residues and their composts are presented in Table 4.1.

The carbon content of fresh crop residues *viz.*, paddy straw and maize stalk were 39.58 and 40.06 per cent, respectively and the their composts contained 15.84 and 23.06 per cent, respectively. The data indicated that total organic carbon content decreased with the decomposition, which might be due to loss of carbon as CO₂ through microbial respiration and part of it may be assimilated by microorganisms (Bharne *et al.*, 2003).

The per cent nitrogen content of paddy straw, maize stalk and their composts were 0.71, 0.81, 0.89 and 1.22, respectively. The lowest nitrogen content was recorded in paddy straw over the maize stalk and its compost. The C:N ratios of paddy straw, maize stalk and composts were 55.74, 45.01 and 19.5, 18.9, respectively. The composts recorded narrower C:N ratio than fresh crop residues. The phosphorus, potassium, sulphur and micro nutrients also followed similar trend. The high nutrient content in crop residue composts as compared to fresh crop residues might be due to mineralization of organic fractions leading to loss of carbon and accumulation of inorganic nutrients (Swetha *et al.* (2010); Palanivell *et al.* (2013)). The results are in agreement with Bharne *et al.* (2003), Pal and Jat. (2004), Surekha *et al.* (2004) and Adamu *et al.* (2014).

4.3 SOIL PROPERTIES AT 15 DAYS AFTER INCORPORATION OF CROP RESIDUES AND COMPOSTS

The data pertaining to the soil properties at 15 days after the incorporation of crop residues and composts at the time of transplanting are presented in Table 4.2.

The pH and EC of soils was not significantly influenced by the crop residues. The maximum ammonical nitrogen (11.67 kg ha⁻¹) was observed in treatment supplied with 25% N through maize compost (T₅), which was significantly superior over all others and followed by 25% N through paddy compost (T₃) and control (T₁). The lowest (4.5 kg ha⁻¹) ammonical nitrogen was observed in paddy straw treated pots (T₂) followed by maize stalk treated pots (T₄). Similar trend was observed with nitrate also. The significantly higher ammonical and nitrate nitrogen with composts compared to control (no residue)

indicated the net mineralization of nitrogen within 15 days of the compost application. Nitrate nitrogen followed similar trend to that of ammonical nitrogen. The compost treatments recorded significantly higher value than no residue treatments. Data also indicated high nitrate nitrogen contents than ammonical nitrogen, which could be due to the nitrification under aerobic conditions.

The perusal of the data indicated that the treatments comprised of raw residues (maize stalk and paddy straw) recorded significantly lower nitrogen (both ammonical and nitrate forms) compared to no residue treatment, indicating net immobilization. Overall it can be concluded that the ammonical and nitrate nitrogen were immobilized in the soil amended with crop residues and mineralized in the treatments which are amended with the crop residue composts. This was also reported by Yadvindersingh *et al.* (1988) and Singh *et al.* (1992).

The maximum microbial populations of 80.67×10^5 , 16.00×10^3 , 61.90×10^3 CFU g⁻¹ soil, respectively (bacteria, fungi and actinomycetes) were recorded in the treatment which received 25% FN through maize compost and the lowest values (45.33×10^5 , 8.67×10^3 , 38.9×10^3 CFU g⁻¹ soil, respectively) in the control *i.e.*, with no residue. In general the treatments supplied with composts recorded higher microbial populations compared to raw residues. Overall a significant increase in microbial populations was observed in organic treated pots compared to that of no residue treated pots.

The highest (32.67 g⁻¹ soil) dehydrogenase enzyme activity was recorded in the treatment incorporated with 25% RDF through maize compost and the lowest value (13.87 g⁻¹ soil, respectively) was recorded in the treatment supplied with 100% RDFN *i.e.*, without any residue. In general the treatments supplied with composts recorded higher microbial populations and enzyme activity compared to raw residues. Overall residue treated plots were superior over no residue treatments due to supply of carbon and energy for microorganisms.

4.4 INFLUENCE OF CROP RESIDUES AND COMPOSTS ON SOIL PROPERTIES

Bulk density (BD)

The bulk density of soils at harvest of paddy was not significantly influenced by the treatments (Table 4.3). Among the treatments bulk density values varied from 1.30 to 1.34. The lowest bulk density value of 1.30 Mg m⁻³ was observed in T₅, which received 100% RDFN and 25 % N through maize composts. The treatments supplied with crop residue compost recorded comparatively lower bulk density values than the treatments which received raw crop residues. This could be due to the higher percentage of organic carbon content and proliferation of biotic activity. Soil biota might have influenced the soil bulk density through formation of stable aggregates, development of organo-mineral complexes by improving macro porosity. This was reported by Mali *et al.* (2015) and Brar and Walia (2010).

Lowering of bulk density by incorporation of crop residues and composts under long term experiments was reported by Rajkhowa (2012), Das et al. (2001) and Bellakki *et al.* (1998) who reported that reduction in bulk density was due to higher organic carbon, more pore space and good soil aggregation. However the non-significant effect of treatments on bulk density in the present study could be due to shorter time period.

Water holding capacity (WHC)

The data presented in Table 4.3 revealed a significant improvement in the water holding capacity of soils in the treatments, which were amended with crop residues and composts compared to no residue treatment (47.61%). Water holding capacity was the highest (51.87%) in the treatment which was supplied with 100% RDFN + 25% RDN through maize compost (T₅) followed by the treatment supplied with 100 % RDFN + 25% RDN through paddy compost (T₃). The treatments comprised of maize stalk or composts were found to be significantly superior over all other treatments except T₇ (75% RDFN + 25% N through paddy compost), which was on par with T₈ (75% RDFN + 25% N maize stalk).

The data indicated that maize stalk or compost performed better in improving the water holding capacity of soil over paddy straw or compost. Incorporation of crop residues decreased the bulk density and increased the soil porosity, thus significantly enhanced the water holding capacity of soil. Better aggregation in soil with residue incorporation might be attributed to increase in soil organic carbon and microbial biomass carbon. Organic materials with high C:N ratio like cereal crop residues improves the soil physical properties like water holding capacity. This was reported by Yadav and Kumar (1993) and Das *et al.* (2001).

Cation exchange capacity

The data pertaining to cation exchange capacity (CEC) of the soils at harvest are presented in Table 4.3. The CEC of soils was not significantly influenced by different treatments at harvest as compared to initial CEC. Among the treatments CEC values ranged from 43.00 to 46.33. The lowest CEC value was recorded in 100 per cent RDFN while, the highest value in T₅ which received 100 per cent RDFN and 25 per cent nitrogen through maize compost. It was inferred that CEC of the soil was increased at harvest as compared to that of initial soil and that increase was higher in treatments which received crop residue compost. During decomposition, several organic compounds are formed, which result in metal-organo complexes or chelates, which helps in improving CEC.

Similar influence of integrated nutrient supply system on CEC was earlier reported by Pareek and Yadav (2011). Incorporation of crop residues in soils form humic substances on their decomposition, which play a dominant role along with clay micelle in the complex soil reactions and enhance the CEC of soils (Yadav and Kumar, 1993).

Soil pH

There was no significant influence of incorporation of crop residues on pH at any time of crop growth. On the other hand the pH decreased in all treatments as compared to the initial pH of the experimental soil (Table 4.4)

Crop residues can influence soil pH through accumulation of CO₂ and organic acids during their decomposition in the soils. A slight decrease in soil pH with the application of cereal residues was also reported by Gangaiah *et al.* (1999), and Kushwaha *et al.* (2000). However, Verma and Bhagat (1992) noted no significant effect of crop residue management on pH of soils even after five years of experimentation.

Electrical conductivity (EC)

The electrical conductivity values of the soils were not significantly influenced by the treatments at 30, 60, 90 and 120 DAT. The treatments which amended with crop residue compost recorded comparatively lower electrical conductivity values than the treatments incorporated with raw crop residues. The highest electrical conductivity was observed in T₁ (100% RDFN) at all days of study. Non-significant effect of applied sole inorganic fertilizers or combination with crop residue compost / crop residues on electrical conductivity might be due to balanced fertilization, which might not have allowed an increase in salt concentration. This was corroborated with the findings of Beri *et al.* (1992) and Kumar *et al.* (2004) who reported no change in electrical conductivity even after two years of continuous cropping.

Organic carbon

The data pertaining to OC content in soil at different days after transplanting are presented in Table 4.5 and depicted in Fig. 4.1. The content of carbon was significantly influenced by the treatments at all crop growth stages. The treatments supplied with 75% RDFN + 25% nitrogen through raw paddy straw (T₆) recorded the maximum carbon content at all crop growth stages, the lowest carbon content at all growth stages was recorded by T₁ (100% RDFN).

At 30 and 60 DAT, the treatment T₆, which recorded the highest value was found to be on par with all treatments supplied with the crop residue materials except T₉ and T₅ (maize compost with 75 and 100% RDFN, respectively). At 90 and 120 DAT, T₆ (75 % RDFN + 25% N through paddy straw) was comparable with all organic treatments and significantly superior over 100% RDFN (T₁). The organic carbon content irrespective of the treatment followed an increasing trend up to 60 DAT and later decreased. This could be due to the increased crop growth and more release of root exudates at active growth stages.

The perusal of data indicated that raw residue treatments resulted in higher carbon content than their respective compost, which can be attributed to the high carbon content of the applied materials. Slightly higher OC values were observed in treatments with lower dose of fertilizer nitrogen (75% RDFN) compared to higher dose (100% RDFN). However with advancement in growth stage the variation in carbon content among organic treatments was found to be low indicating that the effect of type and stage of material was non-significant. The data also indicated that the soils were enriched with the carbon due to residue application (raw or compost) compared to initial soil (3.70 g kg⁻¹).

Higher carbon content in raw residue treatments could be attributed to their higher C: N ratio, which results in slower decomposition. Addition of 100% RDFN might have favoured quick mineralization leading to lower carbon values than 75% RDFN. No significant effect among organic treatments at harvest could be due to the stabilization of mineralization. These results were corroborated with Yoshida *et al.* (1973) and Mary *et al.* (1996).

The organic nitrogen application might have created environment conducive for the formation of humic acid, which stimulated the activity of soil microorganisms resulting in an increase in the organic carbon content of soil (Bajpai *et al.*, 2006) The higher carbon content in soil in all the treatments at 60 DAT when compared to other stages of crop growth (30, 90 and 120 DAT) might be due to increased biomass of crop and microbial population.

The significant increase in organic content in all the treatments involving integrated use of nutrient sources as compared to use of inorganic fertilizer alone might be due to the enhanced root growth, which lead to the accumulation of organic residues and also direct addition of OC through crop residues in soil. The findings are in agreement with those of Sharma and Gupta (1998), Sharma (2001), Yadvindersingh *et al.*, (2004).

4.5 INFLUENCE OF CROP RESIDUES AND COMPOST ON AVAILABLE NUTRIENTS

Available Macronutrients

Nitrogen

Ammonical and nitrate nitrogen content at all stages of the crop revealed a significant influence of imposed treatments.

Ammoniacal nitrogen content (NH_4^+ - N)

Data presented in Table 4.6 indicated that the maximum ammoniacal nitrogen was observed at 60 DAT and later it followed a decreasing trend up to 120 DAT (harvest) in all the treatments. Application of nitrogen through both inorganic and organic (crop residues and compost) treatments increased the ammoniacal nitrogen content significantly over only inorganic fertilizer treatment with the highest (37.33 kg ha^{-1}) and the lowest (26.00 kg ha^{-1}) values recorded in T₅ (100% RDFN + 25% N through maize compost) and T₁ (100% RDFN), respectively at 30 DAT. Higher amounts of ammoniacal nitrogen was observed when organics were combined with 100% RDFN than 75% RDFN. In general the treatments supplied with composts resulted in higher ammoniacal nitrogen compared to the treatments with respective raw crop residues. Similar trend was observed at 60, 90 and 120 DAT with highest amounts of 42.33 , 36.00 and 34.00 kg ha^{-1} , respectively, recorded by the treatments supplied with 100% RDFN + 25% N through maize compost. The lowest values of 33.33 , 28.33 and 26.66 kg ha^{-1} were observed in treatment with no residues.

The treatment T₅, which supplied with 100% RDFN + 25% N through maize compost was found to be comparable with T₃ at 30 DAT, T₃ and T₉ at 60 DAT, T₃, T₄ and T₉ at 90 DAT comparable with T₃ and T₉ at 120 DAT.

Higher build up of NH₄⁺-N in organic treatments could be attributed to the continuous release of nitrogen from organic forms. Yadav and Singh (1991) also reported the favourable influence of applied manures on ammoniacal nitrogen. The treatments, where nitrogen was applied only through fertilizers, the nitrogen might have lost by leaching or denitrification (Duraismi *et al.*, 2001).

Nitrate nitrogen (NO₃⁻ - N)

Data presented in Table 4.7 indicated that the addition of raw or composted crop residues resulted in a significant effect on nitrate nitrogen content at all stages of crop growth. The nitrate nitrogen content was found to increase up to 60 DAT later it followed a decreasing trend. The lowest nitrate nitrogen content was recorded in control (100% RDFN) at all stages. The data indicated that treatments, which received organics recorded superiority over the no residue treatment up to harvest emphasizing the role of organics in sustaining the nitrogen supply. Further it was observed that at a given level of nitrogen higher nitrate values were recorded in treatments supplied with composts. The high amounts of NO₃⁻ - N at panicle initiation (60 DAT) could be due to high rate of mineralization encouraged by enhanced microbial activity during peak growth stage. T₅ was significantly superior to all treatments at 30 DAT and 120 DAT but comparable with T₃ at 60 and 90 DAT.

The data indicated that the treatments which received nitrogen through organics, in combination with fertilizers recorded higher NO₃⁻-N up to harvest. In case of 100% RDFN (T₁) treatment the conversion of NH₄⁺-N to NO₃⁻-N might have taken place at a rapid rate and this might have resulted in more leaching loss of nitrate nitrogen content in soils. Similar observations were recorded by Udaysoorian *et al.* (1989) Benbe *et al.* (1991) and Subbaiah *et al.* (2013).

Available Nitrogen

Available nitrogen determined by alkaline permanganate method includes both inorganic ($\text{NH}_4^+ + \text{NO}_3^-$) and mineralizable organic nitrogen. Data pertaining to available nitrogen (Table 4.8 and Figure 4.4) shows a significant influence by the imposed treatments at different stages of crop growth (30, 60, 90 and 120 DAT). All the treatments supplied with raw or composted residues resulted in significantly higher nitrogen values over only inorganic treatment (T_1 - 100% RDFN) at all stages of crop growth. The available nitrogen content increased up to 90 DAT and it followed a decreasing trend at harvest in all the treatments except T_1 (100% RDFN). When the decline in N was observed at 90 DAT, the lowest nitrogen content was recorded in the treatment supplied with 100% RDFN (T_1) at all growth stages.

At 30, 60, 90 and 120 DAT, significantly the highest (266, 268, 271 and 259 kg ha^{-1} , respectively) available nitrogen in soil was recorded with application of 100% RDFN in combination with maize compost (T_5), which was on par with all composts at 30 and 60 DAT and all compost treatments except T_7 (75% RDFN + 25% N through paddy compost) at 60 and 90 DAT. However, at 120 DAT, T_5 (100% RDFN + 25% N through maize compost) was comparable with all organic treatments except T_8 (75% RDFN + 25% N through maize stalk).

The data revealed that addition of organics resulted in considerably higher available nitrogen content of the soil throughout the plant growth. Significantly higher amounts of available nitrogen in initial stages of crop growth in compost treatments could be attributed to the quick mineralization of residues due to low C: N ratio. However at harvest, the effect was found to be nullified due to the increased mineralization of the raw residues.

When an organic matter of high C:N ratio (raw residue) is added to the soil, the microbes become active due to substrate availability and multiply rapidly to decompose the material. As a result, their demand for nitrogen increases with decreases in soil available nitrogen to plant. As the decomposition proceeds and the level of substrate decreases, the demand for nitrogen by

microbes also decreases and the mineralized nitrogen becomes more available to plant. In case of organic matter of low C:N ratio, due to less substrate (carbon), the multiplication of microbes is not much and hence there is less demand for N, resulting in more availability of nitrogen in soil for the crop.

Available Phosphorus (P_2O_5)

The data presented in Table 4.9 and depicted graphically in Figure 4.5 revealed a significant influence of treatments on soil phosphorous at different crop growth stages.

The content of phosphorous decreased with advancement of crop growth in treatments which received only fertilizer nitrogen while in treatments supplied with both fertilizer and organic nitrogen increased up to 90 DAT and then decreased. Among the treatments, the highest available phosphorus was observed in T_5 and the lowest in T_1 , which received 100 per cent RDFN + 25 per cent N through maize compost and 100 per cent RDFN, respectively at all stages of crop growth. Significant differences were observed with respect to phosphorus content between crop residue and compost treatments at each level of fertilizer N substitution. At lower level of nitrogen (75% RDFN) paddy straw and compost were at par with maize stalk and maize compost, respectively.

At 30 DAT and 60 DAT, the treatment supplied with 100 per cent RDFN + 25 per cent N through maize compost (T_5) was superior to rest of the treatments. The treatment T_3 (100 per cent RDFN + 25 per cent N through paddy compost) and T_9 (75 per cent RDFN + 25 per cent N through maize compost) were statistically comparable with each other. At 90 DAT, T_5 was found to show similar effect on available P content to that of T_9 and T_3 . While, it was on par with T_9 and superior to other treatments at 120 DAT.

The higher available phosphorus content of soil due to incorporation of crop residues may be attributed to the direct addition of phosphorus as well as solubilization of native phosphorus through release of organic acids. Displacement of phosphate by organic anions (citrate, oxalate, malate etc.,)

formed during the decomposition of organic residues and coating of sesquioxide particles by humus, which reduces P fixation. The results are in agreement with the findings of Urkurkar *et al.* (2010). The increase in the P availability may also be due to the formation of organophosphate, which is plant assimilable phosphorus humic compound (Narayanasamy and Biswas. 1998). This was more pronounced at the higher moisture level under irrigated conditions (Tiwari, 2003). These findings were in agreement with those of Kachroo and Dixit. (2005).

Available Potassium (K₂O)

Data pertaining to the available potassium content of the soil at 30 DAT, 60 DAT, 90 DAT and 120 DAT presented in Table 4.10 revealed that the content of potassium was significantly influenced by the treatments at all the crop growth stages. The content of potassium increased up to 90 DAT and later decreased at 120 DAT.

Among the treatments the highest available potassium was observed in treatment T₅, which received 100 per cent RDFN in combination with 25 per cent N through maize compost and the lowest was observed with T₁ (100% RDFN only) at all the stages of crop growth. Treatment T₅ was found to be comparable with that treatments receiving 100% N with extra 25% n through paddy compost and maize stalk (T₃ and T₄) and 75% RDFN + 25% N through maize compost and paddy compost (T₉ and T₇) at all growth stages.

Similar beneficial effect of added organic amendments on available potassium was earlier reported by Jambhekar (1994). The increase in available K due to organic matter application might be attributed to the direct addition of potassium to the available pool of the soil besides the reduction of potassium fixation and release of potassium due to the interaction of organic matter with clay (Tandon and Sekhon, 1988 and Guled *et al.*, 2002). The organic acids released during decomposition of manures mobilize the native or non-exchangeable forms of potassium and charge the soil solution with potassium ions, so that it will be readily available (Anuradha, 2003).

Available Sulphur

The data presented in Table 4.11 and depicted in Figure 4.7 revealed that the available sulphur content in soil was significantly influenced by different treatments at all growth stages of crop. The content of sulphur decreased with increase in stage of crop growth in treatment T₁ which received 100 per cent recommended doses of fertilizer N only, while treatments which received both fertilizer nitrogen and organic nitrogen through crop residues (T₂ to T₉ treatments) recorded an increase in sulphur content up to 60 DAT and then decreased at 90 DAT and 120 DAT. Significantly the highest available sulphur was recorded with 100 per cent RDFN + 25 per cent RDFN through maize compost (T₅) and the lowest at all crop growth stages was recorded in T₁, where there was no organic manure application in all the crop growth stages. The available sulphur content of soil was significantly higher with application of raw residue or compost with 100% RDFN compared to the respective organic source at lower level of nitrogen (75% RDFN).

At 30 DAT and 60 DAT, the treatments which received 100% RDFN + 25% N through maize compost (T₅) recorded the highest sulphur content followed by 75% RDFN + 25% paddy straw (T₃). They were on par with each other and statistically superior to the remaining treatments.

At 90 DAT and 120 DAT, the highest was recorded in treatment with 100% RDFN + 25% N through maize compost (T₅), and was markedly superior to all other treatments.

The significantly higher values in available sulphur content in all the organic treatments as compared to use of inorganic fertilizer might be due to release of organic bound sulphur and native sulphur through mineralization process. During decomposition of organic matter, organic sulphur compounds are transformed or oxidized to sulphates (Sekhon *et al.* 2002).

Available Micronutrients

The effect of crop residues and compost on micronutrients *viz.*, iron, zinc, manganese and copper contents are presented in the Tables 4.12 to 4.15 and depicted graphically in Figures 4.8 to 4.11, respectively.

The status of available micronutrient cations *viz.*, iron, zinc, manganese and copper at different crop growth stages (Table 4.12 to 4.15 and Figures 4.8 to 4.11) were significantly influenced by the treatments. The status of all the micro nutrients increased up to 60 DAT and then followed decreasing trend up to harvest in all the treatments.

Available Iron

At 30 and 60 DAT, the highest iron content (8.62, 9.18 $\mu\text{g g}^{-1}$, respectively) was recorded in the treatment supplied with 100% RDFN + 25% N through maize compost (T₅), which was significantly superior to all treatments except T₃ (100% RDFN + 25% N through paddy compost). While, at 90 and 120 DAT, T₅ (100% RDFN + 25% N through maize compost) which recorded the maximum values (8.51, 8.45 $\mu\text{g g}^{-1}$, respectively) was found to be at par with all organic treatments with 100% RDFN but superior over treatments with 75% RDFN. At 30 and 60 DAT all organic treatments except T₆ and T₈ were found to be superior over the control. All organic treatments were found to be superior to control at later stages of the growth. At 90 DAT, the treatments supplied with either raw residue or compost with 100% RDFN was comparable. At 120 DAT, all organic treatments with 75% RDFN were also comparable related to available iron. At all growth stages composts resulted in higher iron content compared to the raw residues and among the type of material maize residue or maize compost performed better than paddy straw or its compost.

Available Zinc

The results of the experiment showed that all the combined treatments significantly influenced the available zinc content over only inorganic nitrogen. At all crop growth stages the highest available zinc content was observed with T₅ (100% RDFN + 25% N through maize compost) followed by T₃ (100% RDFN + 25% N through maize compost), which were comparable and significantly superior over all other treatments. In general application of higher dose of N resulted in significantly higher available Zn content with respect to residue or compost. At a given dose, composts (paddy or maize) were significantly superior to raw residues.

Available Copper

At 30, 60 and 90 DAT, the highest copper content of 1.91 and 2.20 $\mu\text{g g}^{-1}$, respectively were recorded in treatment supplement with 100% RDFN + 25% N through maize compost (T₅) followed by the treatment, supplied with 100% RDFN + 25% N through paddy compost (T₃), which were statically at par and superior to the rest of the treatments.

At 120 DAT, the treatment 100% RDFN + 25% N through decomposed maize stalk (T₅) was statically on par with the remaining treatments, which retained 100 % RDFN (T₃, T₄, and T₂) and treatment with 75% RDFN + 25% N through maize compost (T₅).

Available Manganese

The treatments 100% RDFN + 25% N through maize compost (T₅) and 100% RDFN + 25% N through paddy compost (T₃) were statistically on par with each other and significantly superior over remaining treatments at all growth stages. The lowest manganese content was recorded in the treatment which was supplied with 100% RDFN.

The higher availability of micronutrients in soil with organics may be ascribed to mineralization, reduction in fixation of nutrients by organic matter and complexing properties of humic substances released from organics. The integrated treatments with organic manures either increased or retained the critical fertility status of micronutrients. Organic manures on decomposition produce a variety of biochemical substances (organic acids, polyphenols, amino acids and poly saccharides) which stimulate the solubility, transport and availability of micronutrients. Humic substances and organic acids formed after decomposition of crop residue by microflora may help in the translocation of iron which can be transported only with difficulty within the plant. Kumar *et al.* 2000, Dwivedi and Thakur. 2000 and Lakshmi *et al.* 2011.

The maximum availability of Fe, Zn, Mn and Cu in treatments which received crop residue and compost might be due to their release through mineralization and also due to production of chelating agents, which have the ability to reduce their adsorption, fixation and precipitation resulting in their enhanced availability in soil. Similar opinion was expressed by Dhanushkodi *et al.* (2009).

Meelu *et al.* (1994) Sharma *et al.* (2000) and Yadvindersingh *et al.* (2000) also observed the significant enhancement in DTPA-extractable micronutrients due to incorporation of crop residues and FYM compared to application of only chemical fertilizers. The organics being the storehouse of all plant nutrients including micro nutrients might have released them gradually and steadily contributed towards balanced nutrition of the crop. Incorporation of crop residues caused a slight increase in the availability of P, Mn, and Zn (Verma and Bhagat, 1992).

4.6 INFLUENCE OF CROP RESIDUES AND COMPOST ON BIOLOGICAL ACTIVITY OF SOILS

4.6.1 Microbial Populations

Bacterial population

The results of bacterial population presented in Table 4.16 and Plates 4.1 and 4.2 indicated a significant influence of imposed treatments on bacterial population. The highest values at 30, 60, 90 and 120 DAT (93.33×10^5 , 97.66×10^5 , 93.00×10^5 and 87.33×10^5 CFU g⁻¹ soil, respectively) were recorded in treatment T₅ which received 100% RDFN + 25% N through maize compost and the lowest counts (61.66×10^5 , 66.33×10^5 , 57.00×10^5 and 45.00×10^5 CFU g⁻¹ soil, respectively) were recorded in 100% RDFN treatment (T₁). The bacterial population in treatments supplied with cereal crop residue and compost in all combinations (T₂ to T₉) was found to be statistically higher than control treatment (T₁) at all crop growth stages. The treatments which received 25% N through crop residue composts (T₃, T₅, T₇ and T₉) recorded relatively higher values than the raw crop residue treatments (T₂, T₄, T₆ and T₈).

Increase in the bacterial population was observed at all stages of crop growth compared to the initial population of the experimental soil (40×10^5 CFU g⁻¹ soil). The bacterial counts were maximum at 60 DAT and followed a decreasing trend up to 120 DAT, which may be attributed to the release of more root exudates during active growth of the plant (Colvan *et al.*, 2001).

Fungal population

The fungal population (Table 4.17 and Plates 4.3 and 4.4) was significantly influenced by the imposed treatments and followed similar trend to that of bacterial population. Maximum population counts (10^3) of 16.00, 18.66, 14.00 and 8.00 CFU g⁻¹ soil were observed at 30, 60, 90 and 120 DAT, respectively in the treatment T₅ (100% RDFN + 25% N through maize compost). While the minimum population (4.66×10^3 , 5.33×10^3 , 2.66×10^3 , and 2×10^3 CFU g⁻¹ soil, respectively) was noticed in the treatment with no crop residues.

Application of nitrogen either through raw crop residue (T₂, T₄, T₆ and T₈) or with crop residue compost (T₃, T₅, T₇ to T₉) recorded significantly higher population compared to only inorganic treatment (T₁). The fungal counts at all growth stages were found to be higher than the initial population (3.0×10^3 CFU g⁻¹ soil).

Actinomycetes population

Data presented in the Table 4.18 and Plates 4.5 and 4.6 indicated that actinomycetes population of the soils at all stages of the crop growth was significantly influenced by different treatments. The highest actinomycetes population at 30, 60, 90 and 120 DAT (66.5×10^3 , 75.3×10^3 , 54.2×10^3 and 49.1×10^3 CFU g⁻¹ soil, respectively) was observed in T₅ (100 % RDFN + 25% N through decomposed maize stalk) which was significantly superior to all other treatments at 30, 60 and 90 DAT. At 120 DAT composts with 100% N were comparable. The data indicated that presence of higher actinomycetes population at 60 DAT which later decreased at 120 DAT.

Residue incorporation into the soil leads to increased bacterial and fungal population. Among the microbes, bacterial population was highest as compared to fungi and actinomycetes due to their high multiplication rate. The organic residues addition might have exerted a stimulating influence on the preponderance of the bacteria emphasizing the importance of easily degradable carbonaceous compounds in proliferation of bacterial population in soil. The results are in corroboration with those of Ghate *et al.* (1994) and Selvi *et al.* (2003).

The increase in microbial population with incorporation of crop residues (paddy straw / maize stalk) provides a stable supply of carbon and energy for microorganisms, and increase the microbial population (Dobermann and Fairhurst 2002). Addition of crop residues might have also resulted in increased supply of secondary and micronutrients required for the build up of body tissue. Similar observations were demonstrated by Krishnakumar *et al.* (2005) and Rushi *et al.* (2013).

4.6.2 ENZYME ACTIVITY

The dehydrogenase activity of soils at all stages of crop growth was significantly influenced by different treatments (Table 4.19 and Figure 4.12) and it was improved over the initial activity at all stages. The highest dehydrogenase activity was recorded in T₅ (100% RDFN + 25% N through maize compost) at all growth stages of the crop. The treatments supplied with composts *viz.*, T₅, T₃, T₉ and T₈ were found to be at par and significantly superior over raw residue treated (T₂, T₄, T₆ and T₈) and control (T₁) treatments at 30 DAT. At 60 and 120 DAT the composted materials with 100% RDFN were found to be at par while, the T₅ treatment was significantly superior over all other treatments at 90 DAT.

The higher dehydrogenase activity may be associated with high microbial growth due to decomposition of organic matter with the passing time, resulting in availability of substrate. Higher microbial population and desirable C: N ratio leads to higher dehydrogenase activity of soil.

Among the integrated treatments, the treatments which received more inorganic nitrogen recorded higher activity when compared to the treatments which received low inorganic nitrogen. Added organic matter in the presence of inorganic nitrogen promoted biological and microbial activities and accelerated the breakdown of organic substances. The highest organic matter levels in the organic nitrogen treatments might have provided a more favorable environment for the accumulation of enzymes in soil matrix, since soil organic constituents were important in forming stable complexes with free enzymes.

The highest dehydrogenase activity at 60 DAT might be due to increased bacterial population (Pedrazini and Mckel, 1984), root exudates, mucigel and sloughed-off cells (Gogel *et al.*, 1992). Decline in dehydrogenase activity with the crop growth in soil amended with organic source was also reported by Gaind and Nain (2011). Goyal and Kapoor (1995) also reported that the dehydrogenase activity is directly related to the microbial count in soil. The addition of compost coupled with inorganic fertilization might have exerted a stimulating influence on the preponderance of bacteria (Selvi *et al.*, 2005).

4.7 INFLUENCE OF CROP RESIDUES AND COMPOST ON DRYMATTER PRODUCTION, GRAIN AND STRAW YIELD OF PADDY

4.7.1 Drymatter Production at 60 DAT

Dry matter production at 60 DAT varied among the treatments from 32.78 to 45.72 g pot⁻¹. All treatments supplied with raw residues or composts resulted in significantly higher dry matter over treatment with no crop residue. The highest (45.72 g pot⁻¹) dry matter production was observed in T₅ (100% RDFN + 25% N through maize compost), which was on par with treatment T₃ (100% + 25% N through paddy compost) and significantly superior over all other treatments. The lowest (32.78 g pot⁻¹) dry matter production was observed in the treatment which received 100% RDFN (T₁). Application of raw residue or compost resulted in significantly higher dry matter production with high level (100% RDFN) of nitrogen compared to the respective low level (75% RDFN). At each level of nitrogen the dry matter produced was comparable within raw residues (paddy straw and maize stalk) and composts (paddy compost and maize compost).

This could be due to readily available nitrogen through inorganics at critical growth stages of crop. The better performance of the treatments T₅ and T₃ might be due to narrow C: N ratio of decomposed crop residues which helped in their quick mineralization than raw residue treatments. The higher dry matter production in integrated treatments can be attributed to improved physical condition of soil and microbial activity resulting in enhanced nutrient availability and also increased uptake of nutrients. The results are in conformity with those of Han *et al.* (1991), Sistani *et al.* (1998), Ali *et al.* (1995) and Waseem *et al.* (2011).

4.7.2 Grain Yield

The data presented in Table 4.20 and depicted graphically in Figure 4.13 revealed that grain yield of paddy was significantly influenced by the imposed treatments. The crop residue (raw or compost) in combination with fertilizers

resulted in a significant increase in grain yield over the treatment, which received only 100% RDFN. Grain yield ranged from 32.58 to 46.12 g pot⁻¹. The highest grain yield of 46.12 g pot⁻¹ was recorded with the application of 100% RDFN + 25% N through maize compost. However, it was on par with the treatment T₃ which was supplied with 100% RDFN + 25% N through paddy compost. Application of 100% N through the fertilizers resulted in significantly higher yield over supply of 75% RDFN with all the residues. At both the levels of applied nitrogen, composts made up of paddy straw and maize stalk resulted in comparable yield. Similarly the raw residues also resulted in at par values at each level of nitrogen. The lowest grain yield of 32.58 g pot⁻¹ was obtained with the application of 100% RDFN (T₁). The performance of treatments in terms of grain yield was in the order of T₅ > T₃ > T₄ > T₂ > T₉ > T₇ > T₈ > T₆ > T₁.

The significant and positive response of combined application of fertilizer nitrogen with organic crop residues might be attributed to the better nutrient availability and its favourable effect on soil physical, physico-chemical and biological properties resulting in increased yield attributes and finally higher yields. Increased grain yield under organic manure treated treatments might be due to better and continuous availability of nutrients for plants up to grain development (Farhad *et al.*, 2009). Similar results were reported by Sharma and Mitra (1990) and Witt *et al.* (2000).

4.7.3 Straw yield

The results indicated that straw yield ranged from 58.41 to 70.48 g pot⁻¹. The highest straw yield (70.48 g pot⁻¹) was obtained with the application of 100% RDFN + 25% N through paddy compost. However, it was on par with the treatment T₅ (100% RDFN + 25% N through maize compost) and significantly superior over the remaining treatments. The lowest straw yield (58.41g pot⁻¹) was recorded in T₁, which was supplied with 100% RDFN and it was on par with T₈ and T₆, supplied with 75% RDFN + 25% N through maize stalk and paddy straw.

The production of organic acids and growth promoting substances during decomposition of organic manures might have facilitated easy availability of macro as well as micronutrients. Adequate supply of nutrients to the crop helps in the synthesis of carbohydrates, which are required for the formation of protoplasm, thus resulting in highest cell division and cell elongation. Thus an increase in straw yield might have been obtained on account of overall improvement in the vegetative growth of the plant due to the application of 25 per cent RDN through organics in combination with 75 per cent RDFN. The findings were in complete agreement with the results reported by Ahmad *et al.* (1990) and Krishnamurthy *et al.* (2005).

4.8 INFLUENCE OF CROP RESIDUES AND COMPOSTS ON NUTRIENT UPTAKE

Nitrogen

Significant influence of treatments on nitrogen uptake by paddy was recorded at both the stages of crop growth (Table 4.21 and Figure 4.14). The highest nitrogen uptake at panicle initiation (727 mg pot^{-1}) was recorded in treatment supplied with 100% RDFN + 25% N through maize compost (T_5), which was on par with the treatments receiving organics with 100 per cent RDFN (T_2 - T_4). The lowest nitrogen uptake at panicle initiation (488 mg pot^{-1}) was recorded in treatment supplied with 100% RDFN (T_1).

The highest nitrogen uptake in grain and straw at harvest were recorded in the treatment T_5 (100% RDFN + 25% N through maize compost). The nitrogen uptake at harvest was significantly higher with application of raw residue or compost with 100% RDFN compared to the respective organic source at lower level of nitrogen (75% RDFN). The lowest nitrogen uptake at harvest in grain and straw (619 and 415 mg pot^{-1}) was recorded in treatment supplied with 100% RDFN (T_1).

Overall the data indicated a positive influence of organics on uptake of nitrogen. Increase in nitrogen uptake in grain and straw may be due to better root establishment under the influence of organic materials resulting in enhanced translocation of absorbed nutrients leading to their enhanced concentration and uptake. The results are in accordance with those reported by Verma and Pandey (2013), Kumar *et al.* (2000) and Dwivedi and Thakur (2000). Increase in N uptake with integrated use of organics with mineral fertilizers might be due to early release of N as a result of decomposition of organics (Singhal *et al.*, 2012)

Phosphorus

The data presented in Table 4.21 and Figure 4.15 revealed that the phosphorus uptake in plants was significantly influenced by the treatments. At panicle initiation the highest (137 mg pot⁻¹) P uptake was recorded by the treatment that received combined application of 100% RDFN + 25% N through maize compost (T₅) while, the significantly lowest P uptake (72 mg pot⁻¹) was obtained in T₁ (100% RDFN). At higher level of fertilizer N, treatments supplied with composts were superior over raw residue incorporated treatments. Whereas, at lower level of N the organic treatments were comparable. The phosphorus uptake at harvest by grain and straw were significantly higher (203 and 175 mg pot⁻¹, respectively) in the treatment supplied with 100% RDFN + 25% N through maize compost. Maximum phosphorus uptake was observed when organics were combined with 100% RDFN than 75% RDFN. In general the treatments supplied with composts resulted in significantly higher phosphorus uptake compared to the treatments with respective raw crop residues.

Application of manures have improved the soil environment, which encouraged the proliferous root system resulting in better absorption of nutrients from lower layers and thus resulting in higher yield and nutrient uptake. Similar results were also reported by Pathak *et al.* (2005) and Thenmozhi and Paulraj (2009).

Potassium

The data pertaining to uptake of potassium presented in Table 4.22 and depicted in Figure 4.16 revealed a significant influence of treatments on potassium uptake. At panicle initiation the uptake varied from 872 to 1257 mg pot⁻¹. The highest K uptake was recorded by the treatment that received combined application of 100% RDFN and 25% nitrogen through maize compost (T₅), which was at par with other organic treatments receiving 100 per cent RDFN. The potassium uptake at harvest by grain and straw were higher (482 and 1188 mg pot⁻¹, respectively) in T₅. In grain similar potassium uptake was recorded by compost supplied treatments at both the levels of RDFN. In straw, T₅ (100% RDFN + 25% N through maize compost) was significantly superior to all other treatments except T₃ (100% RDFN + 25% N through paddy compost). The lowest uptake of potassium was observed in T₁ (100% RDFN) as compared to all other treatments at both the stages.

Higher uptake of potassium under integrated management might be due to release of potassium from organic manures during decomposition and increase of native potassium availability. Similar trends were also reported by Bhandari *et al.* (1992) Mahavishnan *et al.* (2004) and Hammad *et al.* (2011). Faster decomposition and rapid mineralization resulted in higher dry matter production and nutrient concentration leads to increase in potassium uptake by crop (Rajkhowa, 2012).

Sulphur

Significant influence of treatments on sulphur uptake by paddy was recorded at both the stages of crop growth (Table 4.22 and Figure 4.17). The highest (210 mg pot⁻¹) sulphur uptake at panicle initiation was recorded in treatment supplied with 100% RDFN + 25% N through maize compost (T₅), which was on par with treatments received 100 percent RDFN. The lowest (101 mg pot⁻¹) was recorded in control (T₁), which was statistically inferior to all other treatments. The sulphur uptake at harvest by grain and straw were significantly higher (454 and 286 mg pot⁻¹, respectively) in the treatments

supplied with 100% RDFN + 25% N through maize compost (T₅). The treatment T₃ and T₄ resulted in comparable values to that of the best treatment. The lowest uptake of sulphur was observed in T₁ (100% RDFN) as compared to all other treatments at both the stages.

The high sulphur content in organic treatments could be due to the continuous supply of organically bound sulphur from the residues or their composts, when compared to treatments supplied with only inorganic nitrogen.

Micronutrients (iron, zinc, copper and manganese)

The data pertaining to uptake of micronutrients by paddy at different stages of crop growth (Tables 4.23 and 4.24 and Figures 4.18, 4.19, 4.20 and 4.21) revealed a significant influence by imposed treatments.

Iron

Application of crop residues and composts in combination with inorganic fertilizers increased the iron uptake significantly over the treatment with only inorganic fertilizers at panicle initiation stage and at harvest (grain and straw). The highest (6.19, 4.38 and 6.11 mg pot⁻¹) iron uptake was recorded with treatment 100% RDFN + 25% N through maize compost (T₅) which was followed by T₃ (100% RDFN + 25% N through paddy compost) at panicle initiation and in grain and straw, respectively. The lowest values (3.47, 2.51 and 3.91 mg pot⁻¹) at panicle initiation and in grain and straw, respectively in 100% RDFN (T₁) which was comparable with raw residues at low level of RDFN at panicle initiation and with all raw residues in grain and straw except T₄ (100% RDFN + 25% N through maize stalk).

Zinc

At panicle initiation the highest uptake of zinc (5.64 mg pot⁻¹) was recorded in the treatment supplied with integration of 100% RDFN and 25% N through maize compost (T₅), while lowest uptake (2.68 mg pot⁻¹) was recorded T₁(100% RDFN). The zinc uptake was comparable in treatments supplied with

composts (maize and paddy) at higher level of nitrogen and was significantly superior over the compost treatments with 75% RDFN. The highest uptake values (3.94 and 7.90 mg pot⁻¹) in grain and straw at harvest, respectively were observed in the treatment with supply of 100% RDFN and 25% N through maize compost (T₅). In grain Zn uptake was significantly high in T₅ compared to other treatments, whereas in straw T₅ and T₃ were comparable. The lowest (1.40 and 3.91 mg pot⁻¹, respectively) uptake of manganese was recorded in T₁ (100% RDFN).

Manganese

The uptakes at panicle initiation and in grain and straw at harvest were observed to be highest (6.86, 4.95 and 9.78 mg pot⁻¹) in the treatment supplied with 100% RDFN + 25% N through maize compost (T₅). The treatment T₅ was found to be at par with all organic treatments along with 100% RDFN and maize compost with 75% RDFN at 60 DAT. In grain, statically similar values were observed in T₅, T₄, T₃ and T₉. In straw at a given dose of nitrogen irrespective of source, compost supplied treatments resulted in comparable values. Similar results were observed with raw residues also. The lowest values of 3.60, 2.30 and 4.97 mg pot⁻¹ were recorded in 100% RDFN (T₁).

Copper

The treatments which received 100 percent RDFN + 25% nitrogen through maize compost (T₅) recorded the highest (1.03, 0.85 and 1.43 mg pot⁻¹) uptake at panicle initiation and in grain and straw at harvest. The treatment T₅ was comparable with all compost treatments and raw maize stalk with 100% RDFN, whereas, grain and straw recorded comparable copper uptake values in all compost supplied treatments. The lowest values at all stages were observed in 100% RDFN (T₁). At both the levels of nitrogen all raw residues recorded similar copper uptake.

Uptake of micronutrients was increased when crop residues or composts were added along with inorganic fertilizers. The increase in the uptake of

micronutrients with incorporation of crop residues or composts along with inorganic nitrogen might be due to release of micronutrients on mineralization of applied organic materials. Further the production of organic acids during their decomposition having ability to solubilise the insoluble compounds might have led to the increased uptake (Barik *et al.*, 2006 and Kumar *et al.*, 2009). During mineralization some chelating compounds capable of complexing with micronutrients are produced. The chelates help in holding micronutrients in soluble complexes making them more available to plant and reduce their precipitation into their corresponding hydroxides and carbonates. Similar findings were observed by (Prasad *et al.*, 1984 and Madhavi *et al.*, 2008).

Chapter II

REVIEW OF LITERATURE

The literature pertaining to the present investigation entitled, "Nutrient release and biological activity of soils incorporated with cereal crop residues " has been reviewed in this chapter under the following heads

- 2.1 Influence of crop residues and composts on soil physical and physico-chemical properties
- 2.2 Influence of crop residues and composts on nutrient availability
- 2.3 Influence of crop residues and composts on biological activity of soils
- 2.4 Influence of crop residues and composts on yield attributes and yield of rice
- 2.5 Influence of crop residues and composts on nutrient concentrations and uptake

2.1 INFLUENCE OF CROP RESIDUES AND COMPOSTS ON SOIL PHYSICAL AND PHYSICO-CHEMICAL PROPERTIES

2.1.1 Bulk Density and Water Holding Capacity

A significant decrease in bulk density with incorporation of organic manure and vermicompost as compared to only chemical fertilizer application was observed by Patil (1998). Panda *et al.* (1999) reported that application of organic manures had a beneficial effect on soil bulk density and maximum water holding capacity.

Sharma *et al.* (2000) observed a significant reduction in the bulk density of soils incorporated with residue and FYM and it was attributed to the build up of soil organic matter and better soil structure. Srikanth *et al.* (2000) found a significant decrease in bulk density (1.27 to 1.18 g cc⁻¹) of soil amended with vermicompost after harvest of second crop when compared to the soil treated with only inorganic fertilizers.

Das *et al.* (2001) reported that bulk density in 20 cm and 20 to 40 cm depth of soil at harvest of rice significantly decreased with the incorporation of different crop residues over the control. Incorporation of crop residues further resulted in increased soil porosity, thus significantly enhanced the water holding capacity of soil compared to initial values.

Surekha *et al.* (2004) reported that there was a significant decrease in bulk density (1.21-1.29 Mg m⁻³) with straw incorporation over burning (1.42 Mg m⁻³) and control (1.41 Mg m⁻³) indicating the improvement in soil structure due to crop residue incorporation.

Bajpai *et al.* (2006) noticed that the incorporation of organic sources considerably decreased bulk density of the soil. When nitrogen was substituted through green manure, FYM and crop residue (rice straw), bulk density was significantly lowered as compared to the initial status and control plot at the time of wheat harvest in rice - wheat sequence.

Singh and Yadav (2006) reported that rice residue incorporation and rice-residue retained treatments recorded significantly lower bulk density over rice residues removed during two years of study.

Brar and Walia (2010) reported that, all the rice residue incorporated treatments were lower in bulk density after harvest of paddy than initial values during both the years of study. The lower bulk density (1.54 Mg m⁻³) was recorded in surface layer of rice residue incorporated treatment due to pulverization of soil.

Saha *et al.* (2010) reported that soil with residue incorporation recorded significant difference in bulk density up to 0.15 m. While, there was no significant difference in bulk density at 0.15 to 0.30 m depth between treatments.

Rameshchandra (2011) reported that in different crop sequences, residue incorporation and fertilizer levels showed no variation in bulk density of soil even after two crop cycles.

Anilkumar *et al.* (2012) reported that the long term application of organic materials along with fertilizers decreased the soil bulk density significantly by 3.3 per cent in comparison to application of fertilizers alone.

Kharache *et al.* (2013) reported that bulk density was considerably reduced from initial value of 1.32 to 1.20 Mg m⁻³ due to integration of chemical fertilizers with organics. The maximum water retention percentage was observed with 50% RDF + 50% N-FYM followed by 75% RDF + 25% N-FYM.

2.1.2 pH and Electrical Conductivity (EC)

Das *et al.* (2001) concluded that soil pH at harvest of rice was not significantly affected by incorporation of different crop residues and application of different levels of NPK fertilizers.

Kumar *et al.* (2004) reported that the retention of crop residue showed a slight decline in soil EC values over residue burning, residue removal and initial value, but marked variations did not exist.

Singh and Yadav (2006) recorded higher pH values under rice residue incorporation in comparison with residue removed and residue retained treatments.

Rameshchandra (2011) conducted a study in different legume based sequences and revealed that their residue incorporation and fertilizers levels showed no variations in the pH of soil after two crop cycles.

Anilkumar *et al.* (2012) reported that the application of FYM, wheat straw and green manure along with inorganic fertilizers decreased the soil pH and soluble salt concentration as compared to the fertilizers alone.

2.1.3 Organic Carbon

Havlin *et al.* (1990) reported that crop management systems that include rotations with high residue-producing crops and maintenance of surface residue cover with reduced tillage resulted in greater soil organic C.

Bird *et al.* (2002) observed that four years of soil incorporation of crop residues resulted in increase in organic carbon content to an extent of 12 to 16 per cent over straw burned.

Sridevi *et al.* (2003) studied that the pattern of carbon mineralization from control soil as well as soil amended with residues and observed faster mineralization in the initial stages followed by a steady decline in the rate of mineralization with time.

Kumar *et al.* (2004) reported that organic carbon was markedly increased, being the highest in those plots where residue was retained on soil surface through conservation tillage or incorporated with the help of traditional method. This was followed by those plots which received deep incorporation of residues.

Pal and Jat (2004) reported a significant improvement in soil organic carbon with all the treated rice straw preparations in contrast to water soaked straw or NPK fertilizers alone in both seasons.

Surekha *et al.* (2004) noticed that the organic carbon was increased significantly in all crop residue treatments (1.16-1.27 %) with maximum value recorded in straw + GM treated plots over control (1.00 %).

Blair *et al.* (2005) reported that at 200 days the *flemingia* treatment had the highest carbon concentration, while the medic and rice treatments were significantly higher than the control. The loss of C from the rice straw was initially slower than the medic but by 200 days they were similar.

Singh and Yadav (2006) reported that residue incorporation increased the organic carbon content by 0.37, 0.35 and 0.31 per cent in residue incorporated, retained and removed treatments, respectively. The organic carbon content in the soil was increased by 17.73 and 5.71 per cent in comparison with residue removed and retained treatment over a period of two years.

Patil *et al.* (2007) reported an increase in organic carbon content in soil (0-15 and 15-30 cm) due to addition of crop residue as compared to only 100 per cent RDN.

White and Rice (2007) reported highest rates of carbon mineralization during the first 25 days of the experiment. Plant residue C mineralization for the residue added treatments was 0.733 kg^{-1} residue C added.

Halpern *et al.* (2010) hypothesized that reducing the tillage intensity and retaining more residues in agroecosystems under continuous corn production would increase the soil organic carbon.

Urkurkar *et al.* (2010) reported that OC content of surface soil increased significantly with incorporation of green manure/ FYM/ rice straw residue in conjunction with fertilizers.

Radhakumari and Srinivasulareddy (2011) reported that post harvest soil fertility status with regard to organic carbon was superior with incorporation of fieldbean crop residues followed by incorporation of cowpea, clusterbean and greengram.

Schulz *et al.* (2011) observed a significant increase in soil organic carbon content when organic matter (straw + manure + green manure) was added for 14 years.

Anilkumar *et al.* (2012) noticed that the long term application of organic materials along with fertilizers significantly increased soil organic carbon as compared to the application of fertilizers alone.

Verma and Pandey (2013) noticed that significantly higher organic carbon content was recorded with rice residue incorporation + 30% excess recommended NPK.

2.1.4 Cation-Exchange Capacity

Bellakki *et al.* (1998) reported that combined application of organic and inorganic sources of nutrients (90:40:45 NPK kg ha^{-1} + paddy straw 25%) recorded more CEC of 54.50 as compared to 100 per cent RDF alone. Babhulkar *et al.* (2000) found that combined application of organics and inorganics (NP +7.5 t FYM ha^{-1}) increased the CEC ($45.65 \text{ cmol (p}^+) \text{ kg}^{-1}$) as compared to the NP alone ($41.74 \text{ cmol (p}^+) \text{ kg}^{-1}$).

Das *et al.* (2001) concluded that crop residues improved the cation exchange capacity of soil over the control. Incorporation of crop residues increased the humus content of soil on their decomposition and thus increased the cation exchange capacity.

Ouedraogo *et al.* (2001) reported that soil CEC was increased in plots received compost. The difference in CEC was significant between control (no application) and 10 Mg ha⁻¹ compost rate, the effect was non significant with 5 Mg ha⁻¹ and no application compost plots.

Dutta (2009) reported that cation exchange capacity of soils reduced in almost all the treatments due to continuous use of chemical fertilizers and amendments except 100 per cent NPK + FYM wherein the initial status of 12.10 c mol (p⁺) kg⁻¹ was almost maintained.

Verma *et al.* (2010) from a maize-wheat cropping system revealed that after continuous cropping for nine years CEC increased in all the treatments over control. However, larger increase in CEC was observed in soil which received nutrients in balanced and integrated form.

Sepehya (2011) reported that amongst the treatments consisting of different organic sources, the plots which received FYM recorded higher CEC followed by wheat cut straw and green manure.

2.2 INFLUENCE OF CROP RESIDUE AND COMPOST ON NUTRIENT AVAILABILITY

2.2.1.Nitrogen

Sharma *et al.* (1988) reported that incorporation of organic wastes like rice husk/chaffed *lantana* @ 7.5 t ha⁻¹ improved soil nitrogen to 410 and 363 kg ha⁻¹, respectively over no organic treatment (230 kg ha⁻¹) on silty clay loam soil during *kharif* season.

Havlin *et al.* (1990) reported that crop management systems that include rotations with high residue-producing crops and maintenance of surface residue cover with reduced tillage resulted in greater soil nitrogen.

Bhat *et al.* (1991) concluded that wheat incorporation and FYM application with higher doses of fertilizer N increased the available nitrogen content in soil compared to initial values, whereas in control plots they declined significantly.

Toor and Beri (1991) observed almost complete immobilization of native as well as applied N (120 mg kg^{-1}) by the seventh day in a soil amended with rice straw. At the end of 60 days of incubation, however about $40 \text{ mg mineral N kg}^{-1}$ soil was remineralized.

Azmal *et al.* (1997) observed that in rice straw amended soil ($200 \text{ mg C per } 100\text{g soil}$ applied every 6 weeks) mineral N was immobilized immediately after each application of rice straw due to its high C:N ratio.

Bending *et al.* (1998) reported that NH_4^+ was the predominant form of mineral-N in most treatments during the first 7 days, after which NO_3^- dominated, with only very small amounts of NH_4^+ detected after 56 days. Mineral N was released rapidly following incorporation of the shoot materials.

Burgess *et al.* (1998) studied that the effect of tillage (no-till, reduced, or conventional) \times crop residues (removed or retained) on soil nitrate content under corn production. Decline in nitrate levels were greatest in plots without residues after one year. No till and conventional tillage had similar values, but sometimes differed from reduced tillage.

Kushwaha *et al.* (2000) reported that in residue removal treatment nitrogen mineralization rates were maximal during the seedling stage of crops and then decreased through the crop's maturity. At grain forming stage, the N mineralization rates in residue retained treatments considerably exceeded the rates of corresponding residue removed treatments.

Aulakh *et al.* (2001) observed that the mineral nitrogen in treatment (rice residue incorporation @ 6 Mg ha⁻¹) was much lower than the treatment (rice residue incorporation @ 6 Mg ha⁻¹ + fertilizer nitrogen @ 120 kg ha⁻¹ + no manure) in the early wheat season.

Bending *et al.* (2002) observed that the change in net nitrogen mineralization processes largely occurred within the first 28 days of the experiment, and sampling time had no significant effect on N mineralization. N mineralization was higher in the Brussels sprout shoot and wheat straw treatments after 112 days of incubation.

Bird *et al.* (2002) observed that the straw incorporation increased plant available nitrogen after 3 years.

Kumar *et al.* (2004) reported that available nitrogen was significantly increased with the highest in those plots where residue was retained on soil surface through conservation tillage or incorporated with the help of traditional method.

Kachroo and Dixit (2005) reported that available nitrogen in soil after two years increased significantly due to application of residues over no residue treatment and initial values.

Khalil *et al.* (2005) noticed that the values of N mineralization were greater than the respective ones for the control treatment (42.84 mg N kg⁻¹ soil). Irrespective of the soils, both chicken manure and mung bean residue have a significant effect on net N mineralization (68.76-72.59 mg N kg⁻¹ soil) than wheat residue (54.88 mg N kg⁻¹ soil).

Singh and Yadav (2006) observed that the available nitrogen in the soil increased by 10 per cent in residue incorporated plots during the 2 years of study.

Nourbakhsh (2007) observed that for residue amended soils, inorganic N decreased in the first 2 weeks of incubation by 50 to 86 per cent followed by a gradual increase. In contrast, for control soils without residue amendment, the inorganic N concentration increased from 64 to 86 per cent during the first week of incubation.

Kaewpradit *et al.* (2008) reported that the greatest net mineral N content occurred at two weeks after residue incorporation. Mineral N in ground residue and rice straw treatments gradually declined with time and was not significantly different compared with that of the control after 6 weeks.

Urkurkar *et al.* (2010) reported that available nitrogen content of surface soil varied significantly with application of FYM / rice straw residue/green manure in combination with fertilizers over initial status.

Radhakumari and Srinivasulareddy (2011) reported that post harvest soil fertility status with regard to available nitrogen was superior with incorporation of fieldbean crop residues followed by incorporation of cowpea, clusterbean and greengram.

Rameshchandra (2011) reported that irrespective of crop residue incorporation resulted in a significant increase in available nitrogen content over removal after second crop of wheat in soybean-wheat sequences.

Singhal *et al.* (2012) concluded that the NH_4^+ -N in soil varied from 7.4 to 9.9 mg kg^{-1} . The highest NH_4^+ -N was observed under the treatment 50% NPK + NPK enriched compost where as the lowest in control. The NO_3^- -N varied between 14.8 and 28.8 mg kg^{-1} . A positive effect of N substitution through composts was observed in terms of NO_3^- -N of the soil. Adding compost along with inorganic fertilizer exhibited a favourable impact on NO_3^- -N.

Verma *et al.* (2016) reported that nutrient management practices had a significant effect on N content and plots receiving integrated sources [100% NPK + 25% N through FYM), 100% NPK + green manure (sesbania), 100% NPK + crop residues (previous crop)] showed higher mineral nitrogen content than control. Mineral nitrogen under plots 100% NPK and 100% NPK + green manure (sesbania) were statically at par.

2.2.2. Phosphorus

Kumar *et al.* (2004) reported that the available phosphorus values were the highest in plots received shallow incorporation and retention of residue on soil surface. This was followed by the plots where residue was either buried deep or burned in-situ.

Pal and Jat (2004) reported that the compost prepared from treated rice straw + pigeonpea hulls increased the available phosphorus status of soil to the maximum compared to other rice straw preparations. The response to untreated water soaked straw was lowest compared to treated rice straw in both the seasons.

Kachroo and Dixit (2005) reported that available phosphorus in soil after two years increased significantly due to application of residues over no residue treatment and initial values.

Jha and Rattan (2007) reported that incorporation of mungbean and sesbania significantly enhanced the status of phosphorus in soil after 64 days of incubation. The highest value (39.80 mg kg⁻¹) was observed in case of sesbania incorporated soil followed by mung bean and wheat straw.

Urkurkar *et al.* (2010) reported that available phosphorus content of the soil was increased (23.9 kg ha⁻¹) with incorporation of rice straw residue over control (11.5 kg ha⁻¹).

Radhakumari and Srinivasulareddy (2011) reported that the post harvest soil fertility status with regard to available P was superior with incorporation of fieldbean crop residues followed by incorporation of cowpea, clusterbean and greengram.

Rameshchandra (2011) reported that the highest available P was noticed with pigeon pea-wheat sequence, being significantly more by 23.2 per cent over rice-wheat (31.6%) over maize-wheat and 29.0 per cent over sorghum-wheat sequences. Irrespective of cropping sequences, their residue incorporation gave significant increase in the available phosphorus content (7.8%) over removal after second crop i.e., wheat.

Satish *et al.* (2011) observed that the organic sources of nutrients in combination with inorganic fertilizers showed improvement in available phosphorus from 12.3 kg ha⁻¹ to 22.01 kg ha⁻¹.

Dotaniya *et al.* (2014) reported that application of organic residue from 2.5 to 5 g kg⁻¹ soil increased the available phosphorus from 19.2 to 24 mg kg⁻¹.

2.2.3. Potassium

Yadvindersingh *et al.* (2000) concluded that the application of N @ 150 kg ha⁻¹ green manure, and crop residues did not significantly affect available K content compared to control.

Kumar *et al.* (2004) reported that the available K values were the highest in plots received shallow incorporation and retention of residue on soil surface followed by those plots, where residue was buried deeply. The minimum value of available K was noticed in the residue removed plots.

Pal and Jat (2004) reported that the compost prepared from treated rice straw + pigeon pea hulls increased the available K status of soil compared to other rice straw combinations. The response to untreated water soaked straw was lowest compared to treated rice straw in both the seasons.

Surekha *et al.* (2004) reported that available K increased significantly with incorporation of straw or its ash (440-519 kg ha⁻¹) over control (377 kg ha⁻¹).

Yadvindersingh *et al.* (2004) reported that the incorporation of rice residue caused a significant increase in available potassium content in the soil than the residue removal treatments.

Kachroo and Dixit (2005) reported that available K in soil after two years increased significantly due to application of residues over no residue treatment and initial values.

Urkurkar *et al.* (2010) reported that farm yard manure or rice straw residue incorporation to meet 50% N + 50% RDF recorded the higher available K over graded dose of fertilizers and control.

Radhakumari and Srinivasulareddy (2011) reported that post harvest soil fertility status with regard to K was superior with incorporation of fieldbean crop residues followed by incorporation of cowpea, clusterbean and greengram.

Rameshchandra (2011) reported that soybean-wheat sequence recorded the highest and significantly more available K of 20.5, 23.7 and 21.6 per cent over rice-wheat, maize-wheat and sorghum wheat, respectively.

2.2.4. Available Sulphur:

Choi and Rossi (1978) concluded that the application of wheat and barley straw to two soils increased the sulphur concentration in equilibrium solution and increased the available sulphur.

Singh and Sharma (2000) observed a significant increase in the availability of sulphur in soil with the incorporation of crop residues.

Sidhu and Beri (2008) showed that the incorporation of crop residues recorded higher (61 mg kg^{-1}) available sulphur content than the residue removal and residue burning treatments.

Bandan *et al.* (2014) reported that combined application of 150 kg N + organics @ 10 t ha^{-1} increased the available sulphur (2.8 mg kg^{-1}) as compared to sole application of fertilizer nitrogen.

Verma *et al.* (2016) reported that nutrient management practices had significant impact on available sulphur in soil with respect to blank plot, the plot receiving organic source of nutrient could maintain significantly higher sulphur content in soil. Available S content significantly decrease in control than blank plot and plots of 100% NPK + 25% N through FYM), 100% NPK + green manure (sesbania), 100% NPK + crop residues (previous crop) showed higher sulphur content than control.

Available Micronutrients: (Fe, Mn, Zn and Cu)

Katyl (1977) observed that the maximum concentrations of Fe and Mn occur earlier and concentrations were significantly higher in flooded soils amended with rice straw compared to control.

Singh *et al.* (1992) observed that the incorporation of residues decreased the availability of Zn but had no significant effect on Cu and Mn availability in soil.

Meelu *et al.* (1994) reported that the incorporation of crop residues on long term basis increased the DTPA extractable Zn, Cu, Fe and Mn contents in soil.

Prasad and Sinha (1995) conducted an experiment and reported that application of crop residues decreased the capacity factor due to organic acids converting solid phase labile Zn to soluble Zn complexes.

Saviozzi *et al.* (1997) observed no significant effect of wheat straw (applied at 2% by weight) on the content and distribution of Zn and Cu in soils but increased the Zn content of rice plants.

Yadvindersingh *et al.* (2000) reported that the DTPA extractable micronutrients decreased greatly with 150 kg N ha⁻¹ over no nitrogen control. Recycling of crop residues increased the availability of micronutrients in the soil generally similar to that with green manuring.

Singh *et al.* (2011) showed that application of 2.5 kg Zn ha⁻¹ once with first crop and 50% of crop residue of every crop was more effective than 10 kg Zn ha⁻¹ application alone as starter dose, which shows that substantial amount of Zn can be saved by the residue incorporation.

2.3 INFLUENCE OF CROP RESIDUES AND COMPOSTS ON BIOLOGICAL ACTIVITY OF SOILS

2.3.1. Dehydrogenase Activity

Sajjad *et al.* (2002) reported that maximum dehydrogenase activity was observed in sesbania treatment and minimum in unamended soil. No consistent trends in dehydrogenase activity with time of incubation were observed.

Vijay *et al.* (2010) reported that the activity of dehydrogenase increased significantly in all organic farming fields irrespective of cropping systems over conventional farming, with maximum activity being in the soils where organic farming is practiced for > 6 years.

Rameshchandra (2011) reported that crop residue incorporation resulted in significantly higher dehydrogenase activity of 10.2 per cent in soil over removal after second crop. Legumes based wheat (soybean-wheat :92.9 per cent) sequences recorded significantly higher dehydrogenase activity than cereal wheat sequences.

Dadhich *et al.* (2012) reported that the microbial activity of soil showed a positive trend in the treatments in which composts were applied. The top three ranked treatments, in terms of dehydrogenase activity were pigeonpea stover compost, chickpea stover compost and mustard stover compost.

Jadhav *et al.* (2016) reported that significantly higher dehydrogenase activity ($85.0 \mu\text{g TPF g}^{-1} \text{ soil day}^{-1}$) was recorded with application of 100% N equal proportion through FYM, neem cake and vermicompost. However, application of inorganic fertilizers as per soil test to banana resulted in lower magnitude of dehydrogenase activity.

2.3.2. MICROBIAL COUNTS

Beri *et al.* (1992) observed that soil treated with crop residues recorded 5-10 times more aerobic bacteria and 1.5 to 11 times more fungi than soil for which residues were either burned or removed.

Sidhu *et al.* (1995) noticed that the incorporation of crop residues increased both bacterial and fungal population as compared to the residue burned or removed.

Kachroo and Dixit (2005) reported that incorporation of crop residues increased the total microbial population in soil after two years over no residue treatment and initial values.

Bhakare *et al.* (2008) revealed that the count of bacteria, fungi, actinomycetes across different treatments except fertilizer alone was maximum at the time of flowering stage of rabi sorghum than the count taken at sowing, and it decreased at harvest stage of crop. The total microbial count was more with addition of FYM or crop residue added.

Rameshchandra (2011) reported that crop residue incorporation increased the population of total bacteria and fungi over removal but no significant variations were observed in microbial counts.

Rushi *et al.* (2014) reported that the combination of 50% organic and 50% inorganic form of fertilizers resulted in higher bacterial population of 8.80×10^6 CFU g^{-1} soil at 45 DAS when compared to sole inorganic fertilizers, 5.30×10^6 CFU g^{-1} soil.

Upadhyay and Vishwakarma (2014) reported that biological properties of soil after completion of 25 crop cycle on same field with the same lay out plant nutrient supplied through organic sources along with chemical fertilizer had higher microbial population (total fungi, bacteria, azotobacter, phosphorus solubilizing bacteria and actinomycetes) than the control.

Jadhav *et al.* (2016) reported that the higher bacterial populations and fungal mass were noted in the nitrogen management treatment as 33% N (FYM) + 33% N (neem cake) + 33% N (vermicompost) and the population of actinomycetes in soil were reported lower at all the period of study in the plots receiving inorganic fertilizer to banana based on soil test.

2.4 INFLUENCE OF CROP RESIDUE AND COMPOST ON YIELD OF RICE

Das *et al.* (2001) reported that addition of crop residues improved the soil health, thus increased effective tillers, length of panicle, grains per panicle and test weight, which ultimately contributed to increase in grain yield.

Sharma (2002) observed that application of 40 kg N ha⁻¹ (one third of the total dose for rice) at the time of wheat residue incorporation, 40 kg N ha⁻¹ at the time of transplanting and rest at panicle initiation increased the grain yield by 0.5-0.7 t ha⁻¹ and straw yield by 0.5-1.0 t ha⁻¹.

Bharne *et al.* (2003) noticed that treatment of paddy straw compost with *Trichoderma* @ 5t ha⁻¹ was significantly superior to control regarding grain (882.92 kg ha⁻¹) and straw yields (18.37 q ha⁻¹) and at par with the cotton stalk compost with *Trichoderma* @ 5.5t ha⁻¹ and superior to control in case of test weight (26.56 g).

Bhagat *et al.* (2003) reported that *Lantana* incorporation at a rate of 30 Mg ha⁻¹ resulted significantly higher yield compared to control. However in most cases the yield differences between *latana* addition @ 20 Mg ha⁻¹ and @ 30 Mg ha⁻¹ did not differ significantly.

Daleepkumar *et al.* (2003) reported that the highest grain yield (8.4 g pot⁻¹) of wheat was obtained with the application of 120 mg N kg⁻¹ soil in the application of rice straw and FYM (1:2) amended soil.

Surekha *et al.* (2003) reported that influence of crop residue treatments on yield parameters like panicle and spikelet number was more apparent after two cycles of residue incorporation, recording significant effects on rice particularly in the dry and wet seasons of 2000. Rice yield increased by 1.0 to 1.2 t ha⁻¹ in dry season and 0.4 to 0.8 t ha⁻¹ in wet season.

Pal and Jat (2004) reported that maximum grain yield (5.28 t ha⁻¹) of rice recorded in plots receiving treated rice straw + pigeon pea hulls (7.5 t ha⁻¹) being superior to all the treatments.

Surekha *et al.* (2004) reported that grain yields and straw yields were not influenced significantly by the treatments in the first and second season of residue application though there was an increase in the grain yield in 100 per cent straw treated plots over 50 per cent straw and control.

Kachroo and Dixit (2005) observed that rice and wheat straw incorporated plots showed the highest values of yield components of rice, being significantly higher than no crop residue treatment and was at par with left over stubbles of previous crop and fly ash incorporated plots in both the years and resulted in realizing higher effective tillers/m², grains per panicle, grain and straw yields compared to no residue treatments.

Ghosh and Singh (2006) reported that increase in wheat yield due to application of maize fresh, maize compost, kudzu fresh and kudzu compost were 27.9, 50.6, 68.9 and 89.2 per cent with the corresponding value of 17.0, 68.3, 53.8 and 47.8 per cent in rainfed and irrigated conditions, respectively over control plots.

Singh and Yadav (2006) observed that rice residue incorporation increased the thousand grain weight in rice and also gave significantly higher grain and straw yields over residue removed and residue retained treatments during both the years of study.

Tanimu *et al.* (2007) observed that legume incorporation and N fertilizer significantly affected maize grain yield in two seasons. Grain yield was significantly higher with the incorporation of legumes than the control. Yield increases over the control upon incorporation were 0.13 to 1.03 t ha⁻¹ for 1995 season and 0.16 to 1.30 t ha⁻¹ for 1996 season.

Bhakare *et al.* (2008) reported that the highest grain and straw yields were obtained in treatment with 25 kg N ha⁻¹ through crop residue + 25 kg N ha⁻¹ through *Leucaena* loppings supplied @ 1554 kg ha⁻¹ and 4393 kg ha⁻¹, respectively.

Sidhu and Beri (2008) reported that, in the long term experiments residue incorporation resulted in increases of wheat yield ranging from 0.0 to 0.5 t ha⁻¹ over the burning treatment.

Sharma *et al.* (2009) reported that incorporation of crop residues had no significant effect on growth and yield attributing characters of rice.

Das *et al.* (2010) noticed that various organic amendments and recommended NPK improved the grain and straw yield of rice significantly over control. Highest grain yield was recorded with rice straw microbial and nutrient fortified compost (4.60 t ha⁻¹).

Radhakumari and Srinivasulareddy (2011) reported that incorporation of fieldbean crop residues was superior to other crop residues incorporation with regard to higher number of total and productive tillers per unit area and grain yield.

Rameshchandra (2011) reported that soybean-wheat crop sequences gave the highest and significantly more mean yields of grain by 16.6 and 14 per cent over rice-wheat, 17.9 and 14.8 per cent over maize-wheat, and 21.4 and 18.4 per cent over sorghum-wheat sequences, respectively.

Satish *et al.* (2011) reported that application of 25 per cent and 50 per cent N through paddy straw gave significantly higher grain and straw yields, respectively. Significantly lowest productivity was observed in control and in the treatments with only inorganic fertilizers.

Singhal *et al.* (2012) noticed that grain yield of wheat increased from 32.6 to 84.2 per cent over control (27.3 q ha⁻¹) with the application of compost + 50 per cent NPK and corresponding increase in straw yield was 41.9 to 82.3 per cent over control (50.8 q ha⁻¹).

Mohammad *et al.* (2012) reported that residue retained treatment produced 330 kg ha⁻¹ more wheat grain than residue removed treatment. No tillage + residue retained treatment produced 520 kg ha⁻¹ more grain yield than when residues were removed.

Khalid *et al.* (2014) noticed that grains per spike, 1000 grain weight and grain yield were higher in tillage methods with either straw retained or incorporated than tillage methods with straw burnt.

2.5 INFLUENCE OF CROP RESIDUE AND COMPOST ON NUTRIENT CONCENTRATIONS AND UPTAKE

2.5.1 Macronutrient Uptake

Telang *et al.* (1992) reported that nitrogen uptake by wheat crop was increased by incorporation of crop residues, particularly legume residues and fertilizer application.

Verma and Bhagat (1992) found that soil incorporation of rice straw and rice straw incorporation with animal manure had positive residual effect on crop nitrogen uptake.

Rees *et al.* (1993) conducted an experiment with different amount of ¹⁵N labeled legume residues and observed 15 to 23% of legume N recovery by the wheat crop and net nitrogen mineralization reached a maximum where residue concentration were 1.5 per cent. The amount of nitrogen taken up by the crop was directly proportional to the amount applied.

Pathak and Sarkar (1997) conducted an experiment on silty loam soil at IARI, New Delhi and reported that incorporation of rice straw and urea with 2.5 and 10 per cent nitrogen, could supply adequate nitrogen at initial stages. At 70 DAS urea recorded highest nitrogen uptake and rice straw urea material was found to be inferior to other source.

Phongpan and Mosier (2003) observed that the highest nitrogen uptake was recorded with the combined use of organic residues and urea.

Kachroo and Dixit (2005) reported that total N, P and K uptake by rice and wheat was significantly influenced by residue treatments. The highest uptake of nitrogen, phosphorus and potassium were recorded in rice and wheat straw incorporated plot and were at par with left over stubbles and fly ash incorporation.

Singh and Yadav (2006) reported that incorporation of rice residue led to higher nitrogen uptake, which showed an increase of 15 and 19 per cent more over rice residue removed and rice residue retained respectively.

Bhakare *et al.* (2008) reported that the N uptake was higher in treatment with 25 kg N ha⁻¹ through crop residue + 25 kg N ha⁻¹ through *Leucaena* loppings (48.78 kg ha⁻¹).

Sarwar *et al.* (2009) reported that minimum content of total N (0.97 & 1.09%) for control enhanced to the maximum level of 2.21 and 2.28 per cent with the application of fertilizer and compost 24 t ha⁻¹ for wheat and rice grains respectively. Use of chemical fertilizer remained superior to compost 12 t ha⁻¹ alone. Minimum content of total P (0.19 & 0.16%) determined for control enhanced in all treatments and approached the highest values of 0.32 and 0.29% in the application of fertilizer and compost 24 t ha⁻¹ for wheat and rice grains respectively. The highest K concentration (0.63 & 0.52%) was estimated in application of fertilizer and compost @ 24 t ha⁻¹ against the lowest of control.

Kumarvipin *et al.* (2011) observed that the sulphur uptake by rice and wheat increased from 3.5 to 15.9 and 2 to 14.8 kg ha⁻¹ respectively with increasing levels of N,P and K. The sulphur uptake by these crops was in the order compost + crop residue compost, crop residues and no organics.

Singhal *et al.* (2012) observed that the integrated use of mineral fertilizers with enriched compost showed significant effect on N uptake. The maximum N uptake (74.44 kg ha⁻¹) in wheat grain was recorded under the treatment 50% NPK and NPK enriched compost. The lowest N uptake (37.67 kg ha⁻¹) by wheat grain was recorded by control.

Verma and Pandey (2013) reported that the highest nitrogen uptake by grain and straw was recorded under the treatment when rice residue was incorporated with 30% additional NPK + recommended NPK against sowing of wheat without incorporation of rice residue application + recommended NPK and rice residue incorporation + recommended NPK.

Manjhi *et al.* (2014) reported that the total nutrient uptake varied from 17.2 to 103.0, 2.2 to 13.6 and 14.7 to 94.4 (kg ha⁻¹) N, P and K, respectively, in maize 21.0 to 106.2, 2.9 to 16.8 and 20.4 to 101.3 (kg ha⁻¹) N, P and K, respectively, in wheat.

Gundlur *et al.* (2015) reported that the uptake of N, P and K by maize at 75% RDF plus maize stalk incorporation with cellulolytic culture plus biofertilizers with one row of sunhemp between two rows of maize (N-157.3, P- 43.34 and K-215.5 kg ha⁻¹) was on par with 100% RDFN (N-163.8, P- 44.98 and K-218.4 kg ha⁻¹)

Thind *et al.* (2016) reported that Fertilizer nitrogen and FYM caused significant increase in the total uptake of N, P and K in rice, the FYM applied to rice showed significant residual effect on yield and total N, P and K uptake in the subsequent wheat. The increase in N, P and K uptake due to FYM was 29 to 32%, 29 to 33% and 27 to 49%, respectively.

2.3.2 Micronutrient Uptake

Chandel *et al.* (2013) reported that the maximum and minimum uptake of iron was recorded when 100% crop residue was incorporated into soil and absolute control, respectively. This showed that crop residue increased the grain and straw yield of rice and iron content and ultimately iron uptake by the crop.

Yadav *et al.* (2013) observed that Zn and crop residue treatment exerted a favourable influence on zinc uptake by rice crop.

Singhal *et al.* (2012) reported that 1:1 ratio had maximum total uptake of micronutrients which showed an increase from 30.29 to 55.94% for Zn, 27.42 to 37.36% for Cu, 20.64 to 32.73% for Mn and 19.61 to 35.42% for Fe over the treatment where N was applied through urea alone in all the four years of experimentation.

Kaminikumari and Prasad (2014) concluded that increasing levels of crop residue increased the uptake of zinc, copper, iron, manganese by grain and straw. The uptake of zinc by grain with zinc varied from 81.5 to 109.9 and 152.6 to 218.6 g ha⁻¹, The ranges of copper uptake in grain and straw were from 18.2 to 26.5 and 39.2 to 49.7 g ha⁻¹, Incorporation of crop residue also enhanced the iron uptake by rice grain and straw from 142.8 and 229.2 g ha⁻¹ and 559.2 to 802.4 g ha⁻¹ and manganese uptake by 150.9 to 183.0 and 388.1 to 500.6 g ha⁻¹, respectively.

Chapter V

SUMMARY AND CONCLUSIONS

A pot culture experiment entitled “Nutrient release and biological activity of soil incorporated with cereal crop residues” was conducted to study the influence of different levels of recommended dose of fertilizer nitrogen in combination with cereal crop residues and their composts on soil properties, yield and nutrient uptake by rice during *kharif*, 2013-2014 in Green house, Department of Soil Science and Agricultural Chemistry, Agricultural College, Bapatla, The experiment was conducted with nine treatments *viz*, T₁ = 100% RDFN, T₂ = 100% RDFN + 25% N through paddy straw, T₃ = 100% RDFN + 25% N through paddy compost, T₄ = 100% RDFN + 25% N through maize stalk, T₅ = 100% RDFN + 25% N through maize compost, T₆ = 75% RDFN + 25% N through paddy straw, T₇ = 75% RDFN + 25% N through paddy compost, T₈ = 100% RDFN + 25% N through maize straw and T₉ = 100% RDFN + 25% N through maize compost, in completely randomized block design with three replications.

Crop residues were cut into pieces and compost was prepared. The experimental soil and organic sources used in the study were analysed before the initiation of experiment. Among organic sources tested (paddy straw, paddy compost, maize stalk and maize compost) maize compost was found to be superior with respect to C: N ratio and nutrient composition, followed by paddy compost. They were applied to the respective treatments 15 days before transplanting. Soil samples were collected at 15 days after incorporation and analysed for NH₄⁺-N, NO₃⁻-N and biological activity. Recommended dose of fertilizer nitrogen @ 160 kg ha⁻¹ was applied in three equal split doses as per the treatments. Entire quantity of P₂O₅ (60 kg ha⁻¹) was applied as basal, while K₂O (40 kg ha⁻¹) in two equal splits by considering the nutrient contents in organic sources.

Soil samples collected at 30, 60, 90 and at 120 DAT were analysed for physico-chemical properties, available macro and micro nutrient status and biological activity. While, samples at harvest of rice (120 DAT) were analysed for bulk density, water holding capacity and CEC also. The drymatter at panicle initiation, grain and straw yield were determined. The nutrient concentrations in plants at panicle initiation and at harvest were estimated and their uptake was calculated. The findings of the investigation are summarized below

Bulk density, pH, EC and CEC of soils were not significantly influenced by the integrated application of fertilizer nitrogen and different crop residues and their composts. The water holding capacity of soil at 120 DAT, organic carbon, available macro and micronutrient status, microbial populations and dehydrogenase activity at all stages of plant growth (15, 30, 60, 90 and 120 DAT) were significantly influenced by the treatments. Among the treatments, the treatment supplied with 100% recommended dose of nitrogen in combination with maize compost was superior in maintaining the higher organic carbon, available macro and micronutrient status, microbial populations and dehydrogenase activity. While, lowest values were recorded in treatment with 100% RDFN.

Integrated application of 100 per cent recommended dose of fertilizer nitrogen and 25 per cent nitrogen through cereal composts significantly influenced the dry matter production over sole application of 100 per cent RDFN. The grain and straw yields were also increased significantly by supplementing different levels of inorganic fertilizers with 25% nitrogen through cereal crop residues and their composts. The results indicated that grain and straw yields were higher in the treatments, which received 100 per cent recommended dose of fertilizer nitrogen + 25 per cent nitrogen through maize or rice composts, respectively. The lowest was recorded in treatment which received only inorganic fertilizers (100% RDFN).

The uptake of macro (N, P, K and S) and micronutrients (Fe, Cu, Mn and Zn) by rice crop at 60 and 120 DAT were significantly influenced by various treatments. The highest uptake of nutrients was observed in T₅ (100% RDFN + 25% N through maize compost).

Keeping in view of the above results, the following conclusions are drawn

- ❖ Maize compost has low C:N ratio and high nutrient content compared to rice compost.
- ❖ Addition of compost resulted in mineralization within 15 days after incorporation, while raw residues resulted in immobilization of soil nitrogen.
- ❖ Improvement in soil fertility was recorded as the contents of organic carbon, available nitrogen, phosphorus and micronutrients *viz.*, Fe, Zn, Mn and Cu were significantly higher in case of the treatments which received raw residue or their composts in combination with fertilizer nitrogen than the treatments which received fertilizer nitrogen only.
- ❖ Results also suggest that application of 100 per cent recommended dose of nitrogen along with 25 per cent nitrogen through maize compost was found to be highly effective for achieving more microbial populations and dehydrogenase activity at days of study.
- ❖ Addition of 25 per cent of nitrogen through maize and rice composts performed well in respect to dry matter production, yield and nutrient uptake of rice over sole application of fertilizer nitrogen (100 % RDFN) and in combination with raw residues.

Table 4.3 Influence of crop residues and composts on soil physical and physico-chemical properties at harvest

Treatment	B D (Mg m⁻³)	WHC (%)	CEC (cmol (p+) kg⁻¹)
T ₁ : 100% RDFN	1.34	47.61	43.33
T ₂ : 100% RDFN+25% N through paddy straw	1.33	48.95	44.66
T ₃ : 100% RDFN+25% N through paddy compost	1.31	49.28	45.66
T ₄ : 100%RDFN+25% N through maize stalk	1.32	50.78	45.33
T ₅ : 100% RDFN+25% N through maize compost	1.30	51.87	46.33
T ₆ : 75% RDFN+25% N through paddy straw	1.34	46.39	43.00
T ₇ : 75% RDFN+25% N through paddy compost	1.32	47.34	43.00
T ₈ : 75% RDFN+25% N through maize stalk	1.32	49.28	44.00
T ₉ : 75% RDFN+25% N through maize compost	1.31	50.37	45.66
SEm±	0.02	0.77	0.71
CD @ 0.05	NS	2.29	NS
CV (%)	4.99	4.71	4.84

Table 4.4 Influence of crop residues and composts on physico-chemical properties of soils

Treatment	pH 1:2.5 soil water suspension				EC (dS m ⁻¹) 1:2.5 soil water suspension			
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	7.3	7.3	7.2	7.2	0.48	0.47	0.47	0.46
T ₂ : 100% RDFN+25% N through paddy straw	7.2	7.2	7.1	7.1	0.48	0.46	0.45	0.44
T ₃ : 100% RDFN+25% N through paddy compost	7.2	7.2	7.1	7.1	0.47	0.46	0.44	0.43
T ₄ : 100%RDFN+25% N through maize stalk	7.2	7.2	7.1	7.1	0.47	0.46	0.44	0.44
T ₅ : 100% RDFN+25% N through maize compost	7.2	7.1	7.1	7.1	0.45	0.45	0.43	0.44
T ₆ : 75% RDFN+25% N through paddy straw	7.1	7.1	7.0	7.0	0.46	0.47	0.45	0.44
T ₇ : 75% RDFN+25% N through paddy compost	7.1	7.1	7.0	7.1	0.46	0.45	0.45	0.43
T ₈ : 75% RDFN+25% N through maize stalk	7.1	7.0	7.0	7.0	0.46	0.45	0.45	0.45
T ₉ : 75% RDFN+25% N through maize compost	7.1	7.0	7.0	7.0	0.46	0.44	0.44	0.44
SEm±	0.02	0.01	0.04	0.02	0.003	0.003	0.005	0.003
CD @ 0.05	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	0.88	0.75	1.79	1.18	2.17	2.29	3.7	2.55

Table 4.5 Influence of crop residues and composts on soil organic carbon content

Treatment	Organic carbon (g kg ⁻¹)			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	3.80	3.90	3.70	3.55
T ₂ : 100% RDFN+25% N through paddy straw	4.53	4.55	4.35	4.20
T ₃ : 100% RDFN+25% N through paddy compost	4.38	4.40	4.21	4.16
T ₄ : 100%RDFN+25% N through maize stalk	4.45	4.48	4.29	4.23
T ₅ : 100% RDFN+25% N through maize compost	4.28	4.31	4.18	4.18
T ₆ : 75% RDFN+25% N through paddy straw	4.57	4.60	4.38	4.28
T ₇ : 75% RDFN+25% N through paddy compost	4.40	4.42	4.30	4.20
T ₈ : 75% RDFN+25% N through maize stalk	4.52	4.55	4.32	4.24
T ₉ : 75% RDFN+25% N through maize compost	4.31	4.35	4.28	4.20
SEm±	0.07	0.07	0.07	0.07
CD @ 0.05	0.21	0.21	0.20	0.22
CV (%)	4.97	5.00	4.82	4.91

Table 4.6 Influence of crop residues and composts on ammoniacal nitrogen content of soils

Treatment	30 DAT	60 DAT	90 DAT	120 DAT
	NH ₄ ⁺ -N (kg ha ⁻¹)			
T ₁ : 100% RDFN	26.00	33.33	28.33	26.66
T ₂ : 100% RDFN+25% N through paddy straw	32.00	38.33	32.66	30.33
T ₃ : 100% RDFN+25% N through paddy compost	35.66	41.00	35.00	33.00
T ₄ : 100%RDFN+25% N through maize stalk	34.33	39.33	34.66	31.33
T ₅ : 100% RDFN+25% N through maize compost	37.33	42.33	36.00	34.00
T ₆ : 75% RDFN+25% N through paddy straw	30.00	37.00	31.33	29.66
T ₇ : 75% RDFN+25% N through paddy compost	32.66	38.66	33.33	31.00
T ₈ : 75% RDFN+25% N through maize stalk	33.00	38.33	32.33	30.33
T ₉ : 75% RDFN+25% N through maize compost	35.00	40.66	34.33	32.33
SEm±	0.61	0.56	0.57	0.59
CD @ 0.05	1.83	1.69	1.70	1.77
CV (%)	4.63	4.41	4.22	4.80

Table 4.7 Influence of crop residues and composts on nitrate nitrogen content of soils

Treatment	30 DAT	60 DAT	90 DAT	120 DAT
	NO ₃ ⁻ -N (kg ha ⁻¹)			
T ₁ : 100% RDFN	29.76	31.70	27.70	25.56
T ₂ : 100% RDFN+25% N through paddy straw	34.60	37.87	32.27	28.81
T ₃ : 100% RDFN+25% N through paddy compost	38.22	41.27	37.42	31.68
T ₄ : 100% RDFN+25% N through maize stalk	35.99	38.80	33.84	29.86
T ₅ : 100% RDFN+25% N through maize compost	40.74	43.41	41.02	33.71
T ₆ : 75% RDFN+25% N through paddy straw	30.90	30.74	28.04	26.80
T ₇ : 75% RDFN+25% N through paddy compost	34.59	36.52	32.28	30.77
T ₈ : 75% RDFN+25% N through maize stalk	32.94	34.85	29.53	27.82
T ₉ : 75% RDFN+25% N through maize compost	38.49	41.96	36.64	31.44
SEm±	0.47	0.60	0.56	0.48
CD @ 0.05	1.40	1.78	1.66	1.42
CV (%)	4.04	4.82	4.87	4.89

Table 4.8 Influence of crop residues and composts on available nitrogen content of soils

Treatment	Nitrogen (kg ha ⁻¹)			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	231	254	231	219
T ₂ : 100% RDFN+25% N through paddy straw	253	255	258	252
T ₃ : 100% RDFN+25% N through paddy compost	262	265	266	258
T ₄ : 100%RDFN+25% N through maize stalk	250	252	259	254
T ₅ : 100% RDFN+25% N through maize compost	266	268	271	259
T ₆ : 75% RDFN+25% N through paddy straw	250	255	257	250
T ₇ : 75% RDFN+25% N through paddy compost	257	258	259	255
T ₈ : 75% RDFN+25% N through maize stalk	249	256	256	249
T ₉ : 75% RDFN+25% N through maize compost	260	263	265	256
SEm±	3.32	3.35	3.66	3.34
CD @ 0.05	10.00	10.00	11.00	10.00
CV (%)	4.11	4.10	3.97	4.12

Table 4.9 Influence of crop residues and composts on available phosphorous content of soils

Treatment	Available P₂O₅ (kg ha⁻¹)			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	30.94	29.23	28.34	26.10
T ₂ : 100% RDFN+25% N through paddy straw	33.97	35.68	37.61	35.53
T ₃ : 100% RDFN+25% N through paddy compost	37.55	39.57	43.20	38.82
T ₄ : 100%RDFN+25% N through maize stalk	34.16	36.03	38.52	34.56
T ₅ : 100% RDFN+25% N through maize compost	39.57	43.75	44.09	40.61
T ₆ : 75% RDFN+25% N through paddy straw	32.07	33.02	36.03	33.12
T ₇ : 75% RDFN+25% N through paddy compost	35.98	37.32	40.76	37.15
T ₈ : 75% RDFN+25% N through maize stalk	31.10	32.92	34.09	32.96
T ₉ : 75% RDFN+25% N through maize compost	36.95	38.82	42.30	39.87
SEm±	0.37	0.58	0.63	0.44
CD @ 0.05	1.12	1.74	1.89	1.32
CV (%)	4.87	4.86	4.89	3.76

Table 4.10 Influence of crop residues and composts on available potassium content of soils

Treatment	Available K ₂ O (kg ha ⁻¹)			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	442	432	441	428
T ₂ : 100% RDFN+25% N through paddy straw	461	463	466	457
T ₃ : 100% RDFN+25% N through paddy compost	468	476	478	468
T ₄ : 100% RDFN+25% N through maize stalk	463	467	469	461
T ₅ : 100% RDFN+25% N through maize compost	471	478	481	472
T ₆ : 75% RDFN+25% N through paddy straw	458	459	460	450
T ₇ : 75% RDFN+25% N through paddy compost	465	470	472	465
T ₈ : 75% RDFN+25% N through maize stalk	459	465	467	454
T ₉ : 75% RDFN+25% N through maize compost	467	473	476	469
SEm±	2.98	3.66	4.34	3.67
CD @ 0.05	9.00	11.00	13.00	11.00
CV (%)	2.17	1.71	3.85	3.31

Table 4.11 Influence of crop residues and composts on available sulphur content of soils

Treatment	Available sulphur ($\mu\text{g g}^{-1}$)			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	26.91	28.12	24.36	19.50
T ₂ : 100% RDFN+25% N through paddy straw	41.95	44.73	42.19	35.10
T ₃ : 100% RDFN+25% N through paddy compost	46.02	50.95	45.84	37.53
T ₄ : 100% RDFN+25% N through maize stalk	42.17	45.99	43.98	36.56
T ₅ : 100% RDFN+25% N through maize compost	47.39	51.69	47.83	39.38
T ₆ : 75% RDFN+25% N through paddy straw	37.73	40.45	36.69	30.07
T ₇ : 75% RDFN+25% N through paddy compost	42.58	45.09	42.57	33.34
T ₈ : 75% RDFN+25% N through maize stalk	39.34	42.59	37.95	31.67
T ₉ : 75% RDFN+25% N through maize compost	44.81	45.70	44.70	34.69
SEm\pm	0.65	0.69	0.65	0.54
CD @ 0.05	1.93	2.07	1.95	1.50
CV (%)	4.78	4.87	4.92	4.91

Table 4.16 Influence of crop residues and composts on bacterial population ($\times 10^5$ CFU g^{-1} soil) of soils

Treatment	Bacterial population			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	61.66	66.33	57.00	45.00
T ₂ : 100% RDFN+25% N through paddy straw	71.33	72.33	69.66	65.66
T ₃ : 100% RDFN+25% N through paddy compost	88.00	93.00	87.66	83.33
T ₄ : 100%RDFN+25% N through maize stalk	72.33	75.66	73.33	67.33
T ₅ : 100% RDFN+25% N through maize compost	93.33	97.66	93.00	87.33
T ₆ : 75% RDFN+25% N through paddy straw	65.33	71.33	65.33	58.00
T ₇ : 75% RDFN+25% N through paddy compost	76.66	82.33	78.00	74.66
T ₈ : 75% RDFN+25% N through maize stalk	66.33	75.66	67.00	65.66
T ₉ : 75% RDFN+25% N through maize compost	80.33	84.33	82.33	76.66
SEm±	1.09	0.84	1.17	0.96
CD @ 0.05	3.26	2.50	3.50	2.86
CV (%)	4.39	3.16	4.72	4.17

Table 4.17 Influence of crop residues and composts on fungal population ($\times 10^3$ CFU g^{-1} soil) of soils

Treatment	Fungal population			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	4.66	5.33	2.66	2.00
T ₂ : 100% RDFN+25% N through paddy straw	9.00	10.33	8.00	5.00
T ₃ : 100% RDFN+25% N through paddy compost	14.33	16.33	11.66	6.00
T ₄ : 100%RDFN+25% N through maize stalk	10.33	11.66	10.00	6.00
T ₅ : 100% RDFN+25% N through maize compost	16.00	18.66	14.00	8.00
T ₆ : 75% RDFN+25% N through paddy straw	6.66	7.00	7.33	3.00
T ₇ : 75% RDFN+25% N through paddy compost	13.00	10.66	9.33	5.00
T ₈ : 75% RDFN+25% N through maize stalk	5.66	6.33	7.00	4.00
T ₉ : 75% RDFN+25% N through maize compost	9.33	12.33	10.33	6.33
SEm\pm	0.19	0.41	0.14	0.06
CD @ 0.05	0.57	1.22	0.42	0.19
CV (%)	5.58	4.96	4.82	3.82

Table 4.18 Influence of crop residues and composts on actinomycetes population ($\times 10^3$ CFU g^{-1} soil) of soils

Treatment	Actinomycetes population			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	36.2	32.6	31.8	30.0
T ₂ : 100% RDFN+25% N through paddy straw	53.2	56.5	39.6	38.6
T ₃ : 100% RDFN+25% N through paddy compost	56.1	63.8	49.9	47.8
T ₄ : 100%RDFN+25% N through maize stalk	54.2	61.3	48.6	42.2
T ₅ : 100% RDFN+25% N through maize compost	66.5	75.3	54.2	49.1
T ₆ : 75% RDFN+25% N through paddy straw	52.3	58.4	32.6	30.7
T ₇ : 75% RDFN+25% N through paddy compost	56.6	62.2	45.5	42.4
T ₈ : 75% RDFN+25% N through maize stalk	53.2	59.3	38.5	37.1
T ₉ : 75% RDFN+25% N through maize compost	62.2	63.3	51.9	45.7
SEm±	0.85	1.17	0.72	0.69
CD @ 0.05	2.54	3.49	2.13	2.05
CV (%)	4.71	4.92	4.95	5.00

Table 4.19 Influence of crop residues and compost on soil dehydrogenase activity

Treatment	Dehydrogenase ($\mu\text{g TPF g}^{-1} \text{soil day}^{-1}$)			
	30 DAT	60 DAT	90 DAT	120 DAT
T ₁ : 100% RDFN	53.52	57.1	46.02	41.72
T ₂ : 100% RDFN+25% N through paddy straw	58.7	63.26	58.12	54.52
T ₃ : 100% RDFN+25% N through paddy compost	67.72	77.8	68.52	65.32
T ₄ : 100%RDFN+25% N through maize stalk	58.8	64.70	59.06	57.60
T ₅ : 100% RDFN+25% N through maize compost	70.70	79.76	71.6	66.52
T ₆ : 75% RDFN+25% N through paddy straw	55.92	61.5	48.8	45.72
T ₇ : 75% RDFN+25% N through paddy compost	66.42	76.16	52.52	50.80
T ₈ : 75% RDFN+25% N through maize stalk	56.12	59.46	52.92	47.86
T ₉ : 75% RDFN+25% N through maize compost	66.86	73.06	54.40	53.06
SEm\pm	0.76	0.52	0.37	0.40
CD @ 0.05	2.28	1.56	1.12	1.19
CV (%)	3.80	4.60	3.90	4.37

Table 4.1 Chemical composition of crop residues and composts (on dry weight basis)

Nutrient	Rice residue raw	Rice residue compost	Maize stalk	Maize stalk compost
Total carbon (%)	39.58	15.84	40.06	23.06
Nitrogen (%)	0.71	0.81	0.89	1.22
Phosphorus (%)	0.22	0.31	0.30	0.39
Potassium (%)	1.30	1.43	1.32	1.49
C:N ratio	55.74:1	19.5:1	45.01:1	18.9:1
C:P ratio	123.68:1	38.63:1	108.74:1	52.40:1
Iron ($\mu\text{g g}^{-1}$)	89	92	91	98
Zinc ($\mu\text{g g}^{-1}$)	136	140	138	143
Manganese ($\mu\text{g g}^{-1}$)	125	128	127	131
Copper ($\mu\text{g g}^{-1}$)	19	24	21	26

Table 4.2 Soil properties at 15 days after incorporation of crop residues and composts

Treatment	pH	EC (dS m⁻¹)	NH₄⁺-N (kg ha⁻¹)	NO₃⁻-N (kg ha⁻¹)	Bacterial population (CFU g⁻¹ × 10⁵ soil)	Fungal population (CFU g⁻¹ × 10³ soil)	Actinomycetes population (CFU g⁻¹ × 10³ soil)	Dehydrogenase (μg g⁻¹ soil day⁻¹)
T ₁ : No residue	7.3	0.49	6.57	21.44	45.33	8.67	38.9	13.87
T ₂ : 25% N through paddy straw	7.2	0.48	4.50	12.91	59.00	9.00	51.8	28.95
T ₃ : 25% N through paddy compost	7.2	0.46	9.83	28.03	71.83	14.33	57.6	30.42
T ₄ : 25% N through maize stalk	7.2	0.47	6.33	18.23	52.33	10.33	43.6	28.47
T ₅ : 25% N through maize compost	7.2	0.46	11.67	33.7	80.67	16.00	61.9	32.67
SEm±	0.02	0.004	0.18	0.36	1.01	0.46	1.76	0.34
CD @ 0.05	NS	NS	0.54	1.09	3.02	1.40	5.27	1.03
CV (%)	1.21	2.58	4.94	4.38	4.81	3.07	4.18	3.57

Table 4.21 Influence of crop residues and composts on nitrogen and phosphorus uptake by rice

Treatments	Nitrogen				Phosphorus			
	(mg pot ⁻¹)							
	60DAT	Harvest			60DAT	Harvest		
Grain		Straw	Total	Grain		Straw	Total	
T ₁ : 100% RDFN	488 (1.49)*	619 (1.06)*	415 (0.71)*	1035	72 (0.22)*	134 (0.23)*	111 (0.19)*	245
T ₂ : 100% RDFN+25% N through paddy straw	664 (1.52)	713 (1.11)	469 (0.73)	1183	104 (0.24)	173 (0.27)	135 (0.21)	308
T ₃ : 100% RDFN+25% N through paddy compost	715 (1.58)	839 (1.19)	536 (0.76)	1375	131 (0.29)	204 (0.29)	169 (0.24)	373
T ₄ : 100%RDFN+25% N through maize stalk	674 (1.54)	753 (1.12)	504 (0.75)	1257	113 (0.26)	188 (0.28)	148 (0.22)	336
T ₅ : 100% RDFN+25% N through maize compost	727 (1.59)	839 (1.20)	559 (0.80)	1398	137 (0.30)	203 (0.29)	175 (0.25)	378
T ₆ : 75% RDFN+25% N through paddy straw	537 (1.50)	643 (1.08)	417 (0.70)	1060	75 (0.21)	143 (0.24)	119 (0.20)	262
T ₇ : 75% RDFN+25% N through paddy compost	598 (1.55)	756 (1.17)	472 (0.73)	1229	85 (0.22)	162 (0.25)	142 (0.22)	304
T ₈ : 75% RDFN+25% N through maize stalk	549 (1.51)	658 (1.09)	435 (0.72)	1093	76 (0.21)	145 (0.24)	121 (0.20)	266
T ₉ : 75% RDFN+25% N through maize compost	622 (1.56)	768(1.18)	482 (0.74)	1251	95 (0.24)	169 (0.26)	150 (0.23)	319
SEm±	24.26	21.75	17.33	37.57	6.67	6.82	6.32	13.15
CD (P = 0.05)	72.79	65.00	52.00	113.00	20.02	21.00	19.00	39.45
CV%	4.94	5.56	4.98	4.65	4.91	4.95	4.96	4.83

***Data in parenthesis indicates nutrient concentration in %**

Table 4.22 Influence of crop residues and composts on potassium and sulphur uptake by rice

Treatments	Potassium				Sulphur			
	(mg pot ⁻¹)							
	60DAT	Harvest			60DAT	Harvest		
		Grain	Straw	Total		Grain	Straw	Total
T ₁ : 100% RDFN	872 (2.66)*	251 (0.43)*	870 (1.49)*	1121	101 (0.31)*	333 (0.57)*	140 (0.24)*	473
T ₂ : 100% RDFN+25% N through paddy straw	1183 (2.71)	404 (0.63)	975 (1.52)	1380	179 (0.41)	398 (0.62)	244 (0.38)	642
T ₃ : 100% RDFN+25% N through paddy compost	1240 (2.74)	472 (0.67)	1099 (1.56)	1571	194 (0.43)	451 (0.64)	282 (0.40)	733
T ₄ : 100%RDFN+25% N through maize stalk	1190 (2.72)	437 (0.65)	1108 (1.65)	1545	183 (0.42)	423 (0.63)	262 (0.39)	685
T ₅ : 100% RDFN+25% N through maize compost	1257 (2.75)	482 (0.69)	1188 (1.70)	1670	210 (0.46)	454 (0.65)	286 (0.41)	741
T ₆ : 75% RDFN+25% N through paddy straw	956 (2.67)	345 (0.58)	887(1.49)	1233	143 (0.40)	345 (0.58)	220 (0.37)	566
T ₇ : 75% RDFN+25% N through paddy compost	1042 (2.70)	400 (0.62)	995 (1.54)	1395	169 (0.44)	387 (0.60)	252 (0.39)	640
T ₈ : 75% RDFN+25% N through maize stalk	977 (2.69)	356 (0.59)	911 (1.51)	1267	149 (0.41)	368 (0.61)	229 (0.38)	598
T ₉ : 75% RDFN+25% N through maize compost	1089 (2.73)	416 (0.64)	1008 (1.55)	1425	179 (0.45)	403 (0.62)	260 (0.40)	664
SEm±	37.19	22.84	30.55	54.28	11.19	11.96	14.43	26.5
CD (P = 0.05)	111.00	69.00	91.00	163.00	33.00	36.00	44.00	80.00
CV%	4.56	4.92	4.84	4.96	4.96	4.65	4.67	4.73

***Data in parenthesis indicates nutrient concentration in %**

Table 4.23 Influence of crop residues and composts on uptake of iron and zinc by rice

Treatments	Iron				Zinc			
	(mg pot ⁻¹)							
	60 DAT	Harvest			60 DAT	Harvest		
		Grain	Straw	Total		Grain	Straw	Total
T ₁ : 100% RDFN	3.47 (106.00)*	2.51 (43.00)*	3.91 (67.00)*	6.42	2.68 (81.90)*	1.4 (24.07)*	3.91 (67.08)*	5.32
T ₂ : 100% RDFN+25% N through paddy straw	4.99 (114.31)	3.19 (49.82)	4.88 (76.12)	8.08	4.15 (95.23)	2.00 (31.25)	4.97 (77.47)	6.97
T ₃ : 100% RDFN+25% N through paddy compost	5.76 (127.31)	4.23 (60.14)	5.75 (81.72)	9.99	5.21 (115.20)	3.43 (48.73)	7.53 (106.88)	10.96
T ₄ : 100%RDFN+25% N through maize stalk	5.22 (119.28)	3.51 (52.34)	5.09 (75.90)	8.61	4.92 (112.43)	2.39 (35.59)	6.82 (101.63)	9.21
T ₅ : 100% RDFN+25% N through maize compost	6.19 (135.49)	4.38 (62.70)	6.11 (87.48)	10.49	5.64 (123.47)	3.94 (56.47)	7.90 (113.11)	11.85
T ₆ : 75% RDFN+25% N through paddy straw	3.68 (102.83)	2.62 (44.15)	4.10 (68.89)	6.73	3.12 (87.30)	1.65 (27.84)	4.20 (70.57)	5.86
T ₇ : 75% RDFN+25% N through paddy compost	4.69 (121.46)	3.38 (52.40)	4.83 (74.84)	8.22	4.16 (107.91)	2.34 (36.23)	5.38 (83.41)	7.72
T ₈ : 75% RDFN+25% N through maize stalk	3.89 (107.14)	2.84 (47.14)	4.27 (70.76)	7.11	3.56 (98.15)	1.75 (29.00)	4.78 (79.24)	6.53
T ₉ : 75% RDFN+25% N through maize compost	5.12 (128.47)	3.61 (55.48)	5.19 (79.84)	8.80	4.46 (111.96)	2.76 (42.51)	5.62 (86.39)	8.38
SEm±	0.37	0.25	0.29	0.55	0.15	0.10	0.54	0.88
CD (P = 0.05)	1.11	0.76	0.89	1.66	0.45	0.32	1.62	2.66
CV%	4.90	4.65	4.79	4.89	3.27	3.66	4.97	4.81

***Data in parenthesis indicates nutrient concentration in %**

Table 4.24 Influence of crop residues and composts on uptake of Manganese and Copper by rice

Treatments	Manganese				Copper			
	(mg pot ⁻¹)							
	60 DAT	Harvest		Total	60 DAT	Harvest		Total
		Grain	Straw			Grain	Straw	
T ₁ : 100% RDFN	3.60 (110.00)*	2.30 (39.48)*	4.97 (85.20)*	7.28	0.47 (14.44)*	0.42 (7.26)*	0.83 (14.29)*	1.25
T ₂ : 100% RDFN+25% N through paddy straw	5.64 (129.27)	3.39 (52.80)	7.28 (113.50)	10.67	0.77 (17.75)	0.56 (8.67)	1.07 (16.80)	1.63
T ₃ : 100% RDFN+25% N through paddy compost	6.24 (138.00)	4.43 (62.93)	9.10 (129.20)	13.54	0.93 (20.57)	0.83 (11.82)	1.40 (19.88)	2.23
T ₄ : 100% RDFN+25% N through maize stalk	6.18 (141.23)	4.44 (66.07)	7.78 (115.83)	12.22	0.81 (18.51)	0.63 (9.46)	1.16 (17.36)	1.8
T ₅ : 100% RDFN+25% N through maize compost	6.86 (150.10)	4.95 (70.87)	9.78 (140.00)	14.73	1.03 (22.69)	0.85 (12.24)	1.43 (20.48)	2.28
T ₆ : 75% RDFN+25% N through paddy straw	4.33 (121.12)	2.42 (40.60)	5.41 (90.90)	7.83	0.55 (15.61)	0.51 (8.58)	0.93 (15.74)	1.44
T ₇ : 75% RDFN+25% N through paddy compost	4.96 (128.63)	3.35 (51.93)	7.89 (122.17)	11.24	0.83 (21.54)	0.69 (10.69)	1.28 (19.86)	1.97
T ₈ : 75% RDFN+25% N through maize stalk	4.36 (120.06)	2.47 (41.00)	6.22 (103.13)	8.69	0.67 (18.48)	0.58 (9.66)	1.07 (17.82)	1.65
T ₉ : 75% RDFN+25% N through maize compost	5.41 (135.67)	4.40 (67.57)	8.10 (124.50)	12.49	0.93 (23.37)	0.75 (11.54)	1.36 (20.95)	2.11
SEm±	0.45	0.36	0.65	1.01	0.07	0.05	0.08	0.14
CD (P = 0.05)	1.33	1.08	1.96	3.04	0.23	0.18	0.24	0.42
CV%	4.87	4.82	4.37	4.34	4.90	4.25	4.98	4.85

***Data in parenthesis indicates nutrient concentration in %**

Table 3. 2 Characteristics of the experimental soil

S.No.	Characteristics	Value
I.	Physical properties	
A.	Mechanical analysis	
	Sand (%)	32.3
	Silt (%)	12.4
	Clay (%)	55.3
	Textural class	Clay
B.	Bulk density (Mg m^{-3})	1.4
II.	Physico-chemical properties	
a)	Soil reaction (pH 1 : 2.5 soil water suspension).	7.3
b)	Electrical conductivity (EC 1 : 2.5) (dS m^{-1})	0.49
c)	Cation exchange capacity (cmol (p+) kg^{-1})	43
d)	Organic carbon (g kg^{-1})	3.7
III.	Chemical properties	
A.	Macronutrients (kg ha^{-1})	
a)	Available nitrogen	206
b)	Available phosphorus (P_2O_5)	24.5
c)	Available potassium (K_2O)	401
d)	Available sulphur ($\text{SO}_4^{-2} - \text{S}$) ($\mu\text{g g}^{-1}$)	20
B.	Micronutrients ($\mu\text{g g}^{-1}$)	
a)	Zinc	0.42
b)	Copper	0.85
c)	Manganese	4.80
d)	Iron	7.40
IV)	Biological properties	
a)	Bacterial population (CFU g^{-1})	40×10^5
b)	Fungal population (CFU g^{-1})	3×10^3
b)	Actinomycetes population (CFU g^{-1})	37×10^3
c)	Dehydrogenase activity ($\mu\text{g of TPF g}^{-1} \text{ day}^{-1}$)	12.56

Table 4.12 Influence of crop residues and composts on available Iron content of soils

Treatment	30 DAT	60 DAT	90 DAT	120 DAT
	(µg g ⁻¹)			
T ₁ : 100% RDFN	7.49	7.50	7.20	7.00
T ₂ : 100% RDFN+25% N through paddy straw	7.98	8.32	8.22	8.17
T ₃ : 100% RDFN+25% N through paddy compost	8.48	8.90	8.41	8.36
T ₄ : 100%RDFN+25% N through maize stalk	8.06	8.36	8.23	8.19
T ₅ : 100% RDFN+25%N through maize compost	8.62	9.18	8.51	8.45
T ₆ : 75% RDFN+25% N through paddy straw	7.54	7.63	7.57	7.48
T ₇ : 75% RDFN+25% N through paddy compost	7.96	8.29	7.89	7.82
T ₈ : 75% RDFN+25% N through maize stalk	7.64	7.75	7.67	7.52
T ₉ : 75% RDFN+25% N through maize compost	8.28	8.37	8.08	7.88
SEm±	0.10	0.12	0.10	0.14
CD @ 0.05	0.30	0.36	0.32	0.41
CV (%)	3.89	4.51	4.08	4.35

Table 4.13 Influence of crop residues and composts on available zinc content of soils

Treatment	30 DAT	60 DAT	90 DAT	120 DAT
	(µg g ⁻¹)			
T ₁ : 100% RDFN	0.46	0.48	0.41	0.36
T ₂ : 100% RDFN+25% N through paddy straw	0.54	0.73	0.69	0.53
T ₃ : 100% RDFN+25% N through paddy compost	0.64	0.84	0.79	0.65
T ₄ : 100% RDFN+25% N through maize stalk	0.55	0.77	0.73	0.55
T ₅ : 100% RDFN+25% N through maize compost	0.65	0.86	0.81	0.66
T ₆ : 75% RDFN+25% N through paddy straw	0.47	0.58	0.51	0.41
T ₇ : 75% RDFN+25% N through paddy compost	0.55	0.68	0.57	0.46
T ₈ : 75% RDFN+25% N through maize stalk	0.48	0.61	0.52	0.44
T ₉ : 75% RDFN+25% N through maize compost	0.57	0.71	0.61	0.47
SEm±	0.01	0.01	0.01	0.01
CD @ 0.05	0.02	0.04	0.05	0.03
CV (%)	4.71	4.93	4.38	4.81

Table 4.14 Influence of crop residues and composts on available copper content of soils

Treatment	30 DAT	60 DAT	90 DAT	120 DAT
	(µg g ⁻¹)			
T ₁ : 100% RDFN	0.82	0.85	0.81	0.79
T ₂ : 100% RDFN+25% N through paddy straw	1.26	1.70	1.58	1.56
T ₃ : 100% RDFN+25% N through paddy compost	1.85	2.10	1.88	1.58
T ₄ : 100%RDFN+25% N through maize stalk	1.32	1.80	1.61	1.57
T ₅ : 100% RDFN+25% N through maize compost	1.91	2.20	1.94	1.60
T ₆ : 75% RDFN+25% N through paddy straw	1.00	1.10	0.87	0.85
T ₇ : 75% RDFN+25% N through paddy compost	1.50	1.75	1.71	1.54
T ₈ : 75% RDFN+25% N through maize stalk	1.06	1.14	0.90	0.88
T ₉ : 75% RDFN+25% N through maize compost	1.54	1.80	1.75	1.56
SEm±	0.03	0.04	0.04	0.05
CD @ 0.05	0.10	0.13	0.11	0.15
CV (%)	4.83	4.60	4.82	4.92

Table 4.15 Influence of crop residues and composts on available manganese content of soils

Treatment	30 DAT	60 DAT	90 DAT	120 DAT
	(µg g ⁻¹)			
T ₁ : 100% RDFN	5.70	5.81	5.35	5.20
T ₂ : 100% RDFN+25% N through paddy straw	7.37	8.74	6.55	4.57
T ₃ : 100% RDFN+25% N through paddy compost	9.27	10.64	8.47	6.59
T ₄ : 100%RDFN+25% N through maize stalk	7.68	8.91	6.62	4.59
T ₅ : 100% RDFN+25% N through maize compost	9.43	10.85	8.64	6.83
T ₆ : 75% RDFN+25% N through paddy straw	6.58	7.36	6.53	4.44
T ₇ : 75% RDFN+25% N through paddy compost	7.34	8.76	7.73	5.65
T ₈ : 75% RDFN+25% N through maize stalk	6.67	7.66	6.75	4.49
T ₉ : 75% RDFN+25% N through maize compost	7.24	8.81	7.55	5.90
SEm±	0.1	0.12	0.12	0.16
CD @ 0.05	0.30	0.36	0.36	0.49
CV (%)	4.07	4.33	4.76	4.82

Table 4.20 Influence of crop residues and composts on dry matter production at 60 DAT, grain and straw yield of rice

Treatment	Dry matter production 60 DAT	Harvest	
		Grain yield	Straw yield
(g pot ⁻¹)			
T ₁ : 100% RDFN	32.78	32.58	58.41
T ₂ : 100% RDFN+25% N through paddy Straw	43.67	41.48	64.19
T ₃ : 100% RDFN+25% N through paddy compost	45.27	44.49	70.48
T ₄ : 100% RDFN+25% N through maize stalk	43.77	42.46	67.19
T ₅ : 100% RDFN+25% N through maize compost	45.72	46.12	69.89
T ₆ : 75% RDFN+25% N through paddy straw	35.82	36.12	59.55
T ₇ : 75% RDFN+25% N through paddy compost	38.62	39.47	64.61
T ₈ : 75% RDFN+25% N through maize stalk	36.33	36.61	60.36
T ₉ : 75% RDFN+25% N through maize compost	39.90	40.56	65.08
SEm±	0.54	0.51	0.82
CD @ 0.05	1.63	1.66	2.46
CV (%)	4.34	4.20	3.86

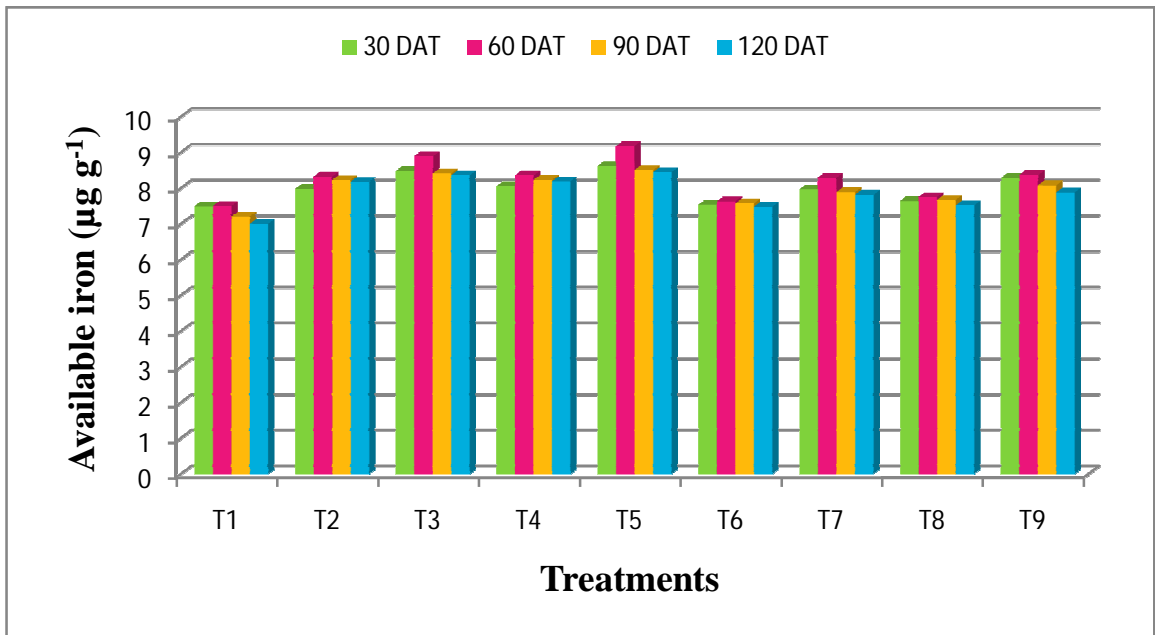


Fig. 4. 8 Influence of crop residues and composts on available iron content ($\mu\text{g g}^{-1}$) in soils

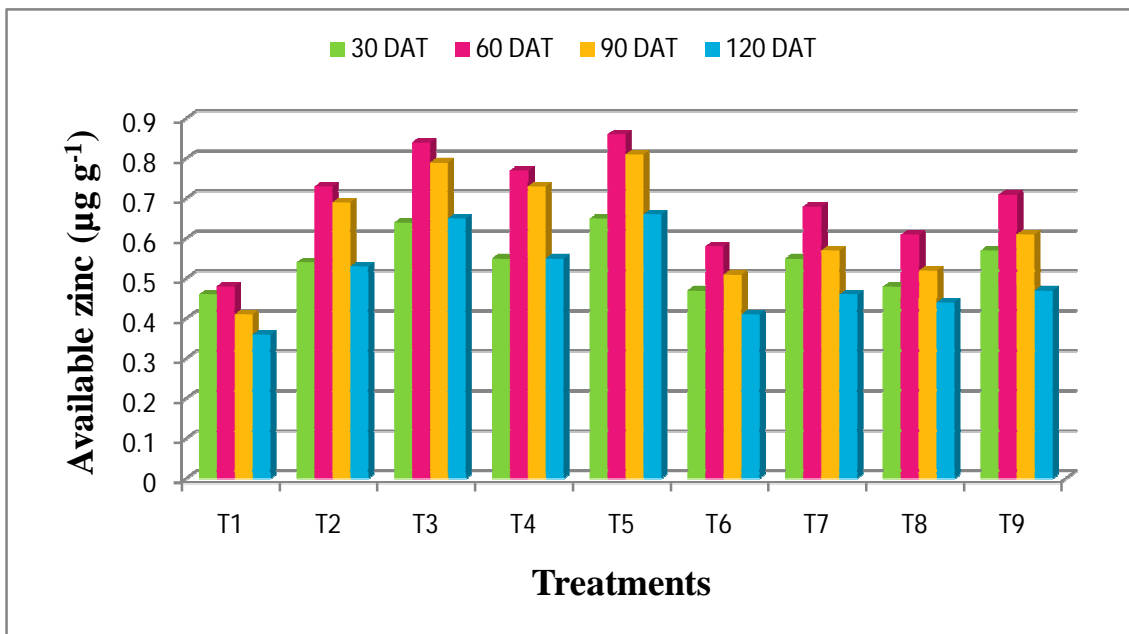


Fig. 4. 9 Influence of crop residues and composts on available zinc content ($\mu\text{g g}^{-1}$) in soils

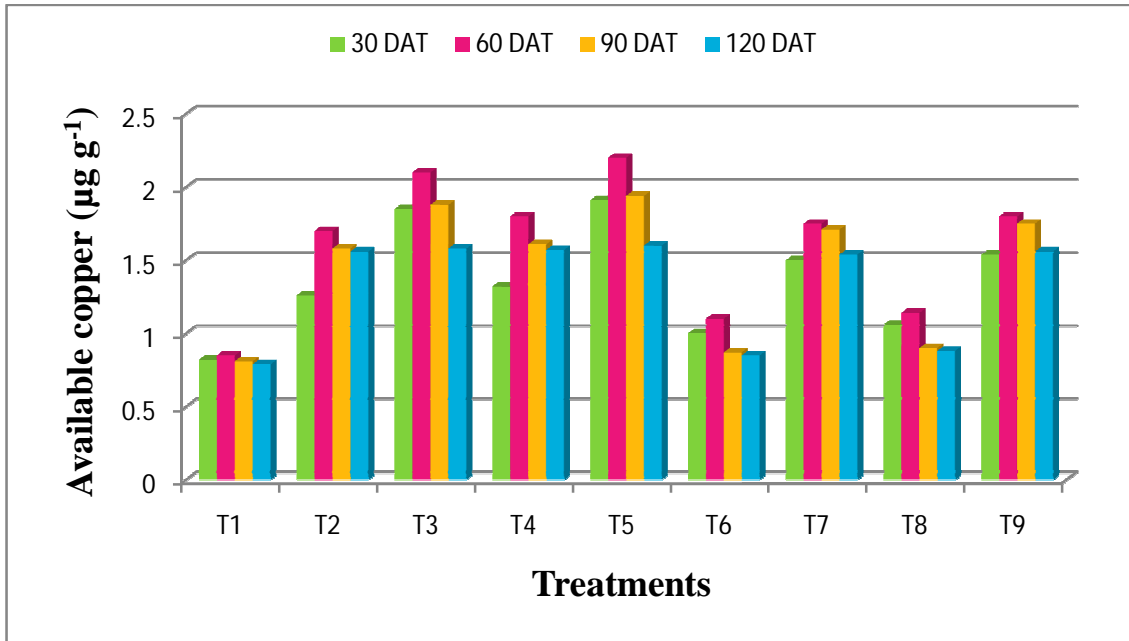


Fig. 4.10 Influence of crop residues and composts on available copper content (µg g⁻¹) in soils

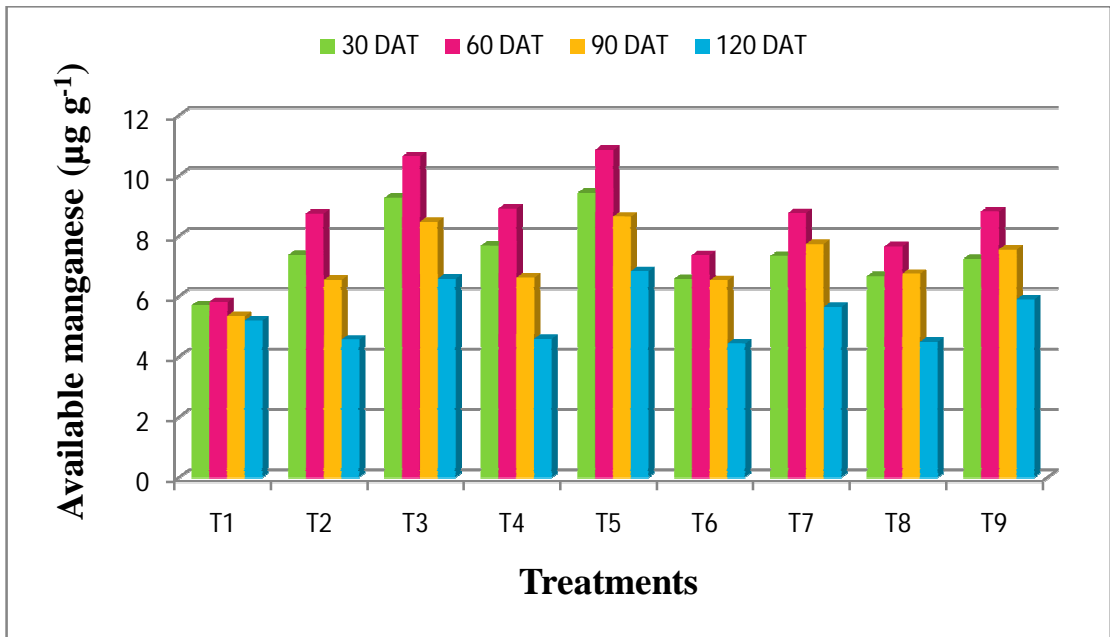


Fig. 4. 11 Influence of crop residues and composts on available manganese content (µg g⁻¹)in soils

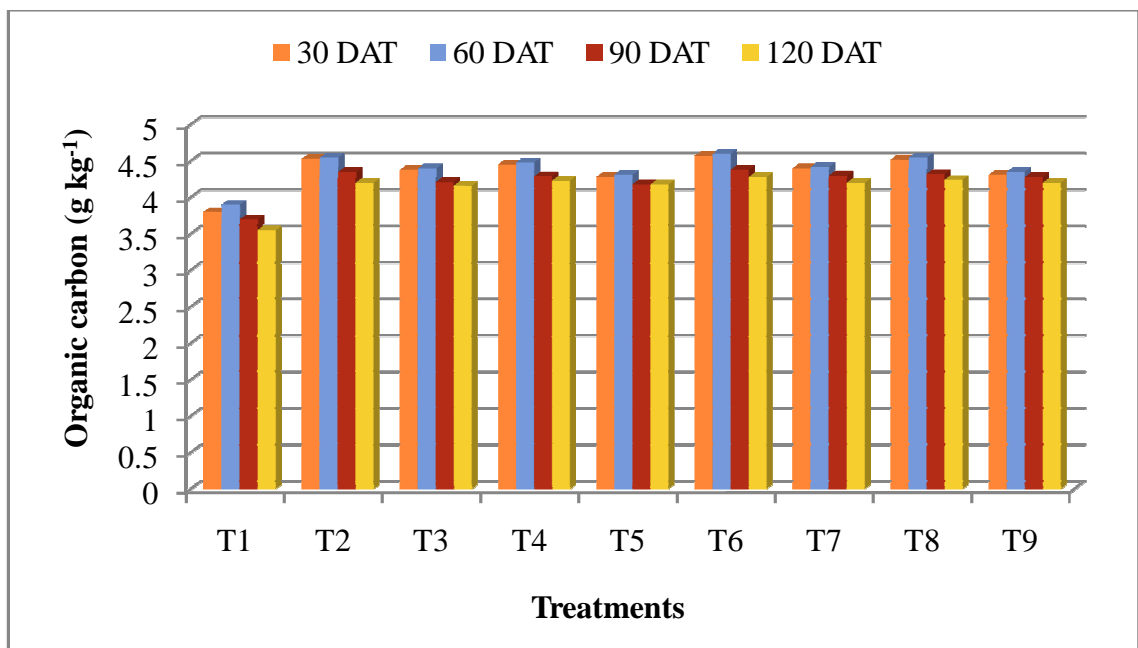


Fig. 4. 1 Influence of crop residues and composts on soil organic carbon content (g kg⁻¹)

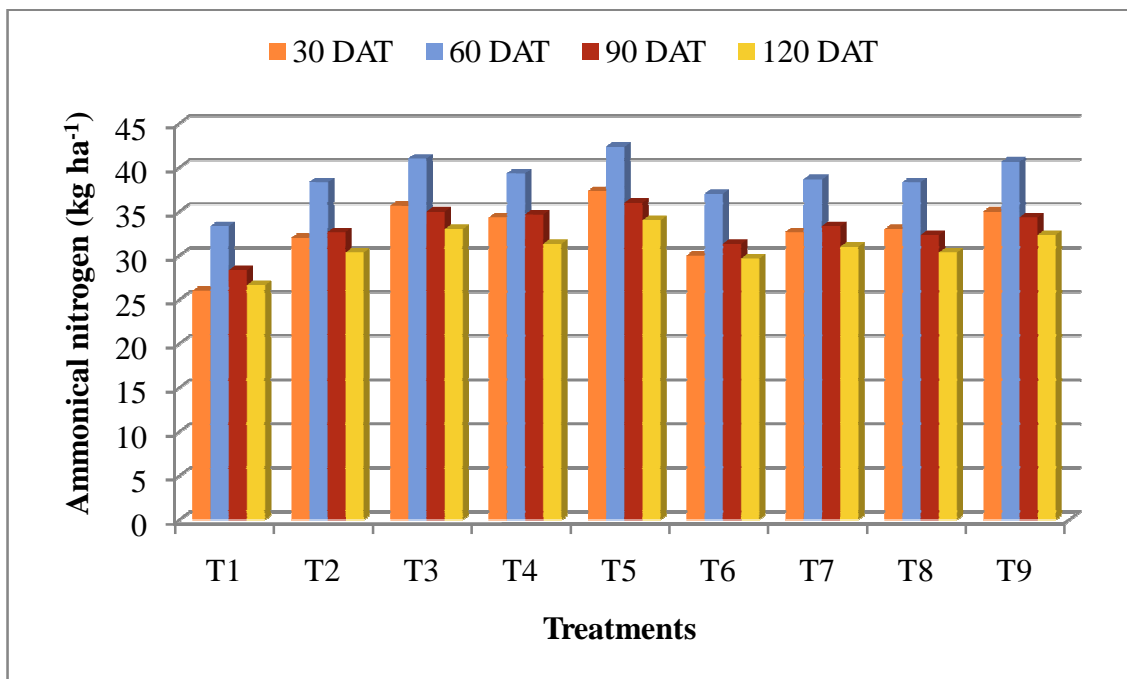


Fig. 4.2 Influence of crop residues and composts on ammoniacal nitrogen content (kg ha⁻¹) in soils

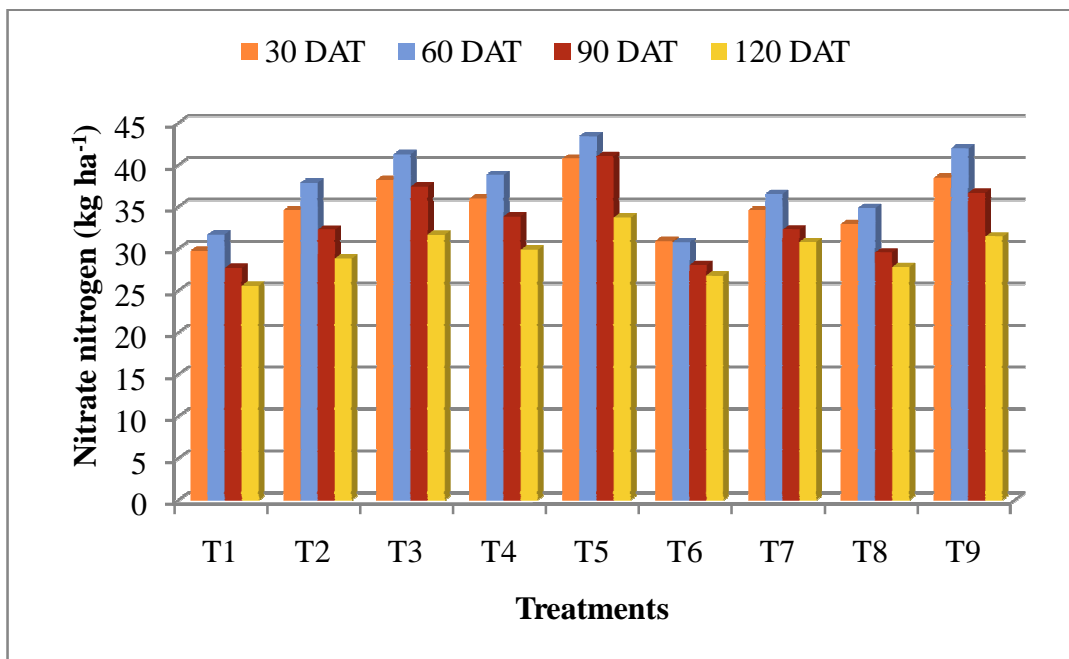


Fig. 4.3 Influence of crop residues and composts on nitrate nitrogen content (kg ha⁻¹) in soils

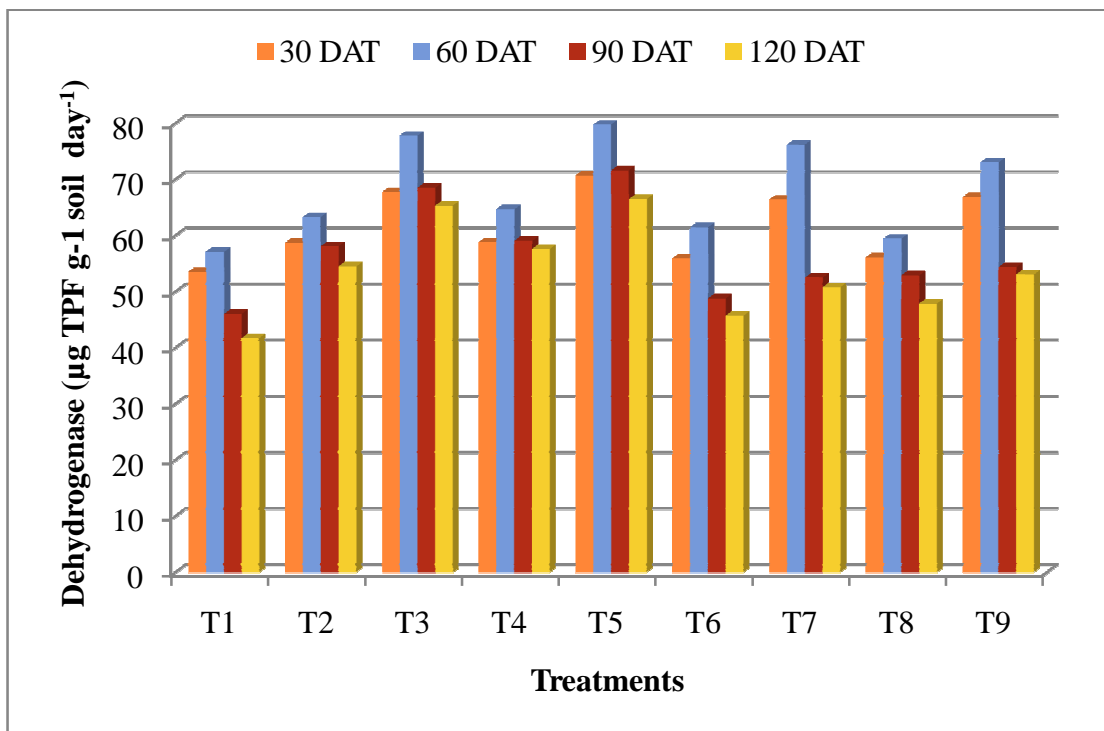


Fig.4.12 Influence of crop residues and composts on soil dehydrogenase activity ($\mu\text{g TPF g}^{-1}\text{ soil day}^{-1}$)

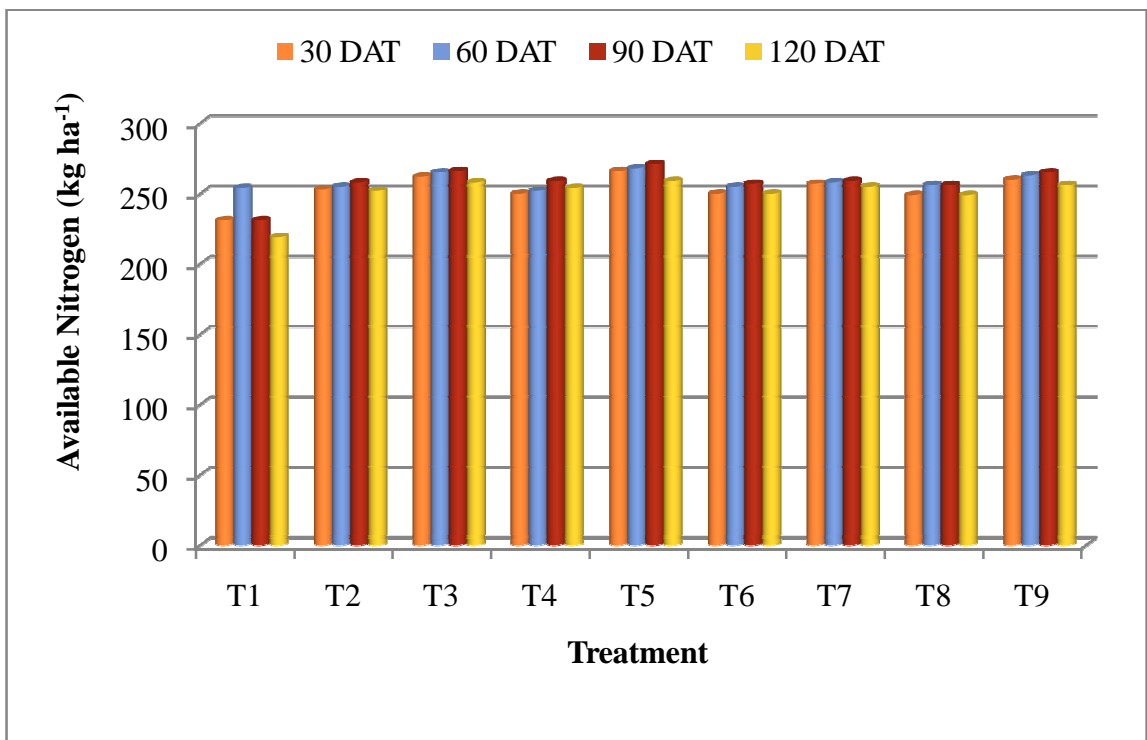


Fig. 4.4 Influence of crop residues and composts on available nitrogen content (kg ha⁻¹) in soils

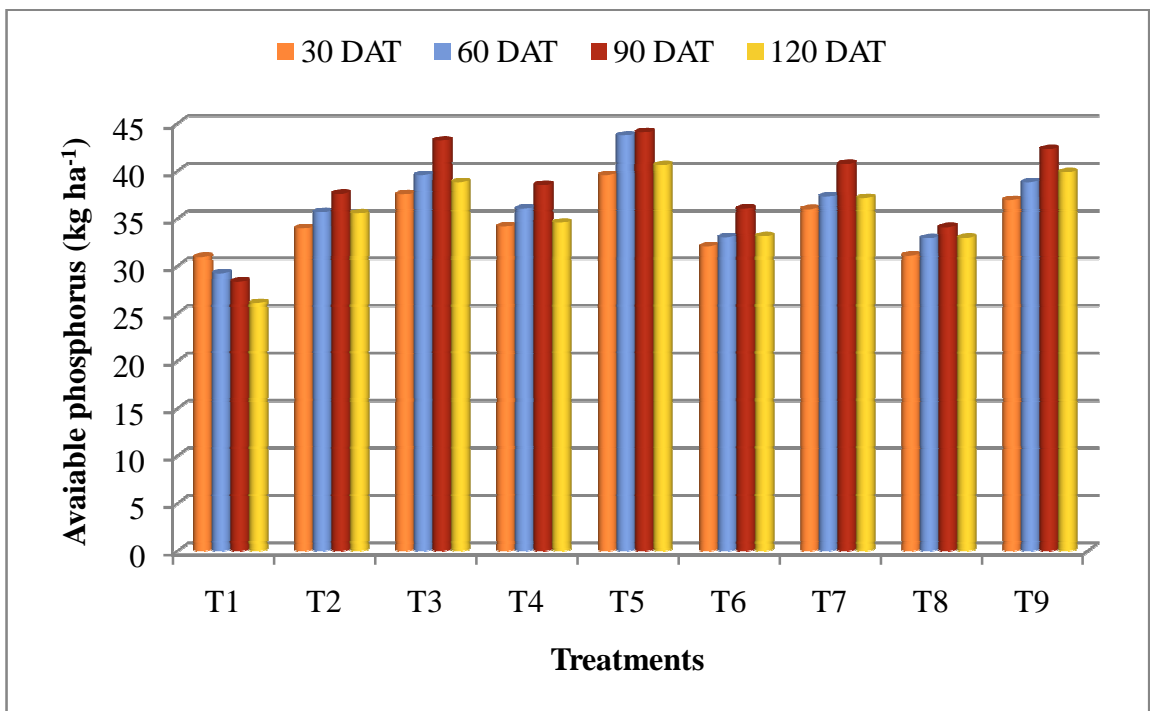


Fig. 4.5 Influence of crop residues and composts on available phosphorus content (kg ha⁻¹) in soils

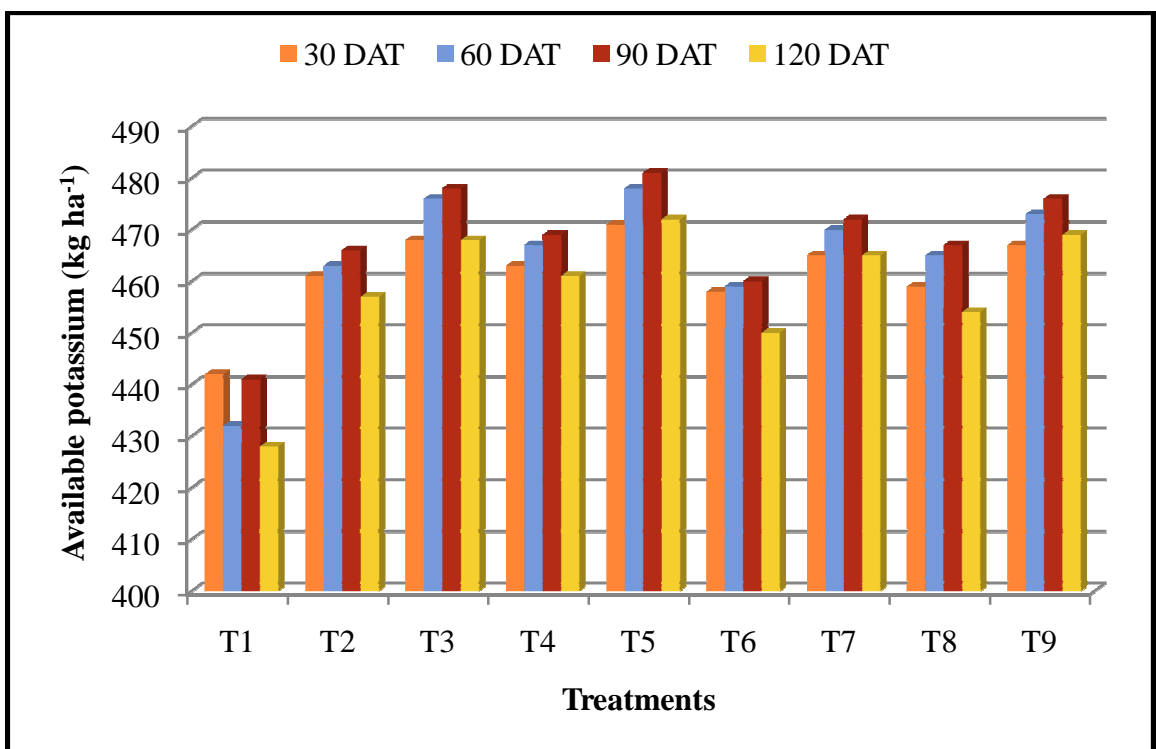


Fig. 4.6 Influence of crop residues and composts on available potassium content (kg ha⁻¹) in soils

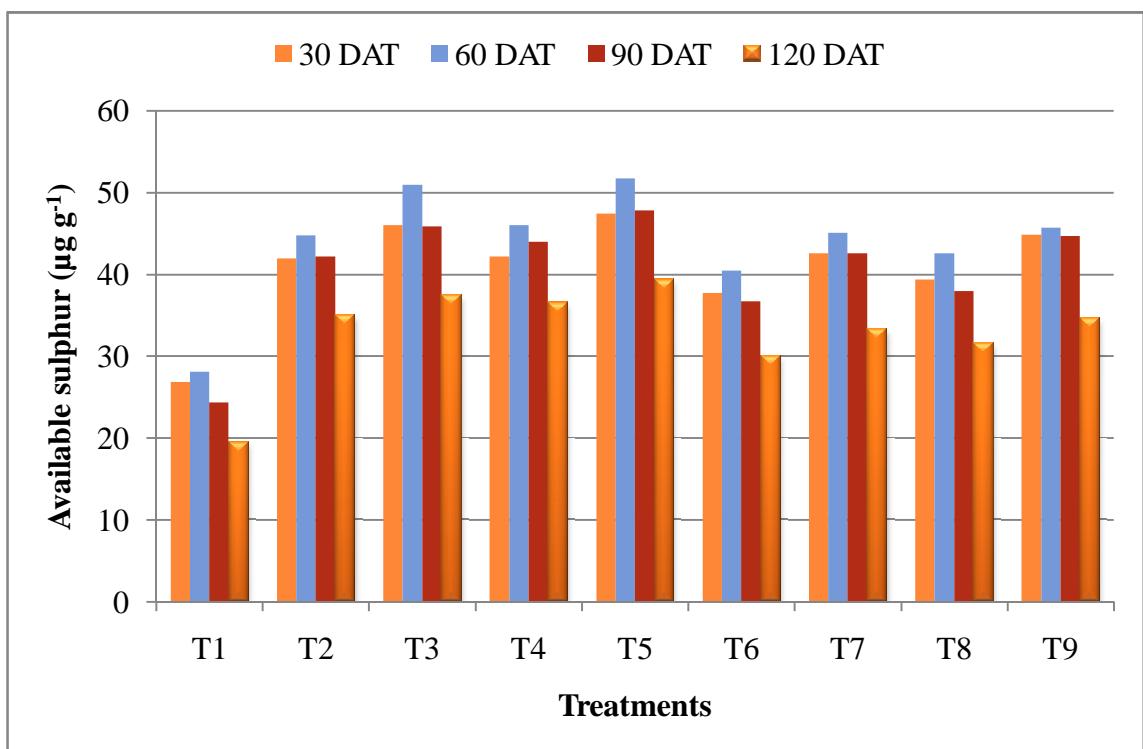


Fig. 4.7 Influence of crop residues and composts on available sulphur content ($\mu\text{g g}^{-1}$) in soils

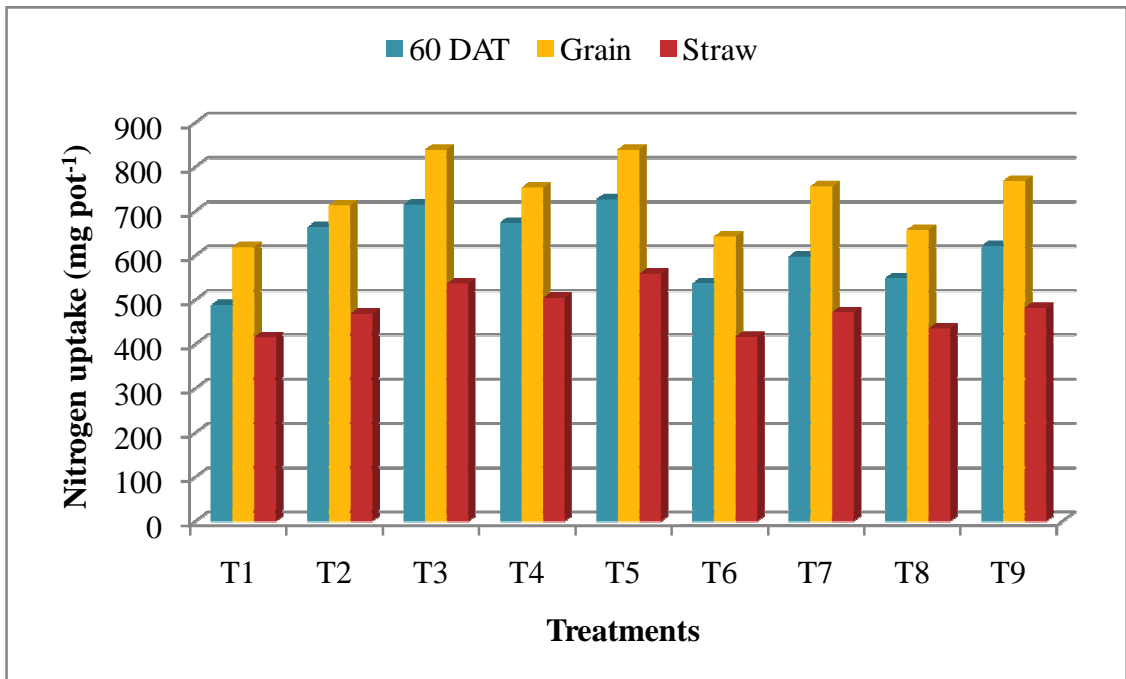


Fig.4.14 Influence of crop residues and composts on nitrogen uptake (mg pot⁻¹) by rice

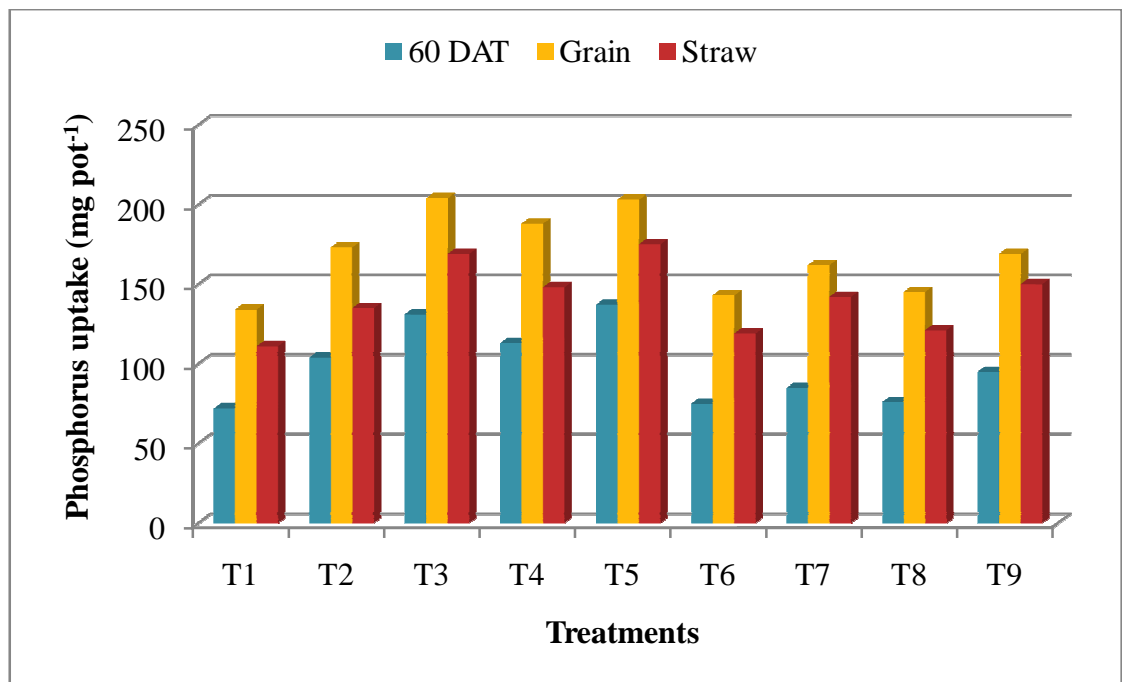


Fig.4.15 Influence of crop residues and composts on phosphorus uptake (mg pot⁻¹) by rice

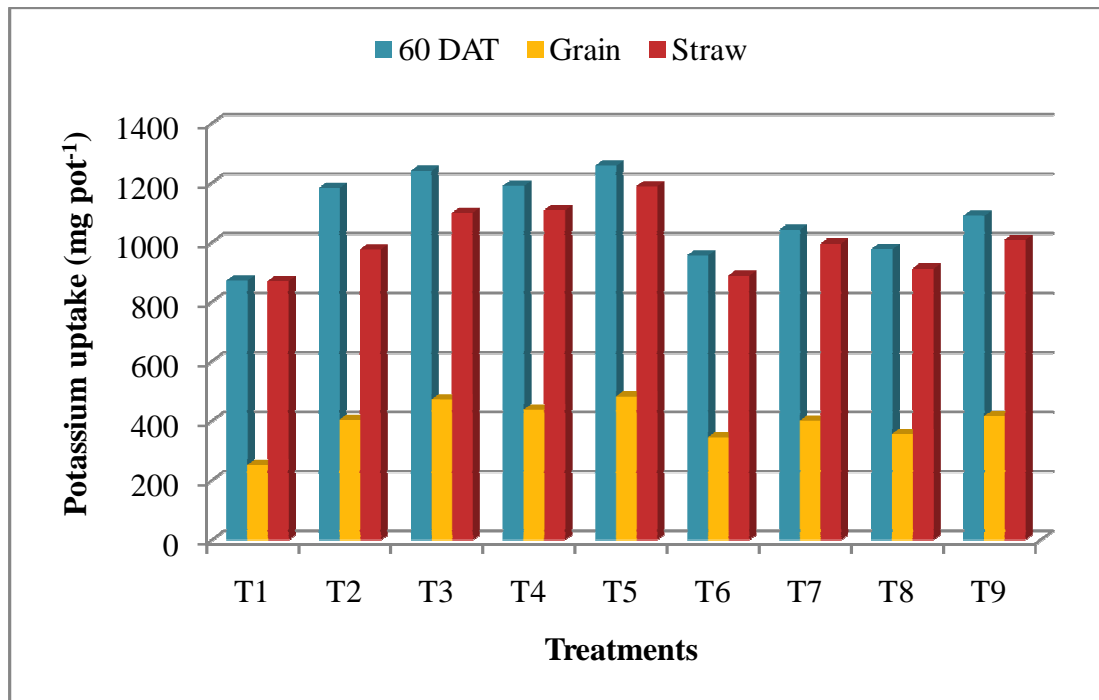


Fig.4.16 Influence of crop residues and composts on potassium uptake (mg pot⁻¹) by rice

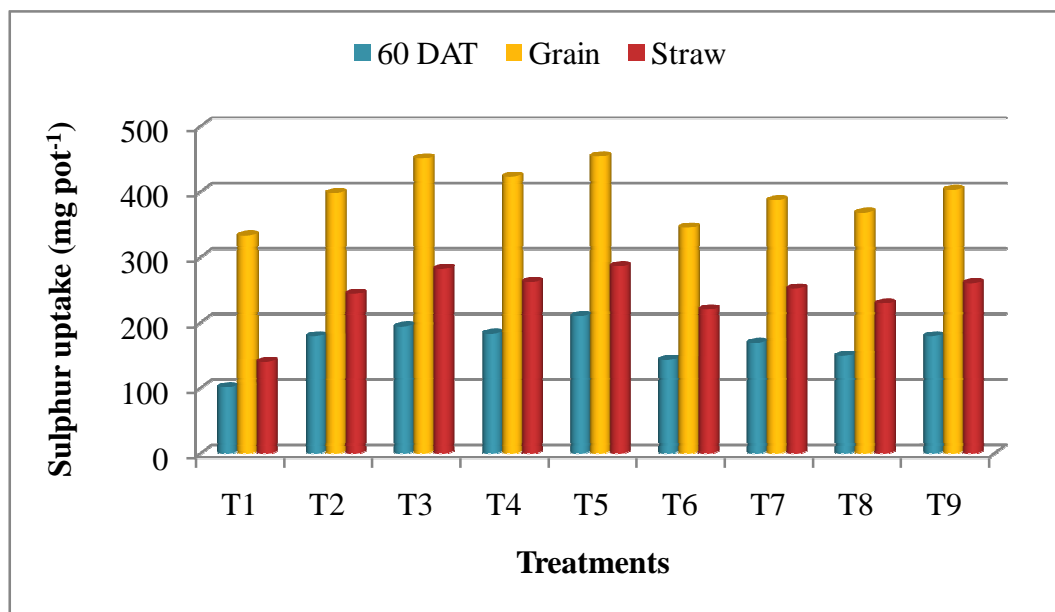


Fig.4. 17 Influence of crop residues and composts on sulphur uptake (mg pot⁻¹) by rice

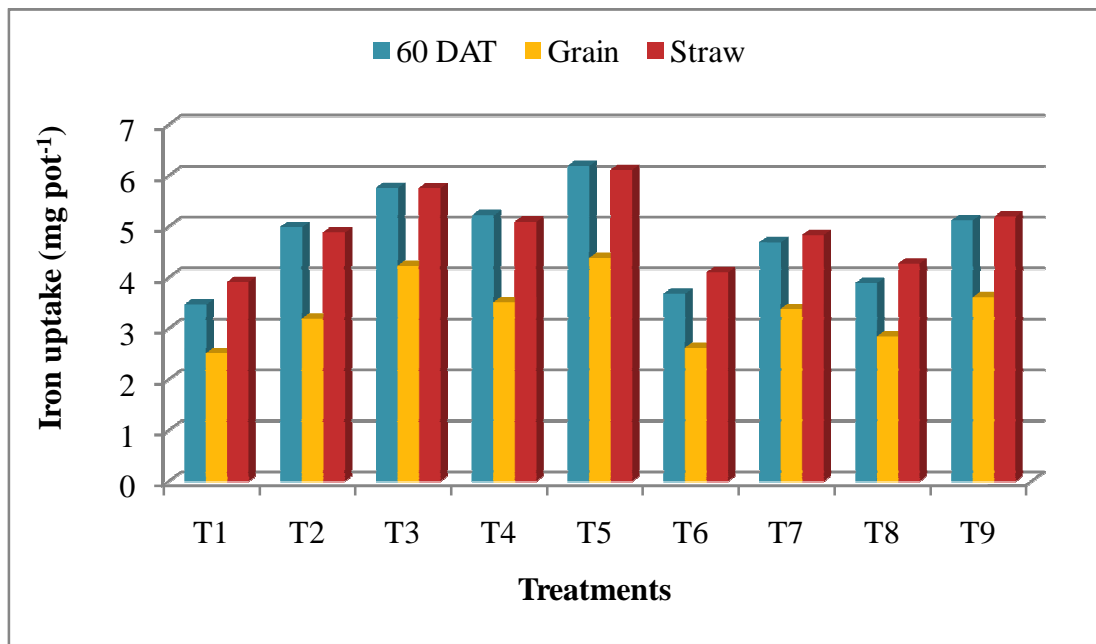


Fig. 4.18 Influence of crop residues and composts on iron uptake (mg pot⁻¹) by rice

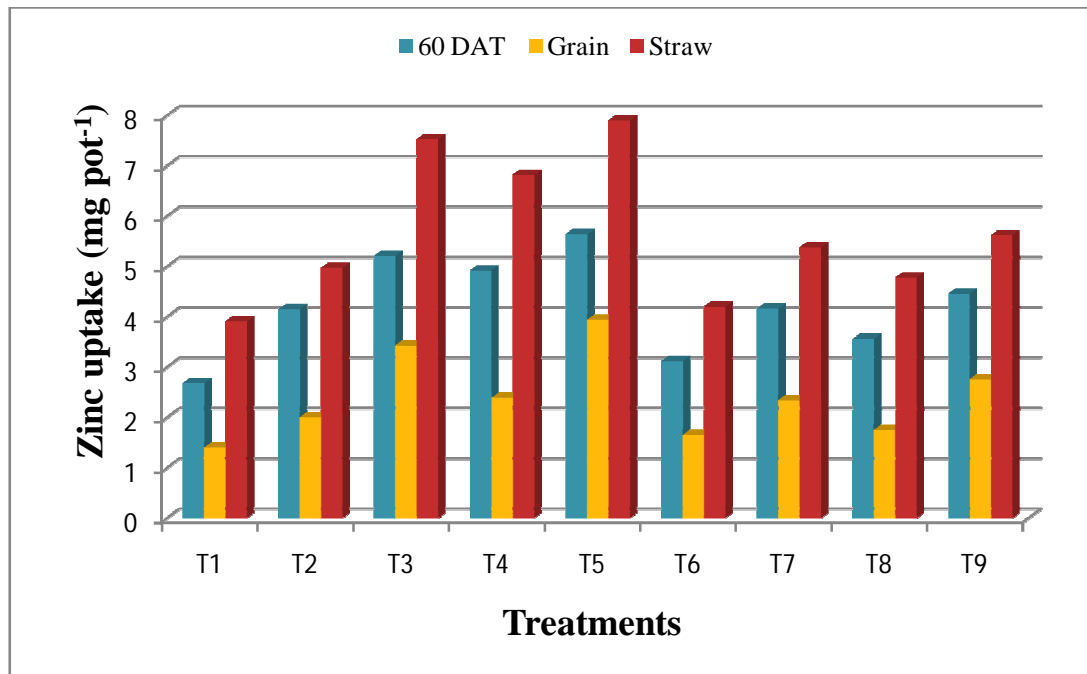


Fig.4.19 Influence of crop residues and composts on zinc uptake (mg pot⁻¹) by rice

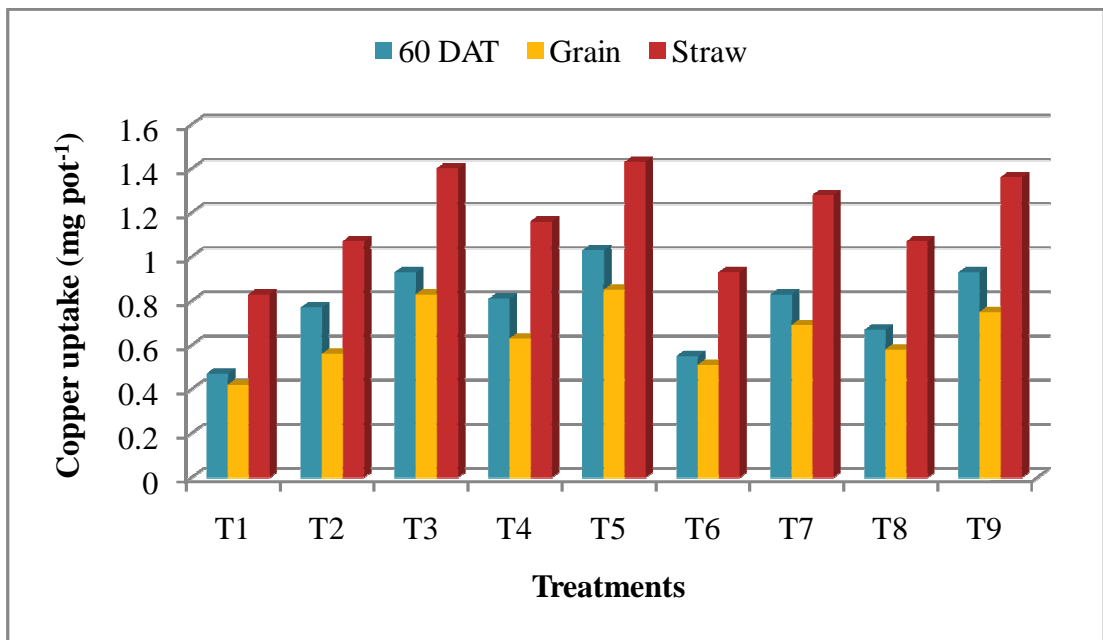


Fig.4.20 Influence of crop residues and composts on copper uptake (mg pot⁻¹) by rice

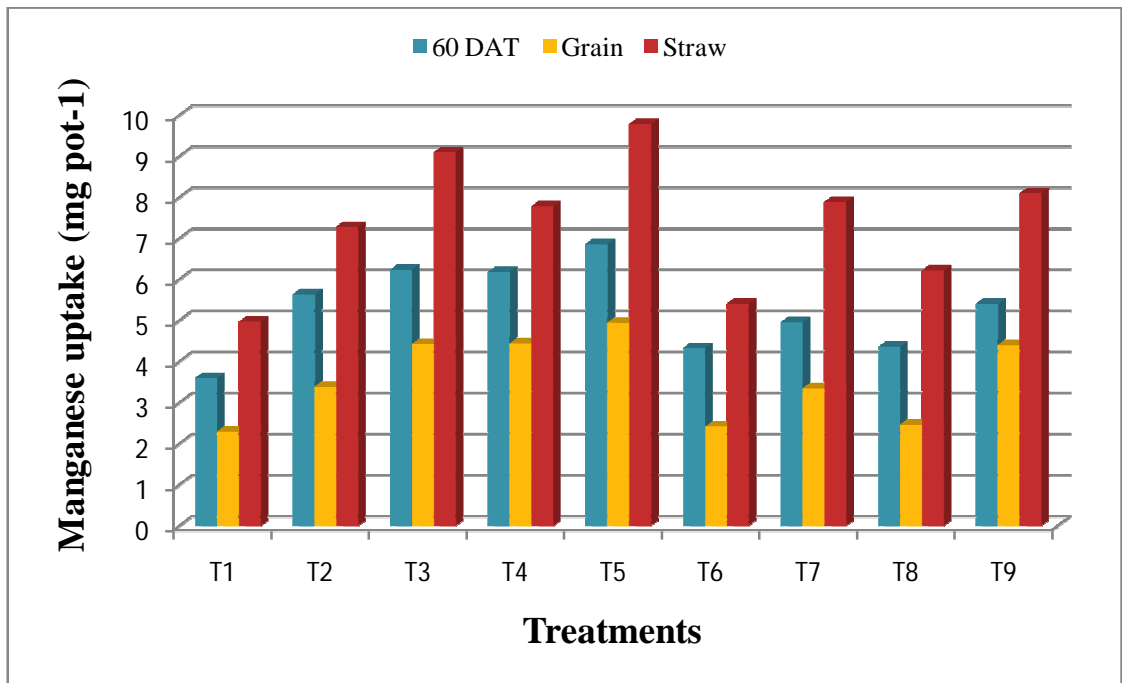


Fig.4. 21 Influence of crop residues and composts on manganese uptake (mg pot⁻¹) by rice

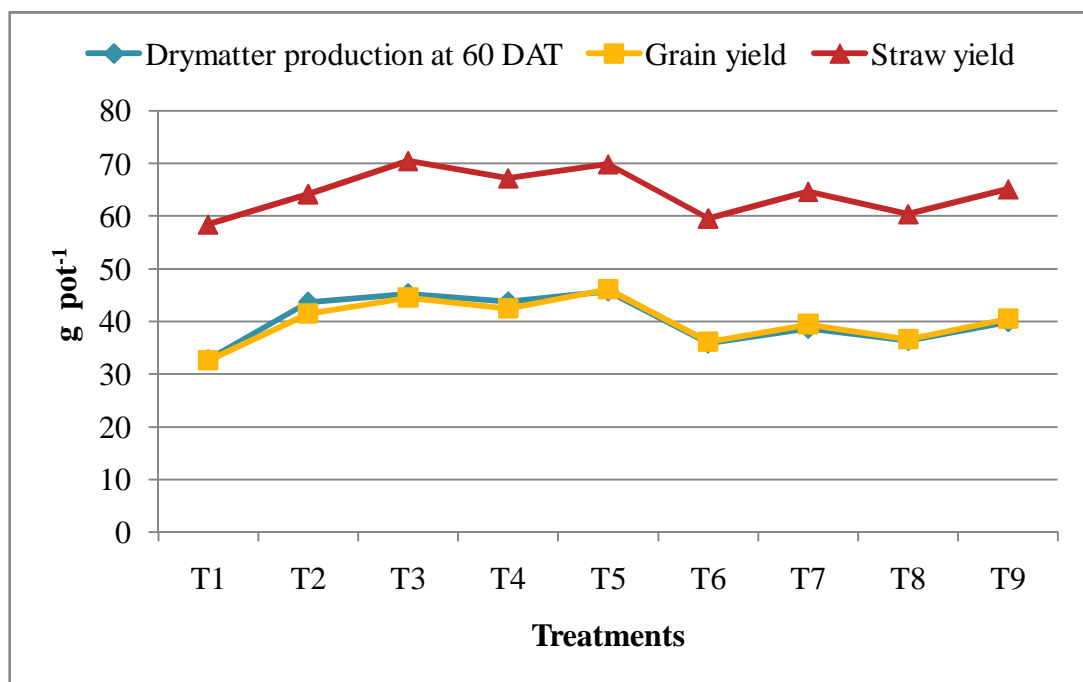


Fig.4.13 Influence of crop residues and composts on drymatter production at 60 DAT, grain and straw yield of rice