

**FORTIFICATION AND MINERALIZATION STUDIES IN
COMPOST UNDER CONTROLLED CONDITIONS**

THESIS

By

**ARTI
(A-2010-30-43)**

Submitted to



**CHAUDHARY SARWAN KUMAR
HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA
PALAMPUR - 176 062 (H.P.) INDIA**

in

partial fulfillment of the requirements for the degree

of

**MASTER OF SCIENCE IN AGRICULTURE
(DEPARTMENT OF SOIL SCIENCE)
(SOIL SCIENCE)**

2012

CSK HPKV LIBRARY PALAMPUR 4.P.

Accession 105405

Date 18-4-13.. Price X.....

Source The Dean, P.G.S., CSK.HPKV, Palampur.

Deptt Soil Science

No 18.. Date 18-4-13

Accessioned by 18-4-13 Checked by

631.875
A79F *h*



*DEDICATED
TO
MY
FAMILY*

Dr. NAVEEN DATT
(Soil Scientist)

Department of Soil Science,
CSK Himachal Pradesh Krishi Vishvavidyalaya,
Palampur (H.P.) India – 176062

CERTIFICATE – I

This is to certify that the thesis entitled **“Fortification and mineralization studies in compost under controlled conditions”** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of **Soil Science** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Ms Arti (Admission No. A-2010-30-43)** daughter of Mr. Ashok Kumar Sandal under my supervision and that no part of this thesis has been submitted for any other degree or diploma.


The assistance and help received during the course of this investigation have been duly acknowledged.

Place : Palampur
Dated : 4th October, 2012

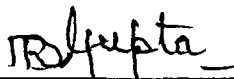

(Dr. NAVEEN DATT)
Major Advisor

CERTIFICATE- II


This is to certify that the thesis entitled "**Fortification and mineralization studies in compost under controlled conditions**" submitted by **Ms Arti (Admission No. A-2010-30-43)** daughter of Mr. Ashok Kumar Sandal to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Soil Science** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.



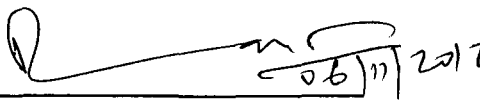
(Dr. Naveen Datt)
Chairperson
Advisory Committee



External Examiner



(Dr. Y.P. Dubey)
Member and Dean's Nominee



(Sh. Rajinder Kumar)
Member



Head of the Department



Dean, Postgraduate Studies

ACKNOWLEDGEMENTS

In this highly complex society no work can be accomplished by a single individual but it needs inspiration and sincere gratitude of intellectuals as well as the grace of that Almighty. With limitless humility, I would like to praise and thank 'GOD', the merciful, the compassionate, who bestowed me with health, tenacity and courage enough to go through this critical juncture. I am grateful to "GOD", for bestowing me with affectionate parents who encouraged me to undergo higher studies. Their selfless persuasion and sacrifice, heartfelt blessings and firm faith has made this manuscript a remuneration to translate their dreams into reality.

With an overwhelming sense of legitimate pride and genuine obligation, I express my deep gratitude to my major advisor Dr. Naveen Datt for his scientific acumen and impeccable guidance in the conduct of this investigation. I shall ever be indebted to him for developing in me the desire to work hard through this valuable suggestions and appreciable humanitarian behavior which evoked in me the be-stir to achieve the destination successfully in spite of all my lapses.

My sincere thanks and heartfelt special recognitions are due towards Dr. Y.P. Dubey and Sh. Rajinder Kumar, esteemed members of my advisory committee for their ever available help and valuable suggestions.

I am highly thankful to Dr. V.K. Suri, Head, Department of Soil Science for providing the necessary facilities to complete the research work. It is my privilege to express my revered sense of gratitude to Dr.S.K. Sankhyan, Dr. S.K. Subehia, Dr. S.P. Dixit, Dr. Sanjay K. Sharma, Dr. S. Sandal and other faculty members of the department for their instinctive help, guidance, suggestions and encouragement during the various stages of the current study. I am grateful to staff, laboratory members and field workers especially Trilok Uncle, Manohar Uncle, Shammi ji, Manjeet ji, Pawan ji and Dinesh ji for their support and best wishes.

I sincerely thank Dr. K.K. Katoch, Dean Postgraduate Studies, CSK HPKV, Palampur and university authorities for providing academic assistance and other infrastructural facilities to carry our the present study.

I can hardly overlook the immense cooperation, timely help and moral support provided to me by my seniors Rohina ma'm, Ruchi ma'm, Vishakha di, Upender Sharma sir and my batch mates Annu Singh, Neha Verma and

my juniors Usha and Iba janai. Genuine appreciation goes for my classmates Shilva Dhiman, Neha Verma, Renu Kapoor, Sapna Kapoor, Poonam Gogoi, Rajbir Kaur and Arti Yadav for their cooperation, support and help rendered.

I would be selfish if I do not appreciate the constant inspiration and ever available help of my younger sisters Anju and Indu and my brother Alpish Sandal who boosted me up morally.

My special thanks to Sh. Ajay Wafia who took great pain in metamorphosing this manuscript to such a presentable form.

At last but not the least, financial assistance provided to me during the course of present study by CSK HPKV, Palampur is duly acknowledged.

Needless to say, all omissions and errors are mine.

Place : Palampur

Dated : 4th October, 2012

Arti
(Arti)

TABLE OF CONTENTS

Chapter	Title	Page
1.	INTRODUCTION	1-4
2.	REVIEW OF LITERATURE	5-29
3.	MATERIALS AND METHODS	30-44
4.	RESULTS AND DISCUSSION	45-119
5.	SUMMARY AND CONCLUSIONS	120-124
	LITERATURE CITED	125-142
	APPENDICES	143-144
	BRIEF BIODATA OF THE STUDENT	

LIST OF ABBREVIATIONS USED

Sr. No.	Abbreviation	Meaning
1	<i>et al.</i>	et alii (and others)
2	<i>i.e.</i>	Id est (that is)
3	<i>viz.</i>	vi delictet (namely)
5	°C	Degree Celsius
6	g	Gram
7	kg	Kilogram
8	/	Per
9	%	Per cent
10	Fig	Figure
11	cm	Centimeter
12	ml	Milliliter
13	ha	Hectare
14	cfu	Colony forming units
15	mg	Milligram
16	CRI	Crown root initiation

LIST OF TABLES

Table no.	Title	Page
3.1	Methods to determine the physical, chemical and microbiological properties of soil	36
4.1	Chemical, physical and microbiological properties of biocomposts	47
4.2	Weekly interval CO ₂ evolution from the soil amended with different organic materials	50
4.3	Effect of treatments on ammonical nitrogen in soil during incubation at 30°C	55
4.4	Effect of treatments on nitrate nitrogen in soil during incubation at 30°C	58
4.5	Effect of treatments on phosphorus in soil during incubation at 30°C	60
4.6	Effect of treatments on potassium in soil during incubation at 30°C	62
4.7	Effect of different treatments on yield contributing characters of wheat	65
4.8	Effect of different treatments on plant biomass, grain and straw yield	66
4.9	Effect of different treatments on N, P, K, S contents (%) and crude protein (%) in wheat grain	70
4.10	Effect of different treatments on N, P, K, S contents (%) and crude protein (%) in wheat straw	74
4.11	Effect of different treatments on N, P, K and S uptake (mg plant ⁻¹) by wheat grain	76
4.12	Effect of different treatments on N, P, K and S uptake (mg plant ⁻¹) by wheat straw	80
4.13	Effect of different treatments on total N, P, K and S uptake (mg plant ⁻¹) by wheat plant (grain + straw)	83

Table no.	Title	Page
4.14	Effect of different treatments on available nitrogen content of soil at different stages of wheat growth	86
4.15	Effect of different treatments on available phosphorus content of soil at different stages of wheat growth	88
4.16	Effect of different treatments on available potassium content of soil at different stages of wheat growth	91
4.17	Effect of different treatments on available sulphur content of soil at different stages of wheat growth	93
4.18	Effect of different treatments on total nitrogen content of soil at different stages of wheat growth	95
4.19	Effect of different treatments on total phosphorus content of soil at different stages of wheat growth	98
4.20	Effect of different treatments on total potassium content of soil at different stages of wheat growth	100
4.21	Effect of different treatments on total sulphur content of soil at different stages of wheat growth	102
4.22	Effect of different treatments on bacterial population of soil at different stages of wheat growth	105
4.23	Effect of different treatments on fungal population of soil at different stages of wheat growth	108
4.24	Effect of different treatments on actinomycetes population of soil at different stages of wheat growth	112
4.25	Effect of different treatments on microbial biomass carbon of soil at different stages of wheat growth	115
4.26	Effect of different treatments on urease activity in soil at different stages of wheat growth	118

LIST OF FIGURES

Fig. No.	Title	Page
3.1	Weekly meteorological data of Growth chamber (Palampur, H.P.) during crop period (30 th Dec, 2011 to 26 th May, 2012)	35
4.1	Pattern in the decomposition of soil organic matter in compost-I (unfortified)	52
4.2	Pattern in the decomposition of soil organic matter in compost-II (fortified with 5% rock phosphate)	52
4.3	Pattern in the decomposition of soil organic matter in compost-III (fortified with 10% rock phosphate)	53
4.4	Pattern in the decomposition of soil organic matter in selected treatments	53

LIST OF PLATES

Plate No.	Title	Page
4.1	Fortified compost prepared from 5% rock phosphate	48
4.2	View of incubation experiment for nutrient transformation	48
4.3	Experimental view of treatments at grain filling stage of wheat	64
4.4	Comparison of treatments at maturity of wheat	64
4.5	Bacterial count in soil at crown root initiation (CRI) stage of wheat	106
4.6	Bacterial count in soil at grain filling stage of wheat	106
4.7	Fungal count in soil at crown root initiation (CRI) stage of wheat	109
4.8	Fungal count in soil at grain filling stage of wheat	109
4.9	Actinomycetes count in soil at crown root initiation (CRI) stage of wheat	113
4.10	Actinomycetes count in soil at grain filling stage of wheat	113

Department of Soil Science
COA, CSK Himachal Pradesh Krishi Vishvavidyalaya
Palampur – 176 062 (HP)

Title of thesis : ~~Fortification~~ and mineralization studies in compost under controlled conditions
Name of the student : Arti
Admission number : A-2010-30-43
Major discipline : Soil Science
Minor discipline : Microbiology
Date of thesis submission : 4th October, 2012
Total pages of the thesis : 144
Major Advisor : Dr. Naveen Datt

ABSTRACT

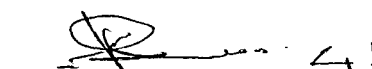
An experiment was conducted in growth chamber of the Department of Organic agriculture, CSKHPKV, Palampur during *rabi* 2011 by taking Wheat crop. Preparation and analysis of biocompost was the first part of study. Biocomposts were prepared by using cow dung, *Eupatorium* weed and were fortified with two levels of rock phosphate i. e. (5% and 10%). Biocomposts were analysed for moisture content, pH, CEC, EC, total carbon, total NPK, micronutrients, C:N ratio, microbial biomass C, N and S. An incubation study which was the 2nd part of the study was conducted with sixteen treatments and three replications in the soil microbiology laboratory of the Department of Soil Science during 31st Oct, 2011 to 26th Dec, 2011 to study the mineralization of nutrients in different biocomposts and the best one among three biocomposts prepared i.e. cowdung + *Eupatorium* weed + 5% rock phosphate was selected and applied to the crop in combination with fertilizers depending upon the treatment in the growth chamber experiment by taking wheat (cv. HS-295) as the test crop. The representative soil sample was taken before sowing of crop and was analyzed for physical, chemical and microbiological properties. The soil was having texture silty clay loam, pH 5.4, organic carbon 10.6g kg⁻¹, available N, P, K and S 138.5 mg kg⁻¹, 8.3 mg kg⁻¹, 74.5 mg kg⁻¹ and 12.4 mg kg⁻¹ respectively, total N, P, K and S 516.4 mg kg⁻¹, 88.6 mg kg⁻¹, 989.5 mg kg⁻¹ and 179.3 mg kg⁻¹ respectively, microbial biomass carbon 54.8 µg g⁻¹, microbial count as 18.9x10⁵ cfu g⁻¹ bacteria, 12.9x10³ cfu g⁻¹ fungi and 20x10⁴ cfu g⁻¹ actinomycetes and urease activity 1.6 µg g⁻¹ min⁻¹. There were seven treatments and four replications in completely randomized design. The yield attributes of the crop were recorded and maximum plant height, number of effective tillers plant⁻¹ and number of grains ear⁻¹ were recorded in treatment fortified compost (5% rockphosphate) + 5ml bioinoculants (i.e. P solubilizer and Azotobacter) + 5% cow urine + 1% urea. The maximum grain yield was recorded in treatment fortified compost + 5ml bioinoculants + 5% cow urine + 1% urea (T₃). At CRI stage, grain filling stage and after harvest of crop, soil samples from each pot were taken and were analysed for chemical and microbiological properties of soil. The results revealed that after harvest maximum available N and S i.e. 146.6 mg kg⁻¹ and 14.7 mg kg⁻¹ respectively were recorded in treatment recommended NPK, maximum available P and K i.e. 11.3 mg kg⁻¹ and 92.2 mg kg⁻¹ respectively were recorded in treatment unfortified compost (no rock phosphate) + 50% recommended NPK, maximum total N, P, K and S contents i.e. 599.2 mg kg⁻¹, 128.0 mg kg⁻¹, 1430.1 mg kg⁻¹ and 245.9 mg kg⁻¹ respectively were recorded in treatment unfortified compost + 50% recommended NPK (T₄), total microbial count was recorded maximum in treatment fortified compost + 5ml bioinoculants, microbial biomass carbon and urease activity were recorded maximum i.e. 93.67 µg g⁻¹ and 6.4 µg g⁻¹ min⁻¹ in treatment unfortified compost + 50% recommended NPK(T₄). Grain and straw samples were collected from individual plants in one pot and were analyzed for total N, P, K and S contents and nutrient uptake and results revealed that total NPKS content in grain and straw increased with addition of fortified compost. The crude protein content of the produce was found maximum in the treatment unfortified compost + 50% recommended NPK (T₄).



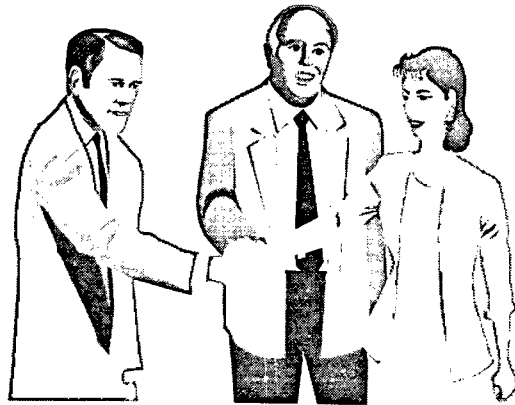
(Arti)
Student
Date: 4.10.2012



(Dr. Naveen Datt)
Major Advisor
Date: 4.10.2012



Head of the Department



INTRODUCTION

1. INTRODUCTION

India is endowed with abundant natural resources for growth of diverse agricultural, horticultural, medicinal and forest crops. Nevertheless, scientific management of the natural resources is of utmost significance to maintain the much needed pace of growth in agricultural production and to meet out the increasing multiple demands against the fast mounting pressure on the limited soil resource base. Efficient management for maintenance of soil health is the key to accomplish sustained high productivity, food security and environment safety. Any ill planned and indiscriminate use of the precious soil resource is likely to result in tremendous reduction in productivity and there by creating a dreadful crisis.

The population of developing countries has been growing rapidly and the demand for food has not always been able to keep pace with population growth. After the introduction of high yielding varieties of crops, chemical fertilizers undoubtedly played a significant role in enhancing global food production. For feeding a population of 1.4 billion by 2025, India will need to produce 301 Mt food grains in addition to other commodities. For producing this much of food and other commodities, at least 45 Mt of plant nutrients would be needed. Demand of chemical fertilizers would be 35 Mt consisting of 5.6-8.8 Mt P_2O_5 , 2.3 - 4.7 Mt K_2O and the rest nitrogen. At least 10 Mt nutrients should come from organic manures, crops and biofertilizers. Thus, food security in future also will be very much linked to the fertilizer input (Tiwari 2002).

In the present scenario it is quite clear that no single source of plant nutrient be mineral fertilizer, organic manure / crop residues or biofertilizers can meet total nutrient requirement for sustainable agriculture taking care of increasing human needs. The harvested crop removes about 12-13 million tonnes more of NPK every year from removable sources than what is supplied through addition of chemical fertilizers showing this contribution from organic and biological resources.

Fertilizers have played a prominent role in increasing food grain production of the country in the past and are going to be crucial input in future as well. However, due to intensification of agriculture the soils are being rapidly depleted of their fertility and are now showing signs of fatigue. The inadequate and imbalanced use coupled with neglect of organic manure has caused deficiency of secondary and micronutrients in many parts of the country. The falling organic matter levels in the soils are adversely affecting the physical, chemical and biological soil properties and resulted in widespread nutritional imbalances throughout the country. The organic carbon content of Indian soil, which has been traditionally low, has declined further during the post green revolution era from 1.2% to 0.6% (Ramasamy 2005). Under such situation, supplementing nutrient needs of crops through organics in combination with inorganics is one of the best options for sustaining farm productivity and improving soil quality.

Recycling of organic matter and nutrient embedded in waste materials of farm, city and agro industries etc. have become an issue of global importance. Often, there is desire and frequently economic necessity, to integrate the use of wastes in agriculture to supplement the nutrient requirement of crops in a beneficial manner. By doing so we are not only aimed to conserve the natural resource but also bridge the gap between the demand and supply of fertilizer nutrients essential for food security of our country. In addition organic matter added through wastes has well proven beneficial effect on soil health and quality.

Soil is a biodynamic system because it supports a large population of diverse beneficial micro organisms such as bacteria, actinomycetes, fungi, algae, protozoa etc, that decompose biomass, mediate in cycling of plant nutrients and protect plants from pest and diseases. All these functions are essential for maintaining soil fertility and productivity.

Composting is one of the component in organic recycling. It is an age-old practice of conversion of biodegradable wastes into manures. This is a microbial process where a community of micro organisms comprising of bacteria , fungi , actinomycetes and yeast decompose the organic material and

synthesize them into a highly stable product called humus. Although compost contains nitrogen, phosphorus, potassium, sulphur and micronutrients, there is need to enrich its manurial value. Enrichment of compost with rock phosphate, nitrogen and phosphorus solublizing micro organisms is essential. Also to avoid immobilization of nutrients addition of cow urine or urea is must (Gaur 1998).

At the time of green revolution higher amount of chemical fertilizers, pesticides, herbicides etc were used to increase the yield of crop. That caused harmful effect to the human and animal health; soil productivity and environmental quality i.e. polluted water caused salinity and acidity in soil. Due to this reason people wants to do organic agriculture. Compost is poor in plant nutrients per unit weight when compared with mineral fertilizers but has other advantages which mineral fertilizers do not have like the role they play in improving soil conditions, besides a plant nutrient effect. Mineral fertilizers are expensive and in general supply only 1 or 2 nutrients for crop growth. The addition of any appreciable quantities of mineral fertilizers to compost is not recommended because these not only increase costs of production but nitrogenous fertilizer may be lost through volatilization and denitrification. Thus, indigeneous, natural and inexpensive materials should be identified for compost enrichment (Gaur 1999). In Himachal Pradesh, for example, some weed plants like Lantana (*Lantana spp.*); Congress grass (*Parthenium hysterophorus L.*) Ageratum (*Ageratum spp.*) and Eupatorium (*Eupatorium adenophorum L.*) are spreading very fast in the grasslands and pastures. Recycling of such wastes not only supply plant nutrients but they do act as amendments, thereby improving physical as well as biological properties of soil and ultimately improving soil productivity on sustainable basis. At the same time crop residues are required to be used in making compost. The present concept is to use every part of the plant other than seed for recycling in the farm itself (Eswaran *et al.* 2005).

Keeping in view the above points in mind the study of "fortification and mineralization studies in compost under controlled conditions" has been proposed.

Wheat is an important rabi crop of Himachal Pradesh having area 362.25 million ha and production 540 million tonnes. This crop requires heavy doses of nitrogen, phosphorus and potassium. It is difficult to fulfil the whole requirement of nutrients from chemical fertilizers due to high cost of chemical fertilizers. Hence, study on use of enriched bio compost in combination with chemical fertilizers has been proposed with the following objectives:-

- a.) To prepare nutrient enriched compost and its fortification with organic and inorganic agents.
- b.) To evaluate fortified compost for mineralization of different nutrients in synchronization with crop growth.



REVIEW
OF
LITERATURE

2. REVIEW OF LITERATURE

Sustainability in agriculture with respect to maintenance of soil fertility and stabilized crop production is the main concern in the present situation. Ever increasing cost of energy would be an important constraint for increased use of chemical fertilizers in crop production. A number of approaches have been tried by workers both in India and abroad to improve nutrient use efficiency. The only economically feasible approach has been found to be the integrated nutrient management which includes the combined use of inorganic fertilizers, organic manures and bio-fertilizers. Use of organic manures to meet the nutrient requirement of crop would be an inevitable practice in years to come for sustainable agriculture since organic manures generally improve the soil physical, chemical and biological properties and thus result in enhanced crop productivity along with maintaining the quality of crop produce.

The relevant literature pertaining to the present investigation has been reviewed under following heads and sub-heads:

2.1 Composting

2.1.1 Technological improvements

2.2 Mineralization of nutrients

2.3 Effect of biocompost on crop yield, nutrient uptake and quality

2.3.1 Crop yield

2.3.2 Nutrient uptake and crop quality

2.1 Composting

Composting is an age old practice involving mainly microbiological decomposition of plant residues and converting them into a manure rich in plant nutrients and humus. In traditional agriculture, compost and farm yard manure formed the most important source of plant nutrients and essential inputs for soil improvement. The basic processes of production of both the materials are

essentially the same with the difference that the major raw material for farmyard manure is animal excreta (dung), while that for compost it is plant residues. In modern intensive farming relying mainly on chemical fertilizers, compost and farmyard manure plays equally important role as supplementary sources of plant nutrients. In fact in enriching soils with much wanted organic matter, composted plant wastes play an unparalleled role. Compost has added advantages as it can be produced even under these farm and non farm conditions which experience scarcity of animal dung. Such situations are likely to develop with progress in an agricultural mechanization.

Conventionally, two methods of composting have been followed in India with suitable modifications as warranted by situations. These are: (1) Indore method and (2) Bangalore method. The first method is essentially aerobic and consists in processing plant wastes, wood ashes, suitable agro-industrial wastes and animal dung in pits or heaps with occasional turnings. Dung is not an essential component of the raw material for composting, though it does the job of an inoculant for the process. Even human excreta serve as good purpose as dung. Plant materials of leguminous nature help to lower C/N ratio and increase decomposition rate. The compost by this method is ready in about 4 months.

The second method is aerobic to start with and semi-aerobic or anaerobic at later stage of decomposition. In this method, the material is decomposed in pits or trenches which are sealed at the top of mud-plastering. The water added in the beginning to moisten the material adequately remains sufficient as there is no loss by evaporation due to mud-plastering at the top. Also, the nutrient losses that occur in aerobic method are avoided in this method. However, the rate of decomposition is relatively slow due to anaerobic conditions in the pit. The compost is ready in about six months but its C/N ratio is generally higher than that attained in Indore method.

2.1.1 Technological improvements

The points that need consideration in compost improvement are high C/N ratio of plant materials generally available for composting, low phosphorus content and slow speed of decomposition. Any efforts made to improve upon

these constraints would contribute to the efficiency and quality of compost. Although it is generally believed that addition of any microbial inoculums to the composting material is unnecessary on the grounds that sufficient micro flora develop in the compost heap or pit during decomposition, yet it has been found that suitably selected fungal inoculants could play added role in promoting decomposition and enriching the compost with nitrogen. The selected fungal inoculants that have yielded positive results are those of *Trichurus spiralis*, *Paecilomyces fuisporus*, *Aspergillus niger* and *Penicillium digitatum*. Five hundred gram of inoculums consisting of the mycelium and spore mass of the fungi was used par tonne of the compost material. It has also been found that C/N ratio of nitrogen poor materials need to be lowered to at least 60:1. This could be done either by adding chemical nitrogen or nitrogen rich plant materials.

Rock phosphate at the rate of 1 percent was tried as mineral additive to compost material to promote microbial activity and to cause enrichment of the compost with water soluble and citric acid soluble phosphate. Inoculation of compost material with effective phosphate solublizing microbial inoculants such as *Aspergillus awamori* enhances the rock phosphate transformations. Simultaneously, *Azotobacter* and rock phosphate as mineral material has been tried to improve quality of compost in multi- locational experiments.

Bhardwaj and Kanwar (1991) evaluated the manorial utility of *Lantana camara* and found it as good material for composting. Gaur (1992) put emphasis on development of suitable technology for preparation of good quality compost at the short possible time from organic residues and reported one possible way of increasing nutrient content of the final product is microbial enrichment technique with cellulose decomposer, nitrogen fixer and phosphorus solubilizers. Goyal *et al.* (1992) studied the effect of continuous inorganic fertilizations and organic amendments on the organic matter-microbial biomass relationship and found that soil microbial biomass carbon and nitrogen increased with balanced fertilizations.

Horwath and Elliott (1996) examined the decomposition of perennial ryegrass straw under mesophilic and thermophilic temperatures and reported that the change in lipids, sugars, soluble polysaccharides, cellulose and lignin was determined during a 45 days incubation; C,H, O and N steadily decreased in

both temperature treatments; the lignin content decreased by 10% under mesophilic and 29% under thermophilic conditions and the lignin C loss was 25 and 39% under mesophilic and thermophilic incubations, respectively. Murata *et al.* (1997) found that microbial biomass carbon and nitrogen increased with organic matter application. Manna *et al.* (1997) reported that the maximum increase in total nitrogen was recorded in composting treatments where N_2 fixer was incorporated with rock phosphate.

Thakur and Sharma (1998) concluded that *Azotobacter* inoculation during decomposition and addition of rock phosphate accelerated decomposition and increased the transformation of rock phosphate into available form. Khamis and Metwally (1998) conducted an experiment in a sandy soil in NW Sinai, Egypt to evaluate water hyacinth, broad bean straw, wheat straw, rice straw and farmyard manure inoculated with and without microbial decomposers and *Azotobacter*, compared with biammonium nitrate as sources of nitrogen for wheat and reported that the incorporation of organic materials inoculated with microbial decomposers and *Azotobacter* in the soil favourably increased the amounts of biomass-N, biomass-C and available N, soils amended with rice straw and wheat straw showed wider C:N ratio, greater rate of N-immobilization and mineralization.

Manna and Ganguly (1999) reported that inoculation of microbial culture increased the available N i.e. (NH_4^+ -N) and (NO_3^- -N) in the enriched compost as compared to that where inoculation is not used. Again, the total P, water soluble P (WSP) and citrate soluble P (CSP) also increased in the enriched compost prepared by using microbial culture. These findings ensure that available nutrients were higher in the enriched compost after 105 days of composting and use of microbial inoculation further improve quality of N and P.

Manna *et al.* (2000) evaluated the compost maturity and mineral enrichment quality through chemical parameters and reported that the application of bioinoculum significantly increased the available nutrient status such as NH_4^+ -N, NO_3^- -N, water soluble P, citrate soluble P and total P over uninoculated control and it also accelerated the compost maturity and shortened the usual period of composting. Siebert *et al.* (2000) reported fresh and old compost directly affects

the soil pH, C/N ratio, annual mineralization rates of C and N, microbial activity and biomass and the chemical composition of soil organic matter. JenHshuan *et al.* (2001) reported that the application of organic fertilizers is an important practice in increasing the productivity of acidic soils.

Sreenivas and Narayanasamy (2003) reported that soils treated with different phospho-composts can maintain higher extractable P status over no P control and phospho-composts can be used as slow release phosphatic fertilizers to maintain adequate P concentration in soil to meet the plants needs on long-term basis. Chettri *et al.* (2004) and Sitangshu and Mondal (2004) also observed positive effects of application of FYM with inorganic fertilizers in maintaining soil fertility status in the soils of Hoogly (West Bengal) and Kalyani (West Bengal), respectively. Likewise, significant improvement in fertility status of the soils due to addition of FYM or crop residues have also been reported by Singh *et al.* (1997) and Roy *et al.* (2001). Zachariah and Chhonkar (2004) reported that both urease and phosphatase activity of the compost increased significantly due to earthworm activity while there was no significant increase in microbial biomass and cellulase activity.

Anwar *et al.* (2005) also reported higher values of organic carbon, available N and P in the plots receiving organic manures in addition to mineral fertilizer compared to those plots treated with chemical fertilizers alone. Sharma and Bhardwaj (2005) studied the residual effect of rock phosphate enriched organics on yield in maize-wheat cropping in an acid Alfisol and observed that P enriched FYM recorded consistent increase in grain yield and the results suggest that there would be no need to add P to the succeeding crop of wheat; if P enriched organics were used for maize in the previous season. Singh and Ganguly (2005) studied the chemical and biochemical quality of various enriched composts prepared by heap and pit methods and compared it with conventional compost. The various composts viz., phosphocompost, nitrogen – enriched phosphocompost, vermicompost, phosphorus - enriched vermicompost were compared with conventional compost. The results showed that the mineral matter content and total mineral constituents (NPK) was higher in all the enriched composts in comparison to conventional compost.

Qureshi *et al.* (2005) conducted a pot experiment to know the direct and residual effect of rock phosphate when applied along with phosphate solubilizers and FYM on available phosphorus, organic carbon and viable counts of phosphate solubilizers in soil and resulted that combined application of phosphate solubilizers in presence of FYM improved the organic carbon status and proliferation of phosphate solubilizers, seed treatment with *Aspergillus awamori* in mustard and wheat improved the soil P status over *Bacillus polymyxa* and number of viable counts of phosphate solubilizers in the rhizosphere soil after the harvest of the mustard and wheat crops due to P sources and seed inoculation with phosphate solubilizers were improved over control.

Ahmad *et al.* (2008) reported that the fortification of composts with chemical fertilizer enhances agronomic effectiveness of both by reducing the amount of fertilizer and improving the quality of compost and explored the potential of organic and chemical nutrient sources with their optimal application and integration for sustainable wheat production. Sharma *et al.* (2008) conducted a field experiment was carried out using three different sources of organic manures *viz.* Lantana vermicompost, congress grass vermicompost and FYM and three levels of recommended NPK fertilizers i.e. 33, 67 and 100% along with control and resulted that among organic composts, lantana vermicompost was found to be superior to congress grass and FYM in terms of nutrient composition as well as in increasing the yield of wheat and among different treatments, 67% recommended NPK along with 10 t ha⁻¹ lantana vermicompost was found to be the best treatment for increasing wheat yield and maintaining soil fertility.

Khan *et al.* (2009) reported that phosphorus solubilizing bacteria play role in phosphorus nutrition by enhancing its availability to plants through release from inorganic and organic soil P pools by solubilization and mineralization and use of phosphorus solubilizing bacteria as inoculants increases P uptake. Bedi *et al.* (2009) reported that microbial biomass carbon was more in wheat straw-treated treatment followed by FYM and green manure treated treatments respectively. Bedi *et al.* (2009) conducted an incubation study to investigate the effect of moisture regime on carbon mineralization pattern from the soil amended

with green manure crops, compost, fertilizer nitrogen and their different combinations at CSKHPKV Hill Agricultural Research and Extension Centre, Dhaulakuan and reported that cumulative CO₂ evolution under aerobic as well as anaerobic followed a similar trend: green manure + 50% N + compost > green manures + 50% N > green manures + compost > green manures alone, rice straw alone or in combinations evolved higher CO₂ as compared to compost alone or in combinations, while rice straw + 50% N/compost + recommended N showed higher CO₂ evolution as compared to rice straw/compost alone. Aerobic conditions showed faster carbon mineralization, while stable carbon mineralization was noticed under anaerobic conditions and green manures dhaincha + 50% N + compost showed higher cumulative CO₂ evolution and lowest CO₂ evolution was found in case of recommended N.

Biofertilizer based integrated nutrient management package treatment showed the highest content of soil microbial biomass carbon, which was at par with the treatment of 50% recommended dose of fertilizers plus 50% N through FYM (Gogoi *et al.* 2010). Chand *et al.* (2010) conducted a field study during rabi 2000-2001 exclusively on the PSB and *Azotobacter* count in the rhizosphere soil using mustard as test crop as influenced by organic and inorganic sources and reported that there was significant increase in PSB and *Azotobacter* population with 10 t FYM ha⁻¹ compared to without FYM application and use of PSB and *Azotobacter* alone or in combination increased the population of PSB and *Azotobacter* in rhizosphere soil of mustard.

Rout *et al.* (2012) conducted a laboratory incubation study to assess the effect of four common organic manures (cattle manure, poultry manure, goat manure and vermicompost) used by the farmers of khurda district on an acid soil which constitutes more than 70% of the total cultivable area of Orissa state and reported that all the three animal manures contained more moisture than the standard range of 20-25%; among the manures poultry manure was biologically most active followed by cattle manure and goat manure; poultry manure maintained highest level of dehydrogenase activity and phosphatase activity; both fungal and bacterial populations were very sensitive to organic manure application in acid soil and the degree of response varied with the type of organic amendment.

2.2 Mineralization of nutrients

Ceccanti *et al.* (1992) studied four extracellular hydrolases (urease, phosphatase and two proteases) and organic carbon content were determined in organic matter extracted from a non composted sewage sludge and one composted for 91 and 210 days. Organic matter extracted from the non-composted sewage sludge had a higher enzyme activity than that from the composted sewage sludge. Composting influenced urease and phosphatase activity in the sludge. Enzymes have importance in knowing the status of compost maturity as these utilize the substrate from the organic matter.

Hadas *et al.* (1995) studied the mineralization dynamics of composted manures and reported that it is essential for their efficient use as a major source of available nitrogen in crop production and the effect of long term management on the rate of mineralization of compost, in relation to soil biological activity. Liang *et al.* (1996) conducted an experiment to evaluate the effects of water-soluble organic carbon extracted from composted dairy manure on C mineralization in soil with different textures i.e. textures varying from 3 to 54% clay were amended with 0 to 80 mg water-soluble organic C kg⁻¹ soil extracted from a composted dairy manure and incubated for 16 weeks at 23°C and reported that the total amount of C mineralized was greater than the amount of C added in the three soils, differences in mineralizable C were approximately 13-16 times, 4.8-8 times and 7.5-8 times greater than the amount of C added to clay, loam and sand soils respectively; and carbon mineralization rate was increased with the application of composted manure.

Conti *et al.* (1997) conducted an experiment to study the relationship of soil carbon light fraction, microbial activity, humic acid production and nitrogen fertilization in the decaying process of corn stubble which included a no till system under maize (*Zea mays* L.) and a soybean (*Glycine max*) rotation with 0 and 45 kg ha⁻¹ nitrogen fertilization treatments called NFS and FS, respectively and reported that a higher proportion of residues with a high N content was found in FS plots; the different substrate quality proved to be the regulating factor for mineralization and this activity was indicated by the increase in soil microbial

activity and soil carbon light fraction in FS compared to NFS; and this light fraction mineralises rapidly but does not contribute to the most stable components, which are related to synthesis and polymerization of humic acids.

Arunachalam and Arunachalam (1999) studied the effect of soil pH on N mineralization. Generally, ammonium concentration decreased with increasing soil pH, while nitrate concentration increased. The results showed that net N mineralization showed a weak positive relationship with soil pH. Dinesh and Dubey (1999) conducted an experiment on use of poultry manure and farmyard manure in a rice-rice sequence and reported that the total N mineralized (66%) was more than twice that of net N mineralized (29%) and the net N mineralization was significantly higher in soils amended with organic manures compared to the unamended control.

Mukherjee *et al.* (1999) studied the carbon mineralization and microbiological changes during decomposition of organic matter in soil and reported that organic additives resulted in augmentation of microbial population in soil with the higher dose, water hyacinth brought the highest proliferation of bacteria, fungi, actinomycetes and phosphorus solubilizing microorganism in soil and paddy straw exerted the maximum stimulation on the population of non-symbiotic nitrogen fixing bacteria in soil. Heller (1999) studied the nitrogen mineralization of composts in an incubation assay under optimal temperature and humidity conditions for 149 days and reported that the total organic nitrogen was nitrified between 0.7% and 6.9% depending on the properties of the composts. Henriksen and Breland (1999) conducted a microcosm experiment on response of wheat straw decomposition to increasing nitrogen availability and reported that concentrations of available N below 1.2% of straw dry matter significantly reduced the rate of carbon mineralization from straw residues and the growth of total soil microbial biomass. The number of cellulase-producing, colony forming bacterial units decreased with decreasing N availability; in straw amended soil, decreased N concentrations reduced activities of exocellulase, endocellulase and hemicellulase while an unamended control soil the effects were opposite.

Sieling *et al.* (1999) studied the soil mineral N and N net mineralization during autumn and winter under an oilseed rape - winter wheat – winter barley rotation in different crop management systems and reported that under wheat, slurry application only slightly affected N mineralization; increased mineral N fertilization decreased N release under oilseed rape, but significantly increased it under cereals and application of fungicides did not affect N mineralization during winter. Adhikari *et al.* (1999) evaluated the productivity and nitrogen nutrition of rice/wheat cropping systems in Nepal and Bangladesh and resulted that soil N-supplying capacities measured as total N accumulation from the zero N-plots and grain yields without N additions were greater for rice than for wheat in both Nepal and Bangladesh; higher soil N-supplying capacities in rice was probably due to greater mineralization of soil organic N in the warm, moist conditions of the monsoon season than in the cooler, drier wheat season; the relationship between grain yield and N accumulation was linear indicating that mobilization of plant N to the grain was less affected by biotic and abiotic stresses than in rice.

Integrated treatments receiving chemical fertilizer along with 25% or 50% of inorganic N through FYM, rice straw or *Azolla* resulted significantly in higher available and total S content in soil than control and 50% NPK fertilizers (Basumatary and Talukdar 1999). Sharma *et al.* (2000) concluded that available S status of soil significantly increased with the addition of crop residues, FYM and inorganic fertilizers as compared to chemical fertilizers alone.

He *et al.* (2000) conducted a field incubation and laboratory analysis to evaluate the mineralization rate and transformation of N in biosolids, yard wastes and west palm beach co-compost and reported that during the first 6 months of incubation, $\text{NH}_4\text{-N}$ was the dominant form of mineralized N, but $\text{NO}_3\text{-N}$ accounted for more than 50% of the mineral N during the later part of the incubation for the yard waste and biosolids, and $\text{NO}_3\text{-N}$ was the dominant mineral N throughout the whole incubation period for the west palm beach co-compost. Hartz *et al.* (2000) reported that an average of 16%, 7% and 1% of organic N was mineralized in 12 weeks of incubation in 1996 and an average of 15%, 6% and 2% in 24 weeks incubation in 1997, in manure, manure compost and plant residue compost,

respectively. Darwinkel and Titulaer (2000) conducted a field experiment during 1996-1999 in the Netherlands to investigate the effects of N fertilizers on N mineralization levels of soil and N uptake in straw and grains of winter wheat and reported that the N supply was composed of N mineralization (between 10 and 95 kg N/ha) + N fertilizer and increased from 200 to 360 kg N/ha, and crop yields of approximately 12 t/ha require the uptake of 260-270 kg N/ha.

Sikora and Enkiri (2000) reported that the amount of available N provided by urea-compost blends was less than the amount provided by NH_4NO_3 -compost blends, blends of 50% NH_4NO_3 and 50% biosolids compost available N or 67% NH_4NO_3 and the equivalent of 33% biosolids compost N produced greater yields and uptake by fescue. Urea did not affect compost similarly, possibly because of larger active N pool in urea compost blends compared with NH_4NO_3 compost blends. Hioki and Kitamura (2000) estimated the amount of nitrogen mineralization from the animal manure compost in paddy soil condition and reported that the cattle manure was consistent with the predicted amount of N absorbed by the rice plants in the plot where the cattle manure composts were applied.

Alvarez and Alvarez (2000) evaluated the role of soil organic pools, specially plant residues, as sources-sinks of nitrogen in a humid and warm temperature environment cropped to wheat, under plough and no tillage in the Argentina Pampa on a Typic Hapludoll and reported that importance of the organic pools as sources of N for wheat in the Humid Pampa; it also showed the importance of evaluating residue decomposition and humus mineralization in warm temperate regions when fertilizer requirements are determined, in order to minimize environmental hazard and economic losses by over fertilization.

Purnomo *et al.* (2000) estimated the mineralization using in situ incubations inside capped PVC tubes, which were sampled every 3 weeks, soil from the tubes was sampled at depth intervals of 2 cm to a depth of 10 cm and at 5 cm intervals from 10 to 20 cm and resulted that the net mineralization decreased with depth to 20 cm; an average of 32% of the N mineralized in the top 20 cm of soil originated from the 0-2 cm layer, 72% was from the 0-6 cm

layer and only 13% was from soil below 10 cm; the decrease in N mineralization with soil depth was highly correlated with decreases in the organic carbon and total N concentrations.

Kahle and Belau (2001) conducted an incubation experiments on the turnover of biocomposts after application to agriculturally utilized soil and reported that application of biocomposts to agricultural soil increased the carbon and nitrogen mineralization. Nannipieri *et al.* (2001) studied the N uptake by crops, soil distribution and recovery of ^{15}N labelled urea-N in a sorghum-wheat rotation in different soils under Mediterranean conditions and resulted that both sorghum and wheat N yields were higher in the driest site probably due to better light conditions, higher temperatures and irrigation; urea-N losses occurred when Rieti Piedifiume and Rieti Casabianca soils were kept bare. Scherer (2001) reported the significance of S in crop production and the effects of S fertilizer application, it include inorganic soil S and sulphate adsorption, soil organic S, mineralization and immobilization, leaching, S uptake and transport in plants, and assimilation and reduction.

Eghball *et al.* (2002) reported that mineralization of organic N is expected to be low for composted manure (~18%) and high for swine or poultry manure (~55%); phosphorus availability from all animal production sources of manure is high (>70%), as most of the manure P is inorganic and potassium availability from manure is nearly 100%. Sridevi *et al.* (2003) conducted a laboratory experiment using sorghum straw and *Gliricidia* prunings and their fractions and reported that the C mineralization from control soil as well as soil amended with residues and residue fractions was exponential, being fast in the initial stages and slowing down with the progress of time and it indicate the dependence of decomposition and C mineralization of plant residues on the proportion of soluble and fibre fractions in the residues, and their N concentration and C/N ratio.

Li *et al.* (2003) studied the processes and characteristics of nitrogen mineralization in paddy soils of the Taihu Region of China with 120 day anaerobic incubation at 25 and 35°C and resulted that the organic nitrogen mineralized ranged from 4.0% to 9.4% of total N and that the mineral N was only

correlated with total N, temperature was the main factor influencing the mineralization of nitrogen and pH changed greatly and was related to the mineral nitrogen contents during mineralization. Cambardella *et al.* (2003) studied the compost mineralization in soil as a function of composting process conditions and resulted that organic substrates that did not degrade due to sub-optimal conditions during the composting process can readily mineralize after incorporation in soil; C and N cycling dynamics in soil after compost incorporation can be affected by compost feedstock, processing conditions, and time; and denitrification after compost incorporation in soil can limit N availability from compost.

KyungHwa *et al.* (2004) studied an urea-nitrogen transformation and compost-nitrogen mineralization in three different soils as affected by the interaction between both nitrogen inputs and resulted that urea hydrolysis was increased by compost blending only in soils with a relatively low organic-C content; compost blending increased N mineralization, thus decreasing nitrification of urea-derived N in soils with high organic-C and inorganic-C contents whereas the reverse was observed in soils with low nutrient contents; a combined application of chemical fertilizer has improved the compost use efficiency by increasing mineralization of compost-N particularly in soil with low inorganic-N content and compost blending would increase immobilization of urea-N in soils with high C and N contents whereas it would increase nitrification of fertilizer-N in soils with low nutrient contents.

The study made by Zachariah and Chhonkar (2004) who reported that composting being a microbiological process, enzymatic activities can be a part of a reliable measure of compost stability and maturity. The results showed that both urease and phosphatase activity of the compost increased significantly due to earthworm activity while there was no significant increase in microbial biomass and cellulose activity. Material used as feed stock also had significant influence on the biochemical properties of the compost.

Gupta *et al.* (2005) studied the effects of N application in three phases of manuring- cumulative (manuring both rice and wheat), residual (manuring rice only) and direct (manuring wheat only) and reported that the nitrate-N contents in different soil layers was more than that NH_4^+ -N content at different stage of wheat. Total mineral-N content at different depths was influenced by the total quantity of N applied to the rice-wheat system, irrespective of the source and farmyard manure resulted in more accumulation of mineral-N in the soil profile than biogas slurry.

Srinivas *et al.* (2006) conducted a laboratory incubation experiment to study N mineralization from the residues and to examine the effect of residue quality on N mineralization and the residues were incubated with soil at 25°C and 9% soil water and the release of N was monitored and reported that there were considerable variations in the N mineralization patterns of the 20 residues. All the residues caused immobilization of N immediately after addition to soil but with the progress of time net mineralization occurred from most of the residues and the proportion of residue N mineralized at the end of 100 days of incubation ranged from 20.67% in sugarcane trash to 81.89% in *Glyricidia sepium*.

Kar *et al.* (2007) conducted a laboratory incubation experiment to evaluate the mineralization rate and transformation of N in different traditional and non traditional organic manures and reported that organic N-mineralization rates during the 30 day incubation were 7.4%, 7.4%, 7.5%, 14.2%, 7.2%, 3.6%, 10.1%, 11.7%, 48.2%, 32.9%, and 42.1% of the total organic N in the soil, vermicompost, poultry litter, oilcake, cow dung, neem cake, cabbage waste, tomato waste, di-ammonium phosphate, urea and ammonium sulphate, respectively. Potentially mineralizable organic N to total N was greater in poultry litter and oilcake and it is least for neemcake among other organic manures/wastes. Nitrate (NO_3^-)-N was dominant mineral in the whole incubation period for the tomato wastes/composts.

Kadlag *et al.* (2007) studied the influence of different sources of phosphorus in combination with different levels of FYM on urease activity and found that there is an increase in urease activity after the application of FYM

along with single super phosphate over the application of single super phosphate. Jaun *et al.* (2008) studied that long term effect of combined application of organic and mineral fertilizers on soil enzymatic activities and reported that with the application of combined use of organic and inorganic sources of nutrients resulted in an increase in urease activities over the application of inorganic sources of nutrients.

Bedi *et al.* (2009) from a long term study under rice-wheat cropping sequence in an acid Alfisol reported that microbial biomass carbon increased with increase in doses of inorganic fertilizers, CO₂ evolution and dehydrogenase activity. CO₂ evolved in controlled treatment was minimum and it was maximum in the wheat straw substituted treatment. Microbial population showed positive and significant correlation with pH of the sub surface soil. Goyal *et al.* (2009) studied the effect of rice straw compost on soil microbiological properties and yield of rice and resulted that the application of rice straw compost @ 5 t/ha along with half of the recommended dose of inorganic fertilizer increased the microbial biomass carbon from 136 to 258 mg/kg soil, dehydrogenase activity from 66 to 118 mg TPF/kg soil/24 h and alkaline phosphatase from 370 to 680 mg PNP/kg soil/h, carbon and N mineralization rates were higher with rice straw than control and soils receiving recommended dose of inorganic fertilizers.

Rao and Ramalaxmi (2009) conducted a field experiment to evaluate the maximum loading rates of urban and agricultural waste composts on soil nutrient status and enzyme activity in vegetable-vegetable (tomato-bhendi) and cereal-pulse (maize-soyabean) crop sequence for two years at College of Agriculture, Acharya N G Ranga Agricultural University, Hyderabad and reported that the nutrient reserves (N, P, K, Ca, Mg, Fe, S, Cu, Mn and Zn) were more in composts treated plots over recommended dose of fertilizer and control, availability of all the cationic micronutrients i.e. Zn, Fe, Cu and Mn were also significantly influenced by the application of composts and use of compost showed highest urease, phosphatase and dehydrogenase activity in post harvest soils of tomato, maize, bhendi and soyabean over other treatments and the lowest activity was observed in control plot.

Gogoi *et al.* (2010) reported that low microbial biomass indicates stressed conditions in soil, while high microbial biomass is an indicator of a healthy soil, because physical and chemical properties are shaped by biological activity and biological activity enhanced or limited by chemical and physical condition of soil. Singh and Singh (2010) reported that a rapid mineralization of pressmud is likely to enhance the supply of N for the rabi-grown crops under aerobic soil conditions and the application of pressmud immediately after rice harvesting could synchronise with the rabi crop need and nutrient supply.

Kumari *et al.* (2011) reported that the continuous application of organic manure alone or in combination with inorganic fertilizer significantly influenced the total soil organic carbon, CO₂ evolution, microbial biomass, water soluble carbon, acid hydrolysable carbohydrates and humic fractions. Integrated use of FYM with chemical fertilizers or use of FYM alone exerted significant effect on the active and passive pools of soil carbon.

Lakaria *et al.* (2012) studied the soil carbon mineralization as affected by land use systems and water regimes and reported that the soil organic carbon content under agriculture was significantly higher than the riverine land; land use significantly affected the active carbon content of soil i.e. 172 to 1817 mg kg⁻¹; dehydrogenase activity was found to be the maximum under the forest land use system; the forest and organic farming systems have higher soil carbon content but the mineralization rate was found to be the minimum. Nath *et al.* (2012) conducted an experiment to understand the influence of integrated nutrient management under rice- toria sequence during 2008 and 2009 and reported that the fluorescein di-acetate, phosphomonoesterase and dehydrogenase involved in energy flow and nutrient cycling showed significantly higher activities under integrated nutrient management treatments; application of enriched compost @ 2 t ha⁻¹ demonstrated clear increase in fluorescein di-acetate and phosphomonoesterase activities with only 25% of recommended nitrogenous and phosphatic fertilizers under the sequence; dehydrogenase activity was higher with the application of compost (2 t ha⁻¹) and biofertilizers with 25% NP

fertilizers; compost coupled with biofertilizers revealed the highest microbial biomass carbon; and available P status of the soil increased significantly on application of rock phosphate with enriched compost.

2.3 Effect of biocompost on crop yield, nutrient uptake and quality

2.3.1 Crop yield

Steffens *et al.* (1992) studied the influence of biocompost on yield, heavy metal transfer and nitrogen dynamics under field conditions. Biocompost produced from organic waste collected in the rural area of Giessen, increased potato tuber yield, wheat and barley grain yields. Soil pH, extractable P and K was also increased by biocompost application. Biocompost produced from organic waste collected in the rural area of Giessen, increased potato tuber yield, wheat and barley grain yields. Soil pH, extractable P and K was also increased by biocompost application. Nasir *et al.* (1994) studied the effect of biocompost on sugarcane crop. It was concluded that biocompost increased cane yield by improving the physico-chemical properties of soil and the efficiency of NPK use. When used without NPK, biocompost improved juice quality.

Prasad and Prasad (1994) reported that targeting of wheat in calcareous soil (available N: 350 kg ha⁻¹, available P₂O₅: 20 kg ha⁻¹ and available K₂O: 150 kg ha⁻¹) revealed that 116 kg N, 50 kg P₂O₅ and 31 kg K₂O ha⁻¹ through chemical fertilizers were needed for attaining 40 q ha⁻¹ target of wheat grain. In the same soil, integrated use of 64 kg N ha⁻¹, 26 kg P₂O₅ ha⁻¹ and 10 kg K₂O ha⁻¹ and 5 t ha⁻¹ compost on dry weight were required to obtain the above target. It shows that use of organic manure can substantially meet the chemical fertilizer requirement for a given target in wheat and other crop. The poor farmer thus would have to invest much less on chemical fertilizer.

Bohne *et al.* (1996) studied the influence of biocompost and FYM on soil properties and on growth of *Acer pseudoplatanus*. The results showed that amount of N, P and K added to the soil with the organic materials was higher. Cation exchange capacity, pH and growth of plants also increased. Jamrisca (1996) studied the effect of biocompost on yield of selected crops. The results showed that only the higher rates of biocompost were effective in increasing yields of maize and oats.

An experiment was conducted to study the effect of phosphocompost on growth of the successive crop [(rice (*Oryza sativa*)-rice-black gram (*Phaseolus mungo*)] with consequent effect on the organic carbon and biological activity of Indo-Gangetic alluvial soil during 1990-91 and 1991-92 by Adhikari *et al.* (1997) and reported that yield of each crop decreased as the organic matter goes down; where as inorganic fertilizer did not decrease the yield. They further reported that organic carbon and soil microbial biomass carbon were decreased gradually with an increase in the number of the crop harvests. The compost treated soil maintained 16-20, 4-13, and 20% higher organic carbon, and 2-36, 13-48, and 14-62% higher soil microbial biomass carbon with the untreated soil after respective harvest of first, second, and third crop.

Yadav and Kumar (2000) reported that FYM and *Sesbania* green manuring hold great promise for 25-50% substitution of inorganic fertilizer to rice – wheat system. In long term greater sustainability in the yield and higher soil fertility may be achieved by integrated use of organic and inorganics. Buchgraber (2000) studied the use of biocompost in agriculture. It is concluded that biocompost increased the yields of summer and winter barley, winter wheat, rape, pumpkin and grassland. Schulz *et al.* (2001) conducted an field experiment to evaluate the effect of biocompost application on crop yield and N-net mineralization in soil and reported that in the biocompost application treatment with optimized mineral N fertilization yield of summer barley and maize was higher than in the optimized mineral N treatment without biocompost application.

Nagumo *et al.* (2001) conducted a study on utility of livestock excreta chemically treated with slaked lime in regard to paddy rice production and reported that N uptake of rice in peat soil applied with slaked lime treated manure was greater than in the plots treated with chemical fertilizers; rice yields from fields treated with slaked lime treated manure were also increased and the protein content of milled rice was higher in the plot treated with chemical fertilizers than in the plot treated with slaked lime treated manure. Smith *et al.* (2001) conducted a pot experiment using sandy soil and reported that common bean (*Phaseolus vulgaris*) performed best when grown on soil mixed with compost.

Wieczorek *et al.* (2002) studied the influence of biocompost on salubrity of replanted tomato and cucumber seedlings. Soil application of biocompost protected tomato against *Fusarium oxysporum f.sp. lycopersici*. It also limited the infection of cucumber seedlings with *Pythium ultimum*. Ruhe (2002) conducted a field experiment on winter wheat cultivation in nitrogen-limited production systems under particular consideration of yield formation, organic fertilizing and mechanical weed control and resulted that in 1994 and 1995 the highest average grain yield was 4.48 t/ha and the highest grain N content 75 kg/ha achieved with hoeing and harrowing; slurry application increased the number of grains per ear, the grain yield and the grain N yield but not the 1000 grain weight which averaged 45.8 g; and the secondary effects of mechanical weed control stimulated the mineralization and thus improved N supply for wheat.

Singh and Chauhan (2002) conducted a study with one inorganic and two organics sources of nitrogen to assess their performance towards sustainability of upland agriculture in hills of Uttaranchal and resulted that all sources were equally effective in influencing yield of wheat, residual effect of organic was prominent in affecting the ragi yield and organic nutrition improved the soil properties. Buchgraber (2003) studied the use of biocompost as fertilizer in agriculture and horticulture. Studies resulted in better soil biological parameters, water quality, plant community, yields, market productivity as well as food quality. Swain *et al.* (2003) conducted a field experiment in a weakly acidic loam soil of Bhubaneswar during kharif 2001 to study the integrated effect of bio-inoculants and fertilizer nitrogen on growth, yield and nitrogen economy of okra and resulted that the integrated treatments had better growth, higher fresh fruit yield as compared to fertilizer alone; integration of bio-inoculants with higher levels of fertilizer N i.e. 75 and 100 percent N doses yielded significantly higher yields i.e. 76.7 and 87.0 q/ha of okra crop.

Nass *et al.* (2003) studied the agronomic performance and quality of spring wheat and soybean cultivars under organic culture and resulted that all spring wheat cultivars at the springfield site did not make 13.5% grain protein required to meet milling quality criteria and soybean yields were reduced by 50%

because of reduced moisture availability and weeds competition. Kanwar and Paliyal (2004) conducted an experiment to study the integrated phosphorus management involving incorporation of P_2O_5 along with two sources of organic manures (FYM and vermicompost) on yield and crude protein content of chick pea, and summarized that grain yield of chick pea was maximum at $50 \text{ kg } P_2O_5 \text{ ha}^{-1}$ applied along with FYM or vermicompost.

Saliha *et al.* (2005) conducted a field experiment during August-December (kharif) and January-April (summer) in Tamilnadu, India to evaluate the effect of organic manures on the yield of lowland rice grown on a clayey loam soil with pH 9.3. The treatments were: control; FYM at 12.5 t/ha ; green leaf manure at 6.25 t/ha ; and biocompost at 3 t/ha and resulted that application of biocompost recorded the highest values for number of panicles per m^2 , filled grains per panicle, 1000 grain weight and grain yield in 2002 and 2003, respectively; this treatment also improved the soil chemical (available NPK) and biological properties (bacteria, fungi and actinomycetes) better than the other treatments. Varalakshmi *et al.* (2005) studied the effect of integrated use of organic manures and inorganic fertilizer on organic carbon, available N, P and K in sustaining productivity of groundnut-finger millet cropping system and reported that pod and haulm yield of groundnut increased significantly due to various management practices over control. The highest pod yield (1.25 q ha^{-1}) was recorded in treatment of package of practices where 100% recommended NPK+ $4.5 \text{ t FYM ha}^{-1}$ was applied.

In a long term (34 years) fertility experiment with rice-rice cropping the biological soil quality was assessed by Ghoshal *et al.* (2005). The results revealed that yield of *Kharif* rice were more sustained when compost was added with NPK fertilizers than fertilizers without compost. Compost maintained the highest biological quality index as compared to fertilizer treatments particularly with imbalanced fertilizer without compost. Sharma and Bhardwaj (2005) studied the direct and residual effect of rock phosphate enriched organics on yield in maize-wheat cropping in an acid alfisol and resulted that the P-enriched FYM and FYM + *Eupatorium* biomass to the levels of 0.22, 0.44 and 0.66% P recorded

consistent increase in grain yield during rabi 1997-98 and 1998-99, respectively; it is inferred that application of FYM/ FYM + *Eupatorium* biomass (1:1) @ 10 t/ha enriched to 0.44% P level through indigenous rock phosphate along with 25% of recommended N had significant direct effect on maize grain yield and P enriched manorial products had pronounced significant residual effect on the wheat grain yield.

Ghuman and Sur (2006) studied the effect of summer season manuring with FYM and green manure on soil properties and performance of rainfed wheat in a loamy sand soil during 1994-2000 and reported that application of FYM and green manure increased organic carbon in the top soil, bulk density and pH of the surface layer decreased with organic manuring whereas steady-state infiltration rate increased by 25-69% and soil moisture storage by 27-65 mm per 1.8 m depth over control; with addition of green manure wheat yield was 51% higher in the treated plots compared to the control yield of 1551 kg/ha but its residual effect produced 33% more grains.

Ahmad *et al.* (2008) studied the use of nitrogen fertilizer in wheat production through enriched compost and reported that application of nitrogen-enriched compost significantly improved the growth, yield and NPK contents of wheat compared with compost and control treatments. Singh *et al.* (2009) studied the effect of phosphocompost on rice-wheat system in a non-calcareous typical Haplustept and observed highest yield of rice in the treatment receiving 120 kg N, 13 kg P₂O₅ and 2 tonnes of phosphocompost and highest wheat yield was observed in the plot receiving recommended dose of fertilizers along with 2 tonnes of phosphocompost.

Kumar and Singh (2010) conducted a long term integrated nutrient management experiment under rice-wheat cropping system to assess the direct and residual effect of green manures on crops with and without farmyard manure and reported that the highest grain and straw yields of rice and wheat were obtained with the application of 100% NPK + green gram + 5 t FYM each year and combined application of 100% NPK + green gram + 5 t FYM each year gave significantly higher available NPK. Bhardwaj *et al.* (2010) studied the effect of

integrated nutrient management on soil fertility, yield and quality of tomato and frenchbean crops in the Mid Himalayas and reported that the highest yield (6.42 and 8.50 t/ha) was recorded with 75% NPK + crop residue during 2002 and 2003 which was statistically at par with 75% NPK + biofertilizer and 100% NPK alone. The highest frenchbean pod yield of 6.89 and 6.70 t ha⁻¹ was recorded under 75% NPK + biofertilizer during the years 2002 and 2003, respectively.

Jatav *et al.* (2010) studied the effect of organic and inorganic sources of phosphorus and potassium on their different fractions under Potato-Radish cropping sequence in a Brown Hill soil and reported that application of recommended dose of N along with 50% PK from inorganic fertilizers and rest from FYM in potato resulted in the highest dry matter yield of potato (5.72 t ha⁻¹) and highest dry matter yield of following radish crop (1.89 t ha⁻¹); integrated use of 50% PK from inorganic fertilizers and 50% from FYM resulted in highest organic carbon and available P content in soil.

Basumatary and Talukdar (2011) studied the effect of integrated sulphur and FYM on yield, quality of crops and nutrient status under Rapeseed-Rice cropping system and reported that the highest seed and stover yields were recorded when 30 kg S ha⁻¹ was integrated along with FYM either @1.5 or 3.0 t ha⁻¹ and an oil content in the seeds significantly increased from 37.5 to 41.1% with increase in S levels from 0 to 60 kg ha⁻¹.

Chesti and Ali (2012) conducted a field experiments during two consecutive kharif seasons of 2004 and 2005 at the crop research farm, SKUAST-K, Shalimar campus, Srinagar to assess the rhizospheric microflora, nutrient availability and yield of green gram as influenced by organic manures, phosphate solubilizers and phosphorus levels in alfisols and results revealed that application of organic manures significantly increased the rhizospheric microbial population (bacteria, fungi and actinomycetes), available soil NPK, grain and straw yield of green gram; soil inoculation with P- solubilizers recorded significant increase in grain and straw yield of green gram, soil available NP and bacteria and actinomycetes population significantly decreased due to inoculation; and increasing levels of P upto 30 kg P₂O₅ ha⁻¹ significantly improved the grain and

straw yield of green gram, microbial population and soil available N whereas available P of the post-harvest soil increased significantly upto 60 kg P₂O₅ ha⁻¹ level.

2.3.2 Nutrient uptake and crop quality

Bangar *et al.* (1989) prepared the nitrogen and phosphorus-enriched paddy straw compost to study its effects on yield and nutrient uptake by wheat and reported that the addition of urea alone to enhance the N content of paddy straw compost is not useful due to losses of N but the addition of pyrites partially reduce the N losses; the N-phosphocompost gave better yield of wheat and greater N and P uptakes as compared with single superphosphate and the phosphocompost.

Sharma and Mitra (1990) studied the effect of organic materials and NPK levels on growth and yield of rice and reported that uptake of N,P and K increased with application of N, NP, NPK and organic materials. Bernal *et al.* (1998) reported that the compost which had not gone undergone a maturation phase had similar nutritional N value as the mineral fertilizer and the greatest N fertilizer efficiency was found in mature compost because of its high concentration of NO₃-N and to a lesser extent also to its mineralizable N. Pape and Steffens (1998) conducted a field experiments between 1993-1997 at 6 sites in Hessen, Germany, to investigate the effects of application of 30 t fresh compost/ha with or without N fertilizers to winter wheat grown on parabraunerde, brown earth of Rendzina and reported that yields were depressed by over fertilization with N and high N mineralization. Nira and Nishimune (1998) observed an accumulation of fertilizer nitrogen applied at different times into grain and uptake of soil nitrogen by winter wheat in Hokkaido and reported that the necessity of estimating the progress of uptake of soil N by wheat plants to control the yield and quality of grain; the amount of N mineralized in the soil from sowing time to harvest was estimated at less than 40% of the amount of soil N absorbed by winter wheat; the residual inorganic N in soil, especially in the sub-soil at sowing time, contributed considerably to N uptake by winter wheat.

Bartal *et al.* (2004) conducted a study on NPK uptake by wheat and their distribution in soil following successive, annual compost applications and resulted that total dry matter, grain production, and the amount of NPK taken up by the plants increased with increasing compost rate; nitrogen uptake by the plants of the fertilized control was much higher than by the plants of the highest compost rate; P and K uptake by the plants amended with the highest compost rate was much higher than by the fertilized control plants; and inorganic N quantity in the soil increased with increasing compost rate and with successive applications.

Kapoor and Goyal (2005) studied the effect of application of different phosphorus sources on dry matter yield and uptake of fluorine in wheat and resulted that N and P uptake was enhanced by the P fertilizers and P fertilizers had no significant effects on the fluorine contents of grain and straw.

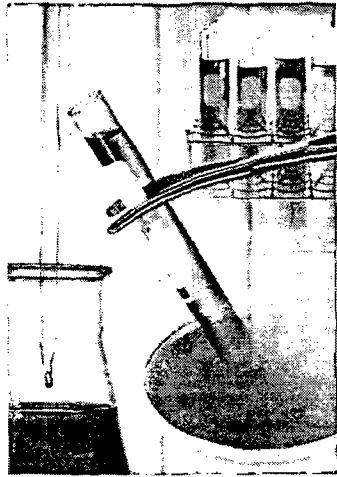
Kumar *et al.* (2006) conducted a field experiment on rice-wheat sequence under irrigated condition and the treatments applied include (T₁) residue burnt; (T₂) residue incorporation; (T₃) residue incorporation + cellulose degrading fungi; (T₄) residue incorporation + phosphocompost; (T₅) residue burnt + phosphocompost; and (T₆) control and reported that uptake of N in wheat was found significantly high under T₄ treatment. Kanwar *et al.* (2006) conducted a field experiment in Dhaulakuan, Himachal Pradesh to monitor the combined use of green manures, crop residues, compost and fertilizers on the yield and N uptake in a rice-wheat cropping system and results revealed that dry matter production was highest in case of sunhemp followed by dhaincha (*Sesbania aculeata*) and moong (*Vigna radiata*); and green manure + 50% N + compost were found statistically at par with 100% NPK in increasing nutrient uptake by the rice crop. Gaiind *et al.* (2006) studied the microbial biomass, P nutrition and enzymatic activities of wheat soil in response to phosphorus enriched organic and inorganic manures and reported that phosphorus uptake was highest with microbial-enriched phosphocompost application.

Nishanth and Biswas (2008) studied the kinetics of phosphorus and potassium release from rock phosphate and waste mica enriched compost and their effect on yield and nutrient uptake by wheat and reported that the enriched

composts prepared with rock phosphate and waste mica along with *A. Awamori* resulted in significantly higher biomass yield, nutrient uptake and recoveries of P and K as well as available P and K in soils than composts prepared without inoculant. Mankotia *et al.* (2008) studied the effect of organic and inorganic sources of nutrients on rice-wheat cropping system and reported that the nutrient uptake (159.1 kg N, 35.0 kg P and 147.9 kg K/ha) from the rice-wheat cropping system recorded higher values with FYM at 5 t/ha, followed by FYM at 2.5 t/ha + mushroom spent compost at 1.25 t/ha (155.0 kg N, 32.5 kg P and 139.0 kg K/ha).

Pandey *et al.* (2009) conducted a field experiment on long term influence of organic and inorganic fertilizers on nutrient uptake by rice and wheat in calcareous soil and reported that the uptake of N, P, K and S by rice increased significantly with graded dose of fertilizer, alone or in combination with compost and crop residue; the uptake of N, P, K and S by rice under control increased to 168.66, 156.84, 138.87 and 406.01% at 150% NPK + compost + crop residue treatment; and the nutrient uptake was enhanced by the integrated use of compost + crop residue with chemical fertilizer at all levels of NPK. Banta and Dev (2009) studied the effect of nitrogen enriched phosphocompost prepared from green biomass of *Lantana camara* in wheat and reported that application of nitrogen enriched phosphocompost in wheat crop along with 75% recommended fertilizer N recorded higher nutrient uptake by crop.

Prasad *et al.* (2010) conducted a pot experiments on salt affected soil during Kharif and Rabi of 2003-04 to study the effect of soil amendments on nutrient uptake by rice and wheat and reported that the total nutrient uptake significantly increased with the application of organic amendment (compost, digested sludge and sulphitation pressmud) or inorganic amendment (pyrite and gypsum) or by both



MATERIALS AND METHODS

3. MATERIALS AND METHODS

To accomplish the objectives of the present study entitled "Fortification and mineralization studies in compost under controlled conditions", an experiment on compost preparation was conducted in the experimental farm of Soil Microbiology during 26th March to 5th August, 2011. An incubation experiment was conducted in the soil microbiology laboratory of the Department of Soil Science during 31st Oct, 2011 to 26th Dec, 2012 and the pot experiment was conducted in the growth chamber of the Department of Organic agriculture, CSKHPKV, Palampur during *rabi* 2011.

The details of compost preparation, incubation experiment for studying decomposition and mineralization of nutrients, pot experimentation the methodology adopted have been described under the following heads:

- 3.1 Preparation and analysis of compost
- 3.2 General description of the study area
 - 3.2.1 Experimental site
 - 3.2.2 Climate and Weather
 - 3.2.3 Soil type
- 3.3 Experimental details
 - 3.3.1 Incubation Experiment
 - 3.3.1.1 Treatments
 - 3.3.1.2 Observations of incubation experiment
 - 3.3.1.2 (a) CO₂ determination
 - 3.3.1.2 (b) Soil sampling and analysis
 - 3.3.2 Growth chamber experiment
 - 3.3.2.1 Treatments

3.3.2.2 Observations of growth chamber experiment

3.3.2.2 (a) Yield attributes

3.3.2.2 (b) Yield

3.3.2.2 (c) Analysis of soil and plant samples

3.4 Statistical analysis

3.1 Preparation of compost

Raw material

Compost was prepared by using farm residue and available weed plants (*Eupatorium*) in the surrounding area and fortified with rock phosphate. The raw material i.e. *Eupatorium* used for preparation of compost contained 82.61 % moisture content, 42.6 % carbon, 2.38 % N, 0.16 % P, 1.48 % K and 0.09 % S content. The rock phosphate used in the composts contained 31.7 % total phosphorus, 29.04 % citrate insoluble phosphorus and 2.41 % citrate soluble phosphorus.

1. Cow dung + *Eupatorium* weed (Compost-I)
2. Cow dung + *Eupatorium* weed + 5% rock phosphate (Compost-II)
3. Cow dung + *Eupatorium* weed + 10% rock phosphate (Compost-III)

The composts were prepared by pit method (1×0.7×0.61) metres. Total quantity of composting material was 3q (wet basis) cow dung, 3q (wet basis) *Eupatorium* weed plants and depending upon the treatment 5 kg rock phosphate in case of 5% RP treatment and 10 kg in case of 10% RP treatment was used.

Analysis of compost

The composts so prepared were then collected by mixing the amount uniformly from upper layer. The collected composts were evaluated for moisture content, pH, CEC, EC, total carbon, total NPK, micronutrients, C: N ratio, microbial biomass C, N and S. Composts were used in incubation and growth chamber experiments as these were having higher nutrients status in comparison to their counter part.

The moisture content of samples of composts was recorded ; air dried and then oven dried at 55 °C their was determined. The dried material was ground and passed through sieve for the determination of total N, P and K and wet samples were kept in refrigerator for the determination of microbiological properties.

Total Nitrogen

The total nitrogen content of composts was determined by conventional Kjeldahl method (Jackson 1967).

Total Phosphorus

The total phosphorus content of composts was determined by digesting the samples with $\text{HClO}_4 + \text{HNO}_3$ acid method (Jackson 1967).

Total Potassium

The total potassium content of composts was determined by digesting the samples with $\text{HClO}_4 + \text{HNO}_3$ acid method (Jackson 1967).

pH

Determined by 1:2.5::sample:water suspension, glass electrode method (Jackson 1967).

Cation Exchange Capacity (CEC)

The cation exchange capacity in composts was determined by the summation method (Black, 1965).

Electrical Conductivity (EC)

Conductivity bridge method 1:2 soil water suspension (Richards 1954).

Total carbon

Determined by ashing 10 g of each material at 500°C in the Muffle furnace to constant weight. The total organic matter lost by combustion was divided by the factor 1.724 to calculate its total carbon content (Allison, 1960).

Micronutrients

The micronutrients were analyzed by DTPA method given by Lindsay and Norvell 1978.

Microbial biomass carbon, nitrogen and sulphur

Determined by fumigation – extraction method, Vance *et al.* (1987), Brookes *et al.* (1985) and Wu J *et al.* (1994), respectively.

Analysis of rock phosphate for total and citrate soluble P₂O₅

Total Phosphorus (P₂O₅)

Treated 1 g of fertilizer sample with 30 ml conc. HCl and 10 ml HNO₃ and digested till brown fumes ceased. Diluted the solution to 250 ml volumetric flask. Took out 25 ml aliquot from 250 ml volumetric flask in a 250 ml beaker and added 100 ml water.

Added 5 ml HNO₃ and heated to boil. Added 65 ml quimociac reagent, covered with watch glass, placed on hot plate and boiled for a minute. Cooled to room temperature, swirled carefully 3-4 times during boiling in order to avoid bumping. Cooled and filtered in crucible previously dried at 250 °C and weighed and washed 4-5 times with some water. Dried the crucible and contents for 30 minutes at 250°C. Cooled in a dessicator to a constant weight, subtracted weight of reagent blank.

$$\text{Total phosphorus (As P}_2\text{O}_5\text{) \%} = \frac{0.03207 \times A - B \times \text{dilution factor} \times 100}{\text{Weight of sample}}$$

Where,

A = weight of sample precipitates in gram

B = weight of sample precipitates in gram for blank

Citrate soluble phosphorus (P₂O₅)

After removing water soluble phosphorus from the sample by leaching the sample using water for one hour, transfer filter paper and residue to a 250 ml conical flask containing 100 ml of neutral ammonium citrate solution previously heated to 65 °C. Close flask tightly with smooth rubber stopper and shake vigorously until paper is reduced to pulp and release pressure by removing

stopper occasionally. Continuously agitate contents of stoppered flask in controlled temperature ($65 \pm 0.5^\circ\text{C}$) for one hour. Exactly one hour after adding filter paper and residue, remove flask from shaker and immediately filter as soon as possible through Whatman No. 5 filter paper or equivalent using a funnel. Wash with distilled water at 65°C until volume of filtrate is approximately 350 ml allowing time for thorough draining before adding more water. If material is such that will yield cloudy filtrate, wash with 5% NH_4NO_3 solution. Throw away the filtrate as it is not required. Transfer dry paper and contents to a crucible; ignite all until organic matter is destroyed. Digest with 10-15 ml HCl until all phosphates are dissolved.

$$\text{Citrate insoluble } \text{P}_2\text{O}_5 \% = \frac{3.207 \times A \times df}{W}$$

Where, A = weight of precipitate,
 W = weight of sample in grams,
 Df = dilution factor

Citrate soluble phosphorus was calculated by using the following formula:

Citrate soluble phosphorus = (Total phosphorus – Citrate insoluble phosphorus)

Fortification of biocompost

The two composts in terms of nutrient status were selected for fortification with organic and inorganic agents. A preliminary incubation experiment was conducted to find out the suitable time for fortification for different of organic and inorganic agents, so that nutrients are not immobilized in different organic sources. Fortification was done with each of bio-inoculants, urea, cow urine and combination of bio-inoculants and cow urine. Periodic observation on the rate of mineralization of nutrients from organic pool to inorganic pool was recorded.

3.2 General description of the study area

3.2.1 Experimental site

The experimental farm is situated at $32^{\circ}6'$ N latitude and $76^{\circ}3'$ E longitude at an altitude of about 1290 meters above mean sea level. The site lies in the Palam valley of Kangra district in the mid hill sub humid zone of Himachal Pradesh in North-West Himalayas.

3.2.2 Climate and weather

The climate of the experimental site is characterized as wet temperate with mild summers (March to June) and cool winters. The mean annual rainfall ranges between 1500 to 3000 mm, out of which about 80% is received during monsoon period from June to September. The mean maximum temperature remains about 31°C during the hottest months of May to June. December to February are the coldest months with minimum temperature of about 4-6 °C.

The important meteorological observations (weekly averages) recorded inside the growth chamber of the Himachal Pradesh Krishi Vishvavidyalaya, Palampur during the cropping period of investigation are illustrated graphically in Fig. 3.1.

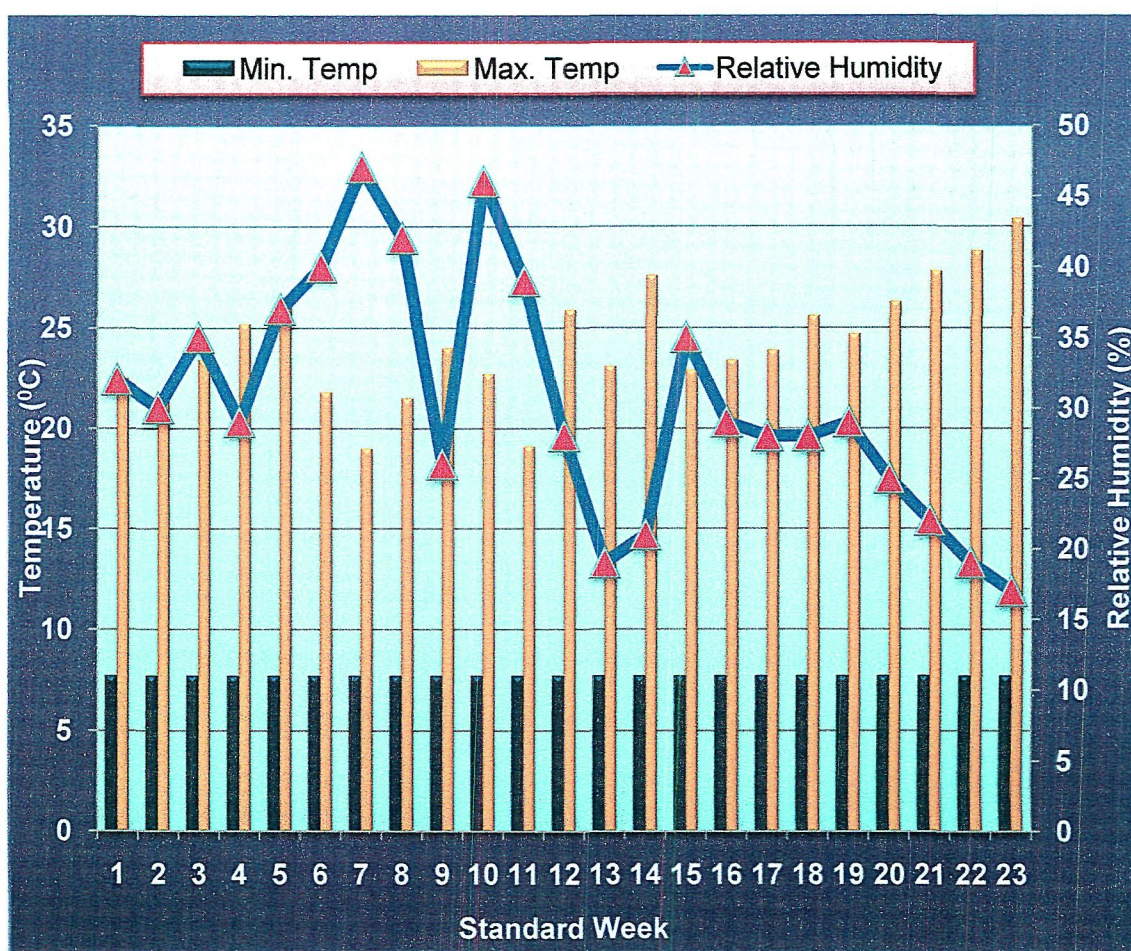


Fig 3.1 Weekly meteorological data of Growth chamber (Palampur, H.P.) during crop period (30th Dec, 2011 to 26th May, 2012)

3.2.3 Soil type

Some important physico-chemical characteristics of the soil at the initiation of the experiment are: In mechanical analysis the sand, silt and clay were 25.8%, 46.5% and 27.5% respectively, textural class was silty clay loam, organic carbon was 10.6 g kg^{-1} and pH was 5.4 (acidic).

Table 3.1: Methods to determine the physical, chemical and microbiological properties of soil

Property	Method
Mechanical analysis	Piper 1966
Organic carbon	Walkley and Black 1934
pH (soil reaction)	Jackson 1967
Available nutrients	
Nitrogen	Subbiah and Asija. 1956
Phosphorus	Olsen <i>et al.</i> 1954
Potassium	Extraction method (A.O.A.C, 1970)
Sulphur	Chesnin and Yien 1950
Total nutrients	
Nitrogen	Micro Kjeldahl's method (Jackson 1967)
Phosphorus	Vanadomolybdo phosphoric acid yellow colour method(Jackson,1967)
Potassium	Celaya <i>et al.</i> 2009
Sulphur	Johnson and Nitisha,1952
Microbial biomass carbon	Vance <i>et al.</i> , 1987
Bacterial count	Wollum, 1982
Fungal count	Wollum, 1982
Actinomycetes count	Wollum 1982
Urease activity	Tabatabai and Bremner 1969

3.3 Experimental details

3.3.1 Incubation experiment:

3.3.1.1 Treatments

Compost-I (Control i.e. only Cow dung + *Eupatorium* weed)

Compost-II (Cow dung + *Eupatorium* weed + 5% rock phosphate)

Compost-III (Cow dung + *Eupatorium* weed + 10% rock phosphate)

- | | |
|-----------------|---|
| T ₁ | Soil + compost-I + 1% urea |
| T ₂ | Soil + compost-I + 5% cow urine |
| T ₃ | Soil + compost-I + 5ml bioinoculants |
| T ₄ | Soil + compost-I + 5ml bioinoculants + 5% cow urine |
| T ₅ | Soil + compost-I + 5ml bioinoculants + 5% cow urine + 1% urea |
| T ₆ | Soil + compost-II + 1% urea |
| T ₇ | Soil + compost-II + 5% cow urine |
| T ₈ | Soil + compost-II + 5ml bioinoculants |
| T ₉ | Soil + compost-II + 5ml bioinoculants + 5% cow urine |
| T ₁₀ | Soil + compost-II + 5ml bioinoculants + 5% cow urine + 1% urea |
| T ₁₁ | Soil + compost-III + 1% urea |
| T ₁₂ | Soil + compost-III + 5% cow urine |
| T ₁₃ | Soil + compost-III + 5ml bioinoculants |
| T ₁₄ | Soil + compost-III + 5ml bioinoculants + 5% cow urine |
| T ₁₅ | Soil + compost-III + 5ml bioinoculants + 5% cow urine + 1% urea |
| T ₁₆ | Control (soil only) |

* {400 g soil was used in each treatment and 10 g compost was used in all the treatments except control}

3.3.1.2 Observations of incubation experiment

3.3.1.2 (a) CO₂ determination

CO₂ was determined by the procedure as described by Pramer and Schmidt (1964). The rate of decomposition was measured by absorbing the evolved CO₂ in 1.5N NaOH solution contained in a tube kept suspended inside the bottle. The containers were kept complete air tight during the period of incubation in B.O.D. incubators.

CO₂ was determined at weekly interval upto 8 weeks. At periodic intervals, the tubes containing NaOH solution were taken out and excess alkali was back titrated with 1N HCl after addition of saturated solution of BaCl₂ (50%).

Calculations: Amount of CO₂ evolved at each temperature was calculated by the following formula:

$$\text{Milligrams of CO}_2 \text{ evolved per 100g} = \frac{A-B \times 22 \times 100}{\text{Weight of soil}}$$

Where, A= ml of 1N HCl required to neutralise 5 ml of 1.5 N NaOH (Blank).

B= ml of 1N HCl required to neutralise the incubated 5 ml of NaOH.

3.3.1.2 (b) Soil sampling and analysis

Nitrogen mineralization

400 g samples of soil passed through 2 mm sieve were amended separately with dried, powdered organic materials and adjusted to moisture level equivalent to field capacity. The treated soils were transferred to 1lt wide mouth glass bottles which were incubated at 30°C. The moisture was maintained at constant level during the period of incubation. Determination of NH₄-N, NO₃-N and NO₂-N were made at weekly intervals upto 56 days by following the method as described by Black (1965).

Ammonium-nitrogen

At each interval 5 g of soil was drawn from the incubated samples. Exchangeable NH₄-N was extracted with 2N KCl of Analar grade. 5ml of 4% boric acid solution was taken in a 50ml receiving flask which was marked to indicate a

volume of 30 ml and placed the flask under condenser. Soil extract was added to distillation flask and 0.2 g of magnesium oxide added through a dry powder funnel having a long stem. The flask was attached to distillation set to achieve distillation of ammonia. When distillate reached 30ml mark on the receiving flask, distillation was stopped by opening stop cock in the steam by-pass, rinsed the condenser and determined $\text{NH}_4\text{-N}$ in the distillate by titration with $\text{N}/150 \text{ H}_2\text{SO}_4$. The colour change at the end point was from green to a permanent faint pink.

(Nitrate + Nitrite)-nitrogen

After removal of ammonium-N from the sample as described in the ammonium N estimation, the stopper was removed from the side arm of the flask and 0.2 g Devarda's alloy was rapidly added through a dry powder funnel. The amount of ammonium-nitrogen liberated by steam distillation was determined as described in ammonium N estimation.

(Ammonium + Nitrate)-nitrogen

Proceeded as described in ammonium N estimation but treated another soil extract in distillation flask with 1 ml of 2% sulphamic acid solution and swirled the flask for few seconds to destroy nitrite before addition of magnesium oxide and Devarda's alloy.

Sulphamic acid was stored in refrigerator. Nitrite nitrogen was determined by subtracting nitrate-nitrogen from (nitrate + nitrite) – nitrogen as determined by the procedure described in ammonium N estimation.

Available Phosphorus

The available phosphorus content of soil was determined by Olsen *et al.* (1954) method.

Available Potassium

The available potassium content of soil was determined by Extraction method (A.O.A.C).

3.3.2 Growth chamber experiment

3.3.2.1 Treatments

The pot experiment was conducted on Wheat using following treatments:

- T₁ Fortified compost + 5 ml bioinoculants
 T₂ Fortified compost + 5 ml bioinoculants + 5% cow urine
 T₃ Fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea
 T₄ Unfortified compost + 50% recommended NPK
 T₅ Recommended NPK
 T₆ Unfortified compost only
 T₇ Control (i.e. no compost and no fertilizers)

* {P solubilizer and Azotobacter bioinoculants were used}

* {12 kg soil and 850 g compost fortified with 5% rock phosphate was used}

Total treatments	Seven
Replications	Four
Design	CRD (i.e. completely randomized design)
Variety	HS-295
Date of sowing	30 th December, 2011
Seed rate	10 seeds pot ⁻¹

Fertilizer application

Hundred per cent NPK application rate corresponds to the state level recommendations for respective nutrients. The crop wise application rates of N, P and K during the period of investigation are given below:

Crop	Nutrient added (kg ha ⁻¹)		
	N	P ₂ O ₅	K ₂ O
Wheat	120	60	30

The sources of N, P and K were urea, single super phosphate and muriate of potash. The compost was applied on dry weight basis at the time of sowing of crop.

The soil from the experimental farm of the university was collected, ground and filled in pots of 0.01584 m³ dimensions. The compost and fertilizer was added as per plan of treatments. The moisture was maintained at field capacity. The seeds of wheat were grown in pots experiment consisted of 4 replications of 7 pots each. Labelling of individual pot was carried out manually. Hand weeding was carried out in order to control weeds. Irrigation of pots was done manually to maintain proper moisture content.

3.3.2.2 Observations of Growth chamber experiment

3.3.2.2 (a) Yield attributes

The emergence of the plants from each pot was observed after one week and two weeks of sowing. The yield attributes *viz.* number of effective tillers, number of grains per ear and protein content of grains were also recorded in each pot.

3.3.2.2 (b) Yield

Crop was harvested manually. The grain yield was recorded on the grain weight basis pot wise. The net pot yield was calculated in grams per plant.

3.3.2.2 (c) Analysis of soil and plant samples

Soil sampling and analysis

Soil samples from 0-0.15m depth were collected from each pot before sowing, at CRI stage, at grain filling stage and after harvest of Wheat crop (2011-2012) and representative sample were made.

Preparation of soil samples

Representative and collected samples were air dried and ground in a wooden pestle and mortar to pass through 2 mm sieve and subsequently stored in polyethylene bags for determination of various chemical and microbiological parameters.

Analysis of soil samples

The processed soil samples were analyzed for available nitrogen, phosphorus, potassium and sulphur; total nitrogen, phosphorous, potassium and sulphur; urease activity, microbial count and biomass carbon in initial soil, at CRI stage, at grain filling stage and after harvest soil samples.

Microbial biomass carbon

Microbial biomass carbon in soil and compost was determined by fumigation-extraction method (Vance *et al.* 1987). Air dried samples passed through 2 mm sieve and weighed 20 g of soil and 5 g of compost into 50 ml capacity beaker. The samples were fumigated with 50 ml ethanol free chloroform in a dessicator. Evacuated dessicator with vaccum pump. After 24 hr of incubation extracted the samples with 80 ml 0.5M potassium sulphate for 30 minutes on shaker and filtered the contents through Whatman number 1 filter paper. Extracted three replicates each of unfumigated and fumigated samples. Refluxed 8 ml of filtrate with 2 ml of potassium dichromate and 15 ml H₂SO₄ and H₃PO₄ diacid mixture in the ratio of 2:1 for half an hour on hot plate at 150°C. Added three drops of phenolphthalein indicator and titrated with ferrous ammonium sulphate solution. The end point was observed as colour change from brown to green and then again brown.

Prepared cold and hot blank by taking 2 ml potassium dichromate, 8 ml potassium sulphate (0.5M) and 15 ml of diacid mixture. Refluxed the hot blank at 150°C and cooled. Titrated both blanks with ferrous ammonium sulphate.

$$\text{Exact normality of FAS (x)} = \frac{0.04 \times 2}{Y}$$

Where,

0.04 = Expected normality of FAS

2 = ml of potassium dichromate

Y = ml of FAS used for cold blank

$$\text{Extractable C (}\mu\text{g g}^{-1}\text{)} = \frac{(\text{Volume of FAS used for hot blank} - \text{Volume of FAS used for sample}) \times \text{X normality of FAS} \times 12 \times 1000 \times (80 + \text{water content of sample})}{4 \times 8 \times \text{dry weight of sample}}$$

Microbial population

The population of bacteria, fungi and actinomycetes in soil and compost were determined by dilution plate method (serial dilution, standard plate technique, Wollum 1982). Weighed and suspended 10 g of soil / compost sample in a 90 ml sterilized water blank and obtained 1/10 dilution. Transferred 1 ml of this suspension to 9 ml water blanks and obtained further dilutions. Inoculated the desired suspensions in different plates and added 15-20 ml specified agar media for quantification of bacteria, fungi and actinomycetes. Examined the plates and counted the colonies.

Urease activity

The urease activity was determined by the method as described by Tabatabai and Bremmer (1972).

Plant sampling and analysis

Grain samples and straw of Wheat were collected at the harvest of crop, dried in oven for 8-10 days at 60°C, then ground and stored in paper bags for further analysis. The detail of chemical analysis is given below:

Parameter	Method	Reference
Total Nitrogen	Modified Kjeldahl's Method	Jackson (1967)
Total Phosphorus	Vanadomolybdate phosphoric acid yellow colour method	Jackson (1967)
Total Potassium	Diacid digestion method	Black (1965)
Total Sulphur	Diacid digestion method	Johnson and Nitisha (1952)

Nutrient uptake

The concentration of nitrogen, phosphorus, potassium and sulphur were determined in grains and straw separately and uptake for each was calculated as follows:

$$\text{Uptake (kg ha}^{-1}\text{)} = (\% \text{concentration of nutrient}) \times \text{yield (seed or straw) of crop in kg ha}^{-1} \text{ on dry wt. basis) / 100}$$

The uptake of nutrient obtained in respect of grains and straw was summed up in order to obtain total uptake by the crop for each element.

3.4 Statistical analysis

The data obtained from growth chamber experiment, incubation experiment and laboratory analyses were subject to statistical analysis using the technique of analysis of variance for completely randomised design for the interpretation of results as described by Gomez and Gomez (1984).



RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results emanating from the present investigation, "Fortification and mineralization studies in compost under controlled conditions" are described in this chapter under the following heads and sub heads:

- 4.1 Chemical, physical and microbiological properties of biocomposts
- 4.2 Laboratory incubation studies
 - 4.2.1 Effect of organic, inorganic and integrated sources of nutrients on CO₂ evolution and mineralization of N, P and K
 - 4.2.1.1 Total CO₂ evolution
 - 4.2.1.2 Mineralization of nitrogen
 - 4.2.1.3 Mineralization of phosphorus
 - 4.2.1.4 Mineralization of potassium
- 4.3 Growth chamber studies
 - 4.3.1 Effect of organic, inorganic and integrated sources of nutrients on yield attributes and yield of wheat
 - 4.3.2 Effect of organic, inorganic and integrated sources of nutrients on nutrient content, nutrient uptake and crop quality
 - 4.3.2.1 Effect on nutrient content and quality of wheat grain
 - 4.3.2.2 Effect on nutrient content and quality of wheat straw
 - 4.3.2.3 Effect on nutrient uptake by wheat grain
 - 4.3.2.4 Effect on nutrient uptake by wheat straw
 - 4.3.2.5 Effect on total nutrient uptake by wheat plant (grain + straw)
 - 4.3.3 Effect of organic, inorganic and integrated sources of nutrients on chemical properties of soil at different growth stages of wheat

4.3.3.1 Available nitrogen

4.3.3.2 Available phosphorus

4.3.3.3 Available potassium

4.3.3.4 Available sulphur

4.3.3.5 Total nitrogen

4.3.3.6 Total phosphorus

4.3.3.7 Total potassium

4.3.3.8 Total sulphur

4.3.4 Effect of organic, inorganic and integrated sources of nutrients on the microbiological properties of soil at different growth stages of wheat

4.3.4.1 Total microbial count

4.3.4.2 Microbial biomass carbon

4.3.4.3 Urease enzyme

4.1 Chemical, physical and microbiological properties of biocomposts

Composting is a process whereby organic waste is biodegraded into a nutrient-rich, soil-like mixture. Bacteria and fungi are utilized to quickly and efficiently breakdown waste materials, producing minerals and compounds that are helpful to plant growth in the process. Bacteria are the most abundant group of microorganisms. In normal fertile soil, 10-100 million bacteria are present per gram of soil. Bacteria are the primary agents in organic matter decay. The bulk of the soil bacteria are heterotrophic and utilize readily available source of organic energy from sugar, starch, cellulose and protein. Degradation of lignin is brought about by fungi mainly belonging to basidiomycetes. Actinomycetes are microbes which act upon the resistant fraction of organic matter and their number may be as high as 200 million per gram of soil and may increase in manured soils.

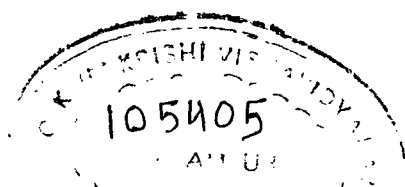
Raw material viz. *Eupatorium*, cow dung and rock phosphate were used for composting. These composts were analyzed for parameters like total N, P, and K, total carbon, moisture content, pH, CEC, EC, C:N ratio, micronutrients,

microbial biomass carbon, nitrogen and sulphur which are given in Table 4.1. The chemical, physical and microbiological parameters of different composts were determined at the end of decomposition process.

Table 4.1: Chemical, physical and microbiological properties of biocomposts

Parameter	Compost-I	Compost-II	Compost-III
Nitrogen (%)	1.62	1.82	1.96
Phosphorus (%)	0.52	0.64	0.73
Potassium (%)	1.00	1.04	1.12
Total carbon (%)	33.6	32.4	31.5
Moisture %	47.3	49.4	45.7
pH	6.3	6.7	6.6
CEC [cmol(p ⁺) kg ⁻¹]	189.6	201.4	212.7
EC (dS m ⁻¹)	0.07	0.09	0.13
C:N ratio	20:1	18:1	16:1
Micronutrients (mg kg ⁻¹ of compost)			
Copper	24.1	21.6	18.4
Iron	987.0	992.0	995.0
Zinc	47.8	44.5	40.2
Manganese	394.0	396.0	399.0
Biomass carbon (µg g ⁻¹)	322	308	316
Biomass nitrogen (µg g ⁻¹)	242	256	263
Biomass sulphur (µg g ⁻¹)	5.4	6.1	6.6

Note: Microbial biomass carbon, nitrogen and sulphur determined in fresh compost and expressed on dry weight basis



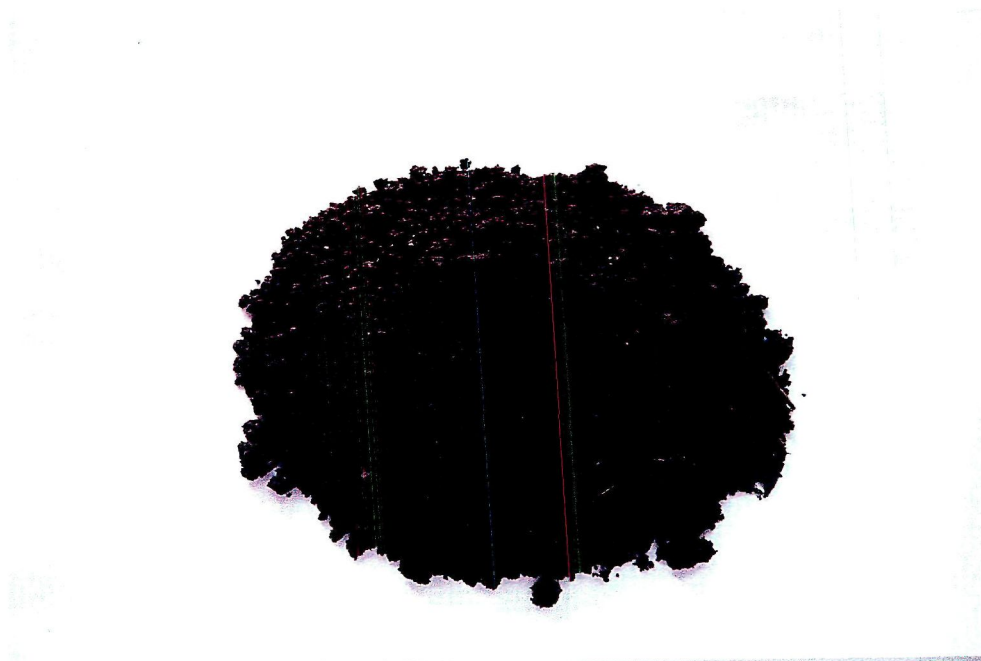


Plate 4.1 Fortified compost prepared from 5% rock phosphate



Plate 4.2 View of incubation experiment for nutrient transformation

The data presented in Table 4.1 revealed that the total N, P and K were highest i.e. 1.96%, 0.73% and 1.12% respectively in compost-III (cow dung + *Eupatorium* weed + 10% rock phosphate). Total carbon and C: N ratio were highest i.e. 33.6%, 20:1 in compost-I (cow dung + *Eupatorium* weed); moisture content and pH were highest i.e. 49.4% and 6.7 in compost-II (cow dung + *Eupatorium* weed + 5% rock phosphate). Cation exchange capacity (CEC) and electrical conductivity (EC) were highest i.e. 212.7 [C mol (p⁺) kg⁻¹] and 0.13 dSm⁻¹ respectively in compost-III. Micronutrients i.e. Cu and Zn and were highest i.e. 24.1 mg kg⁻¹ and 47.8 mg kg⁻¹ respectively in compost-I; Fe and Zn were highest i.e. 995.0 mg kg⁻¹ and 399.0 mg kg⁻¹ respectively in compost-III. Microbial biomass carbon, nitrogen and sulphur were recorded highest i.e. 316 µg g⁻¹, 263 µg g⁻¹ and 6.6 µg g⁻¹ respectively in compost-III. Compost-II (prepared by the addition of 5% rock phosphate) was selected for use in growth chamber studies considering the quality parameters and cost of the rock phosphate. Compost-II has been redesignated as fortified compost for description under growth chamber studies.

4.2 Laboratory incubation studies

4.2.1 Effect of organic, inorganic and integrated sources of nutrients on CO₂ evolution and mineralization of N, P and K

4.2.1.1 Total CO₂ evolution

The weekly data on CO₂ evolution in incubation period of 8 weeks are presented in Table 4.2. It is noted from the data that total CO₂ evolved in 8 weeks of incubation was highest i.e. 211.3 mg kg⁻¹ in the treatment soil + compost-I + 5 ml bioinoculants + 5% cow urine (T₄). Treatments viz. soil + compost-I + 1% urea (T₁), soil + compost-I + 5% cow urine (T₂), soil + compost-I + 5 ml bioinoculants (T₃) and soil + compost-II + 1% urea (T₆) were at par with treatment soil + compost-I + 5 ml bioinoculants + 5% cow urine (T₄). Treatment control (T₁₆) showed minimum CO₂ evolution i.e. 130.86 mg kg⁻¹.

The maximum CO₂ was evolved in treatment soil + compost-I + 5 ml bioinoculants (T₃) i.e. 42.5 mg kg⁻¹ which was at par with treatments viz. soil + compost-I + 5 ml bioinoculants + 5% cow urine (T₄) and soil + compost-II + 5% cow urine (T₇) during 1st week. Treatment T₃ and T₄ were significantly better than T₅. Treatment control (T₁₆) showed minimum CO₂ evolution i.e. 30.7 mg kg⁻¹.

Table 4.2: Weekly interval CO₂ evolution from the soil amended with different organic materials

Treatments	CO ₂ evolved (mg kg ⁻¹)								Total
	Incubation period (weeks)								
	1	2	3	4	5	6	7	8	
T ₁	40.3	28.1	22.0	23.1	22.0	23.1	24.3	24.8	207.8
T ₂	39.8	27.6	21.4	23.6	22.6	24.2	25.3	25.9	210.5
T ₃	42.5	28.1	19.8	23.1	20.3	23.6	24.8	25.4	207.8
T ₄	42.5	29.2	20.3	23.1	22.0	23.6	24.9	25.5	211.3
T ₅	41.5	28.1	23.6	22.5	19.0	20.9	22.0	22.5	200.3
T ₆	35.4	32.0	24.2	23.6	22.1	22.6	23.80	24.3	208.1
T ₇	42.0	33.6	19.2	22.0	20.4	21.2	23.35	23.9	205.8
T ₈	34.8	30.3	22.0	23.1	22.1	22.8	24.1	24.6	203.9
T ₉	34.3	30.0	22.5	23.6	21.1	22.5	23.7	24.2	202.1
T ₁₀	38.1	32.0	20.0	22.0	20.6	21.8	23.1	23.7	201.5
T ₁₁	33.2	27.0	20.0	23.6	21.4	21.9	23.1	23.6	194.0
T ₁₂	34.8	28.4	23.1	24.2	22.5	23.1	24.2	24.8	205.2
T ₁₃	31.0	23.1	23.1	24.2	21.8	22.6	23.9	24.5	194.4
T ₁₄	38.7	31.2	22.0	23.6	21.4	22.4	23.6	24.1	185.2
T ₁₅	34.8	27.8	23.1	23.6	22.0	23.1	24.2	24.8	203.7
T ₁₆	30.7	22.5	18.2	12.1	9.4	11.8	12.8	13.2	130.8
CD (P=0.05)	1.66	1.68	1.44	1.46	1.50	1.46	1.53	1.51	3.77

The maximum CO₂ was evolved in treatment soil + compost-II + 5% cow urine (T₇) i.e. 33.65 mg kg⁻¹ during 2nd week. Treatments viz. soil + compost-II + 1% urea (T₆) and soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₀) were at par with treatment - soil + compost-II + 5% cow urine (T₇). Treatments T₆, T₇ and T₁₀ were significantly higher than rest of the treatments. Treatment control (T₁₆) showed minimum CO₂ evolution i.e. 22.5 mg kg⁻¹. The maximum CO₂ was evolved in treatment soil + compost-II + 1% urea (T₆) i.e. 24.2 mg kg⁻¹ which was at par with T₅ during 3rd week. Treatments viz. soil + compost-I + 5 ml bioinoculants + 5% cow urine + 1% urea (T₅), soil + compost-III + 5% cow urine (T₁₂) and soil + compost-III + 5 ml bioinoculants (T₁₃) were at par with treatment soil + compost-II + 1% urea (T₆). Treatment control (T₁₆) showed minimum CO₂ evolution i.e. 18.2 mg kg⁻¹.

The amount of CO₂ evolved in treatments viz. T₂, T₆, T₉ and T₁₁, T₁₂, T₁₃, T₁₄ and T₁₅ was at par during 4th week. These treatments differed significantly than rest of the treatment during 4th week. Treatment control (T₁₆) showed minimum CO₂ evolution i.e. 12.1 mg kg⁻¹. Significantly higher amount of CO₂ was evolved in the all the treatments in comparison to control and soil + compost-I + 5ml bioinoculants + 5% cow urine+ 1% urea (T₅) during 5th week. As expected, treatment control (T₁₆) showed minimum CO₂ evolution i.e. 9.4 mg kg⁻¹. The treatments T₁, T₂, T₃, T₄, T₆, T₈, T₉, T₁₂, T₁₃, T₁₄ and T₁₅ were at par in CO₂ evolution during 6th week. These treatments differed significantly than rest of the treatments including control. The CO₂ evolution trends were similar during the 7th week and 8th weeks.

It is visualized from the data in fig no. 4.1, 4.2, 4.3, 4.4 and Table 4.2 that first week is the active period of decomposition due to intense state of biotransformation resulting in biodegradation of larger tissues and molecules into smaller ones, which latter combine to form complex humic molecules in soil. A decrease in CO₂ production was observed during the 2nd week and this continued upto 8th week. Similar trends in decomposition of organic matter have been observed by Bhardwaj and Novak (1978); Bangar and Patil (1980); Bhardwaj and Dev (1985). CO₂ evolution was decreased from 1st to 2nd and 2nd to 3rd week of incubation because of less availability of substrate and later on

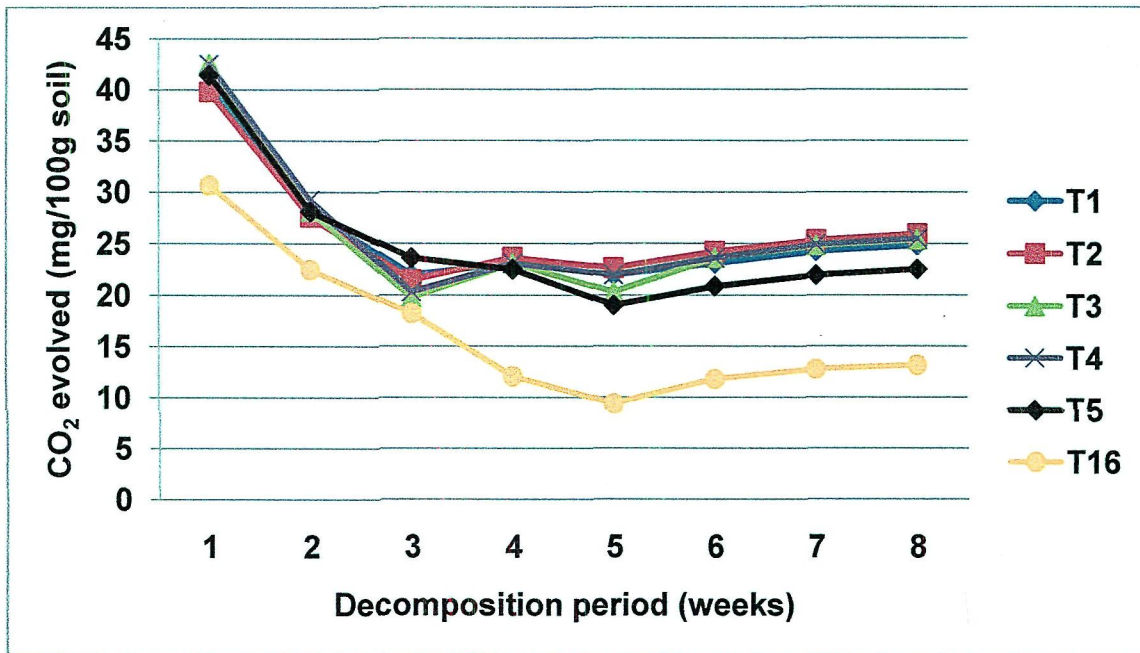


Fig 4.1 Pattern in the decomposition of soil organic matter in compost-I (unfortified)

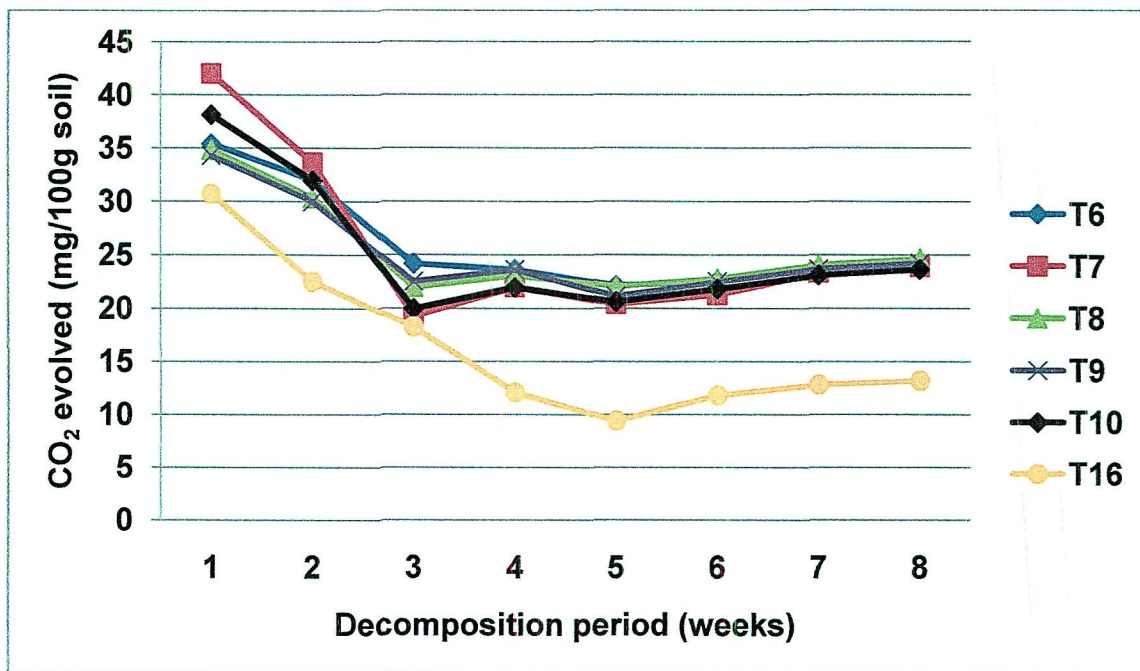


Fig 4.2 Pattern in the decomposition of soil organic matter in compost-II (fortified with 5% rock phosphate)

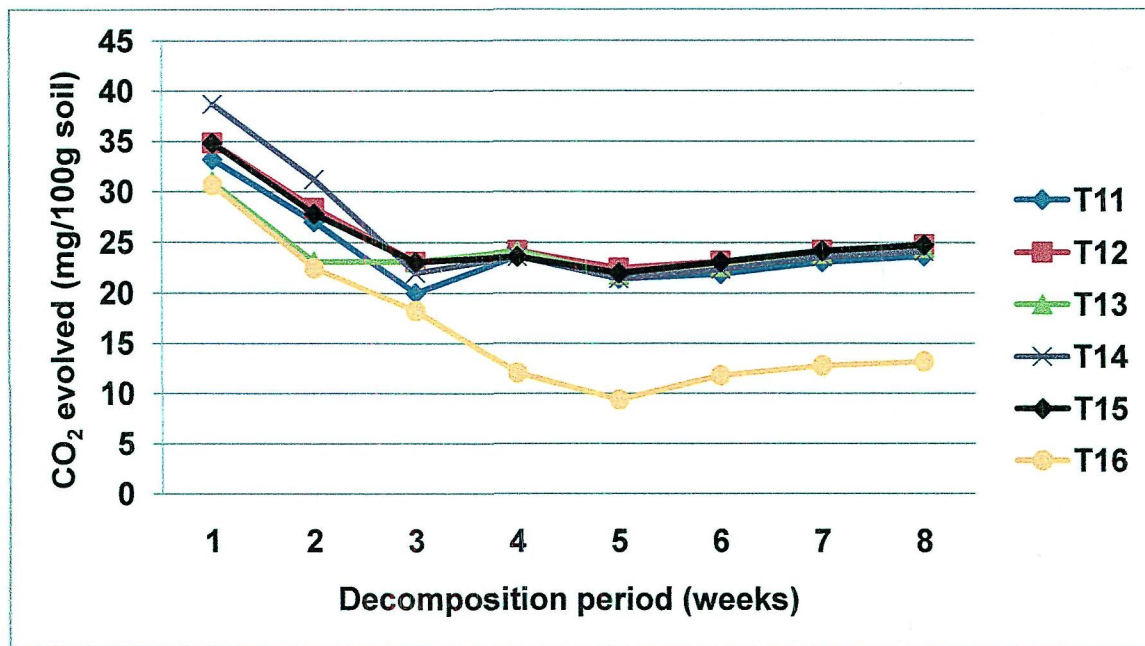


Fig 4.3 Pattern in the decomposition of soil organic matter in compost-III (fortified with 10% rock phosphate)

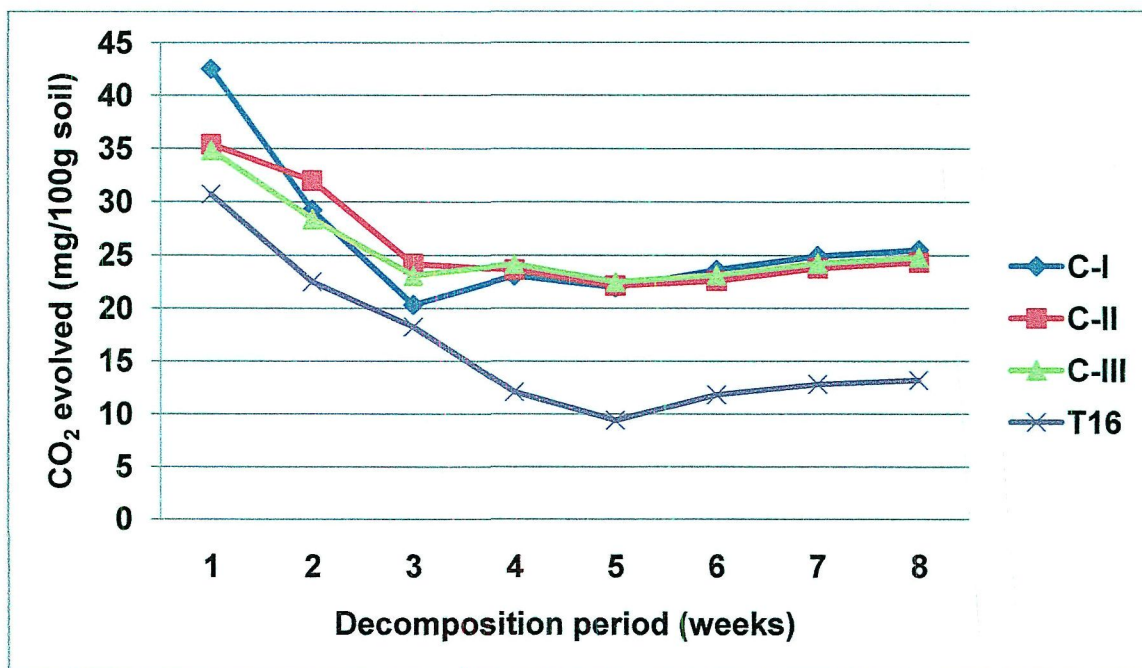


Fig 4.4 Pattern in the decomposition of soil organic matter in selected treatments

from 4th week to 8th week of incubation the CO₂ evolution was slowly increased with increase in incubation period. The secondary spurt in the CO₂ evolution may be due to the increased microbial activity during initial weeks and after the fourth week there is rapid decay of microorganisms due to shortage of food source and the microbes used the dead biomass. Similar results were reported by Kumari *et al.* (2011). Each cow urine and bioinoculants has increased the evolution of CO₂ as observed from the data of 1st week. The results corroborated with the finding of Bedi, *et al* 2009 who reported that addition of nitrogen to the compost hastened decomposition process. Details of treatments were given in page no. 37.

4.2.1.2 Mineralization of nitrogen

4.2.1.2.1 Ammonical nitrogen

The weekly data on mineralization of nitrogen in incubation period of 8 weeks are presented in Table 4.3. The mineralization of nitrogen was measured by formation of NH₄-N and described on weekly basis.

1st week: All the treatments except control were at par in NH₄-N status.

2nd week: Significantly higher amount of NH₄-N was observed in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₀) than rest of the treatments except treatment soil + compost-III + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₅) during 2nd week treatment T₁₀ was at par with treatment soil + compost-II + + 1% urea (T₆). Treatment T₁, T₅ and T₆ were at par. Treatment control (T₁₆) showed minimum NH₄-N i.e. 24.6 mg kg⁻¹.

3rd week: Maximum amount of NH₄-N was mineralized during this week in all the treatments. Comparatively, numerically highest nitrogen i.e. 42.4 mg kg⁻¹ was mineralized in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₀). Treatments *viz.* soil + compost-I + 5 ml bioinoculants + 5% cow urine + 1% urea (T₅) and soil + compost-III + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₅) were at par with treatment T₁₀. Treatment T₃ was significantly lower than rest of the treatment however significantly better than control. Treatment control (T₁₆) showed minimum NH₄-N i.e. 27.8 mg kg⁻¹.

Table 4.3: Effect of treatments on ammonical nitrogen in soil during incubation at 30°C

Treatments	NH ₄ -N (mg kg ⁻¹)							
	Incubation period (weeks)							
	1	2	3	4	5	6	7	8
T ₁	23.2	30.2	38.6	34.2	31.0	29.6	27.5	25.4
T ₂	23.1	28.8	37.2	33.6	29.7	28.2	26.1	24.0
T ₃	23.0	25.5	33.7	29.4	26.5	25.1	22.9	20.9
T ₄	23.1	27.4	36.5	32.7	29.4	27.9	25.7	23.8
T ₅	23.4	31.6	40.4	35.7	32.6	30.8	28.3	26.1
T ₆	23.5	31.9	39.8	35.6	32.2	30.8	28.5	26.7
T ₇	23.0	27.8	36.3	33.1	30.8	27.3	25.1	23.4
T ₈	23.2	29.1	38.0	34.2	30.6	29.2	26.8	25.0
T ₉	23.2	30.2	38.4	33.8	30.4	28.7	26.4	24.6
T ₁₀	23.6	33.8	42.2	38.1	36.5	34.8	32.2	30.1
T ₁₁	23.3	30.6	39.2	35.7	32.3	30.8	28.4	26.5
T ₁₂	23.0	26.9	35.4	31.5	28.1	26.5	24.2	22.2
T ₁₃	23.1	28.0	36.7	33.2	29.9	27.3	24.9	23.1
T ₁₄	23.2	29.2	38.1	34.0	30.7	29.1	26.7	24.9
T ₁₅	23.5	32.7	41.3	37.1	33.6	31.8	29.1	27.0
T ₁₆	22.1	24.6	27.8	25.3	23.8	22.3	21.1	19.3
CD (P=0.05)	0.65	1.98	2.07	1.86	1.99	1.95	2.01	1.97

4th week: Highest amount of $\text{NH}_4\text{-N}$ i.e. 38.1 mg kg^{-1} was found in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T_{10}) which was at par with T_{15} . The contents of $\text{NH}_4\text{-N}$ decreased during this week in comparison to the contents in the 3rd week. Treatment T_3 was significantly lower than rest of the treatment however significantly better than control. As expected treatment control (T_{16}) showed minimum $\text{NH}_4\text{-N}$ i.e. 25.3 mg kg^{-1} .

5th week: The contents of $\text{NH}_4\text{-N}$ decreased in the same pattern as recorded in the 4th week. Similar to the content of 4th week Treatment T_3 was significantly lower than rest of the treatment however significantly better than control. Treatment control (T_{16}) showed minimum $\text{NH}_4\text{-N}$ i.e. 23.8 mg kg^{-1} .

6th week: There was progressive decline in $\text{NH}_4\text{-N}$. Highest amount of $\text{NH}_4\text{-N}$ i.e. 34.8 mg kg^{-1} was found in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T_{10}) and it was significantly higher than all the treatments. Treatment control (T_{16}) showed minimum $\text{NH}_4\text{-N}$ i.e. 22.3 mg kg^{-1} . Treatments T_3 and T_{12} were at par.

7th week: The amount of $\text{NH}_4\text{-N}$ was higher i.e. 32.2 mg kg^{-1} in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T_{10}) and it was significantly higher than all the treatments. Treatments T_3 and T_{12} were at par however both were significantly better than control. Treatment control (T_{16}) showed minimum $\text{NH}_4\text{-N}$ i.e. 22.3 mg kg^{-1} .

8th week: Similar trends to that of 7th week in all treatments with respect to $\text{NH}_4\text{-N}$ were observed during 8th week. Control (T_{16}) showed minimum $\text{NH}_4\text{-N}$ i.e. 19.3 mg kg^{-1} .

Maximum $\text{NH}_4\text{-N}$ was determined at the end of 2nd week of incubation (Table 4.3) contrary to the CO_2 evolution activity which was maximum during the first week of incubation. This indicates that mineralization of carbon in compost precedes net mineralization of carbon in the soil. The results bring out that the level of ammonical nitrogen ($\text{NH}_4\text{-N}$) remained higher in the soil amended with organic and inorganic materials than control, during entire period of incubation because of increase in decomposition rate of organic matter by the

microorganisms. It was also correlated with the CO₂ evolution trend of the same treatment. With the increase in incubation period, the ammonical nitrogen was decreased because it gets converted into nitrate nitrogen by the activity of microorganisms. Ammonical nitrogen was also increased with the addition of urea in fortified compost. The mineralization rate was decreased after 3rd week to 8th week during incubation period. Similar results about the mineralization of nitrogen have been reported by Khind *et al.* (1987) and Heller (1999). Details of treatments were given in page no. 37.

4.2.1.2.2 Nitrate nitrogen

The trends in NO₃-N were reverse to those in NH₄-N. The weekly data on mineralized nitrate nitrogen (NO₃-N) in incubation period of 8 weeks are presented in Table 4.4. The results are described weekly basis.

1st week: All the treatments were at par but significantly better than control. Treatment control (T₁₆) showed minimum NO₃-N i.e. 13.0 mg kg⁻¹.

2nd week: The NO₃-N level increased in all the treatments in relation to that during 1st week. Highest amount of NO₃-N i.e. 20.2 mg kg⁻¹ was found in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₀) which was significantly higher than T₄. Treatments viz. soil + compost-I + 5% cow urine (T₂), soil + compost-II + 5% cow urine (T₇), soil + compost-II + 5 ml bioinoculants + 5% cow urine (T₉), soil + compost-III + 5 ml bioinoculants (T₁₃) and soil + compost-III + 5ml bioinoculants + 5% cow urine + 1% urea (T₁₅) were at par with treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₀). Treatment control (T₁₆) showed minimum NO₃-N i.e. 15.6 mg kg⁻¹.

3rd week: In comparison to with the 2nd week, a sharp increase in the level of NO₃-N was observed during this week. The contents increased from the 1st week to successive weeks of incubation and continued up to 8th week. Highest amount of NO₃-N i.e. 26.0 mg kg⁻¹ was found in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₀). The trends in this week remained similar to that on 2nd week in all treatments.

4th - 6th week: The trend was similar upto 6th week.

Table 4.4: Effect of treatments on nitrate nitrogen in soil during incubation at 30°C

Treatments	NO ₃ -N (mg kg ⁻¹)							
	Incubation period (weeks)							
	1	2	3	4	5	6	7	8
T ₁	13.4	17.4	23.4	31.5	40.1	42.3	43.4	47.7
T ₂	13.6	18.6	24.7	32.7	41.3	43.6	44.6	48.8
T ₃	13.3	16.8	22.7	31.0	39.5	41.7	42.9	47.3
T ₄	13.5	18.1	24.3	32.4	41.0	42.3	43.5	48.0
T ₅	13.3	16.0	22.1	30.2	38.9	41.2	42.5	47.1
T ₆	13.5	18.0	24.1	32.3	40.7	43.1	44.3	48.9
T ₇	13.6	18.8	24.7	32.8	41.3	43.4	44.4	49.1
T ₈	13.4	17.2	22.9	31.2	39.8	42.1	43.0	47.5
T ₉	13.7	19.6	25.9	33.9	42.2	44.5	45.7	50.1
T ₁₀	13.8	20.2	26.0	34.5	44.1	46.4	47.5	51.8
T ₁₁	13.5	17.8	23.5	31.6	40.1	42.5	43.8	48.4
T ₁₂	13.3	16.6	22.5	30.4	39.0	41.1	42.2	46.5
T ₁₃	13.7	19.4	25.6	33.9	42.6	44.9	50.0	54.3
T ₁₄	13.4	17.1	23.0	31.1	39.6	42.0	43.3	47.8
T ₁₅	13.6	18.5	24.2	32.3	40.9	43.1	44.2	48.8
T ₁₆	13.0	15.6	20.7	26.8	34.1	34.3	34.5	34.9
CD (P=0.05)	0.36	1.89	1.94	2.01	1.91	1.97	1.93	1.87

7th - 8th week: In comparison to with the 6th week, a sharp increase in the level of NO₃-N was observed during 7th and 8th week. Significantly highest amount of NO₃-N i.e. 50.0 mg kg⁻¹ and 54.3 mg kg⁻¹ were found in treatment soil + compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₃) during 7th and 8th weeks respectively. Treatment control (T₁₆) showed minimum NO₃-N in the 7th and 8th weeks i.e. 34.5 mg kg⁻¹ and 34.5 mg kg⁻¹ respectively.

The trends in the levels of NO₃-N (nitrate nitrogen) in the soil were of reverse of those in NH₄-N i.e. decreased with incubation period, the NO₃-N showed corresponding increase. This was because of the conversion of NH₄-N in quick succession at each incubation period, the preceding NO₃-N being added to the succeeding level with time. It is commonly observed that higher the nitrogen content of organic materials, more quickly they mineralize and less is the immobilization of nitrogen in soil. Same results were reported by Christensen (1986). Details of treatments were given in page no. 37.

4.2.1.3 Mineralization of phosphorus

The weekly data on mineralization of available phosphorus in incubation period of 8 weeks are presented in Table 4.5.

All the treatments differed significantly in available P status from the control during 1st week of incubation. Treatment control (T₁₆) showed minimum available phosphorus i.e. 7.5 mg kg⁻¹. Similar trend in available P status in different treatments was found during 2nd week of incubation. During 3rd week In comparison to with the 2nd week, a sharp increase in the level of available phosphorus was observed. All the treatments except soil + compost-I + 1% urea (T₁) and soil + compost-I + 5 ml bioinoculants + 5% cow urine + 1% urea (T₅) were at par with treatment soil + compost-II + 1% urea (T₆) during 3rd week.

During 4th week the available P status was at par in all the treatment except T₁ and T₄. However these treatments were significantly higher than control. During 5th week T₆ gave significantly higher available P status than T₁ and T₅. Rests of the treatments except control were at par with each other. During 6th week treatment T₃, T₆, T₈ and T₁₃ were at par but differed significantly from T₁

Table 4.5: Effect of treatments on phosphorus in soil during incubation at 30°C

Treatments	Phosphorus (mg kg ⁻¹)							
	Incubation period (weeks)							
	1	2	3	4	5	6	7	8
T ₁	9.4	13.1	14.5	15.5	16.0	16.5	17.3	18.3
T ₂	9.5	13.6	15.0	16.0	16.4	17.0	17.8	18.8
T ₃	9.6	14.0	16.5	17.4	18.3	18.6	19.2	19.8
T ₄	9.4	13.4	14.9	15.8	16.3	16.8	17.7	18.6
T ₅	9.3	12.8	14.3	15.4	16.0	16.5	17.4	18.3
T ₆	9.9	15.3	16.8	17.4	18.0	18.5	19.4	20.4
T ₇	9.7	14.4	15.8	16.9	17.4	17.9	18.6	19.6
T ₈	9.8	14.8	16.2	17.2	17.7	18.3	19.2	20.2
T ₉	9.5	13.9	15.3	16.4	16.9	17.4	18.3	19.2
T ₁₀	9.5	13.7	15.2	16.1	16.6	17.1	17.9	18.9
T ₁₁	9.6	14.1	15.5	16.4	17.0	17.5	18.4	19.3
T ₁₂	9.4	13.6	15.1	16.0	16.5	17.1	17.9	18.9
T ₁₃	9.8	14.7	16.2	17.2	17.7	18.2	19.1	20.2
T ₁₄	9.5	13.9	15.3	16.3	16.8	17.4	18.2	19.2
T ₁₅	9.7	14.5	16.0	16.9	17.5	18.1	19.0	20.0
T ₁₆	7.5	8.0	9.2	10.0	10.4	10.6	10.7	11.2
CD (P=0.05)	0.71	1.79	1.85	1.86	1.89	1.66	1.79	1.70

and T₅. However these treatments were significantly higher in available P than control. Treatment control (T₁₆) showed minimum available phosphorus i.e. 10.6 mg kg⁻¹ in the 6th week.

A sharp increase in the level of available phosphorus was observed during 7th week in comparison to with the 6th week. Highest amount of available phosphorus i.e. 19.4 mg kg⁻¹ was found in treatment soil + compost-II + 1% urea (T₆). Except treatments viz. soil + compost-I + 1% urea (T₁), soil + compost-I+ 5 ml bioinoculants + 5% cow urine (T₄) and control (T₁₆), all other treatments were at par with treatment soil + compost-II + 1% urea (T₆). In comparison to the 7th week, a sharp increase in the level of available phosphorus was observed during 8th week. Treatment T₆, T₈, T₁₃ and T₁₅ were at par but differed significantly from T₁ and T₅ during 8th week.

Available phosphorus was increased with increase in incubation period. From 1st week to 4th week it was highest where fortified compost and urea were applied, and then in 5th and 6th week it was highest where unfortified compost and bioinoculants were applied and it was again highest in 7th and 8th weeks where fortified compost and urea were applied. Details of treatments were given in page no. 37.

4.2.1.4 Mineralization of potassium

The weekly cumulative data on mineralization of available potassium in incubation period of 8 weeks are presented in Table 4.6.

All the treatments were significantly at par but better than control in available K status during 1st week of incubation. Treatment control (T₁₆) showed minimum available potassium i.e. 79.4 mg kg⁻¹. In comparison to with the 1st week, an increase in the level of available potassium except treatment control (T₁₆) was observed during 2nd week. Highest amount of available potassium i.e. 89.8 mg kg⁻¹ was found in treatment soil + compost-II + 5% cow urine (T₇) which was statistically at par with treatments viz. T₁, T₆, T₈, T₉, T₁₁ and T₁₂. Treatment control (T₁₆) showed minimum available potassium i.e. 73.2 mg kg⁻¹.

Table 4.6: Effect of treatments on potassium in soil during incubation at 30°C

Treatments	Potassium (mg kg ⁻¹)							
	Incubation period (weeks)							
	1	2	3	4	5	6	7	8
T ₁	83.2	88.1	89.5	89.9	89.1	88.2	87.0	86.3
T ₂	83.0	87.7	89.1	89.5	88.7	87.7	86.6	85.8
T ₃	82.9	86.9	88.3	88.7	87.9	86.9	85.8	85.0
T ₄	82.9	86.6	88.1	89.5	87.6	86.6	85.5	84.7
T ₅	83.1	87.3	88.7	89.0	88.2	87.3	86.2	85.4
T ₆	83.4	89.5	90.9	91.3	90.5	89.5	88.4	87.6
T ₇	83.5	89.8	91.2	91.6	90.8	89.9	88.7	87.9
T ₈	83.1	88.5	90.0	90.4	89.5	88.6	87.5	86.7
T ₉	83.2	88.8	90.2	90.6	89.8	88.8	87.5	86.9
T ₁₀	83.3	89.1	90.5	90.9	90.1	89.1	88.1	88.1
T ₁₁	83.0	87.9	89.4	89.7	88.9	87.9	86.7	85.9
T ₁₂	83.3	89.0	90.4	90.8	90.0	89.1	88.0	87.2
T ₁₃	83.2	88.4	89.9	90.2	89.4	88.3	87.2	86.4
T ₁₄	83.1	87.5	89.0	89.4	88.6	87.6	86.6	85.8
T ₁₅	83.2	88.2	89.7	90.0	89.2	88.2	87.1	86.3
T ₁₆	79.4	73.2	74.0	74.4	73.9	73.2	72.7	72.2
CD (P=0.05)	1.86	1.90	1.89	1.77	1.92	1.91	1.94	1.89

In comparison to the 2nd week, a slight increase in the level of available potassium was observed during 3rd week. Treatment control (T₁₆) showed minimum available potassium i.e. 74.0 mg kg⁻¹. There was progressive increase in each treatment while coming from 3rd to 4th and 5th weeks. A slight decrease in different treatments was observed during the subsequent 6th, 7th and 8th weeks. The available K contents were significantly higher in all treatments in comparison to control.

Available potassium was increased from 1st week to 4th week with increase in incubation period and later on it was decreased from 5th week to 8th week with increase in incubation period. Available potassium was highest where fortified compost and cow urine were applied. Details of treatments were given in page no. 37.

4.3 Growth chamber studies

4.3.1 Effect of organic, inorganic and integrated sources of nutrients on yield attributes and yield of wheat

Plant height

The data presented in Table 4.7 revealed that the maximum plant height i.e. 95.0 cm was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) and it was significantly higher than all other treatments i.e. fortified compost + 5 ml bioinoculants + 5% cow urine (T₂), fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃), unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅), unfortified compost only (T₆) and control (T₇). Minimum height i.e. 68.0 cm was recorded in the treatment control (T₇) as compared to rest of the treatments.

Number of effective tillers

Number of effective tillers was found to be non-significant.

Number of grains per ear

Maximum number of grains per ear i.e. 49 was recorded in the treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified



Plate 4.3 Experimental view of treatments at grain filling stage of wheat



Plate 4.4 Comparison of treatments at maturity of wheat

Table 4.7: Effect of different treatments on yield contributing characters of wheat

Treatments	Plant height (cm)	Number of effective tillers plant ⁻¹	Number of grains ear ⁻¹
Fortified compost + 5 ml bioinoculants (T ₁)	89.2	2	46
Fortified compost + 5 ml bioinoculants + 5% cow urine (T ₂)	88.4	3	38
Fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T ₃)	95.0	4	49
Unfortified compost + 50% recommended NPK (T ₄)	79.4	3	28
Recommended NPK (T ₅)	80.8	2	21
Unfortified compost only (T ₆)	86.4	2	25
Control [soil only] (T ₇)	68.0	2	20
CD (P= 0.05)	3.70	NS	4.73

compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment fortified compost + three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄); and recommended NPK (T₅) was the lowest i.e. 21 among these three treatments. Minimum number of grains per ear i.e. 20 was recorded in the treatment control (T₇) as compared to rest of the treatments.

The increase in height can be attributed to the continuous supply of nitrogen as both urea and phosphocompost is added. The increase in height, number of effective tillers per plant and number of grains per ear were due to combined application of chemical and organic sources. Similar results were recorded by Kumarjitsingh *et al.* (2005) in rice.

Plant biomass per plant

The data presented in Table 4.8 revealed that the maximum plant biomass per plant i.e. 6.27 g was recorded in the treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml

Table 4.8: Effect of different treatments on plant biomass, grain and straw yield

Treatments	Plant biomass plant ⁻¹ (g)	Grain yield plant ⁻¹ (g)	Straw yield plant ⁻¹ (g)
T ₁	6.20	2.74	3.45
T ₂	5.27	2.09	3.18
T ₃	6.27	3.24	3.05
T ₄	4.28	1.86	2.33
T ₅	4.06	1.42	2.64
T ₆	4.11	1.89	2.21
T ₇	2.36	1.32	1.04
CD (P= 0.05)	1.81	0.92	0.91

bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); the treatment fortified compost + 5ml bioinoculants + 5% Cow urine + 1% urea (T₃) gave the highest plant biomass per plant i.e. 6.27 g. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); the treatments recommended NPK (T₅) and unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Minimum plant biomass per plant i.e. 2.36 g was recorded in treatment control (T₇) as compared to rest of the treatments.

Grain yield

Maximum grain yield per plant i.e. 2.74 g was recorded in treatment fortified compost + 5ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment Fortified compost + 5 ml Bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) gave highest grain yield per plant i.e. 2.74 g. Among the treatments i.e. unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); the treatments unfortified compost + 50% recommended NPK (T₄) and recommended NPK (T₅) was at par with treatment unfortified compost only (T₆). Treatment recommended NPK (T₅) was gave lowest plant biomass per plant i.e. 1.42 g among these three treatments. Minimum grain yield per plant i.e. 1.32 g was recorded in treatment control (T₇) as compared to rest of the treatments. The wheat grown with the treatments compost + 5 ml bioinoculants (T₁) and compost + 5 ml bioinoculants+ 5% cow urine (T₂) matured ten days ahead of that grown with unfortified compost only (T₆) or with treatment recommended NPK (T₅). The crop status can be visualized from Plate 4.4.

Straw yield

Maximum straw yield per plant i.e. 3.45 g was recorded in treatment Fortified compost + 5 ml bioinoculants (T₁). Treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) and recommended NPK (T₅) were at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatments unfortified compost + 50% recommended NPK (T₄) and unfortified compost only (T₆) were at par with treatment recommended NPK (T₅). Minimum straw yield per plant i.e. 1.04 g was recorded in treatment control (T₇) as compared to rest of the treatments.

The highest plant biomass, grain and straw yield per plant were observed in the treatment where combined use of chemicals, organics and inoculants was done. It may be attributed to the fact that the organics, inorganics and microbial inoculants sustain optimum yields, maintain soil physical, chemical and microbiological properties which in turn make soil a better medium for plant growth. An integrated nutrient management system can be a much better approach in sustaining soil health. Similar reports are presented by Yadav and Kumar (2000) and Steffens *et al.* (1992) and Sharma *et al.* (2008).

4.3.2 Effect of organic, inorganic and integrated sources of nutrients on nutrient content, nutrient uptake and crop quality

4.3.2.1 Effect on nutrient content and quality of wheat grain

Nitrogen

The data presented in Table 4.9 revealed that maximum nitrogen content i.e. 1.38% in wheat grain was recorded in treatment unfortified compost + 50% recommended NPK (T₄). Treatment unfortified compost only

(T₆) at par with the treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) gave lowest i.e. 1.21% nitrogen content per plant among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Treatment recommended NPK (T₅) was gave lowest nitrogen content i.e. 1.19% among these three treatments. Minimum nitrogen content i.e. 1.14% was recorded in treatment control (T₇) as compared to rest of the treatments.

Phosphorus

Maximum phosphorus content i.e. 0.52% in wheat grain was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Treatment recommended NPK (T₅) was at par with the treatment fortified compost + 5ml bioinoculants + 5% cow urine (T₂). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was statistically higher than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost+ 5 ml Bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was higher i.e. 0.50% than treatment unfortified compost only (T₆) followed by treatment unfortified compost + 50% recommended NPK (T₄). Minimum phosphorus content i.e. 0.37% was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.9: Effect of different treatments on N, P, K, S contents (%) and crude protein (%) in wheat grain

Treatments	N	P	K	S	Crude Protein
T ₁	1.29	0.47	0.27	0.63	7.67
T ₂	1.25	0.52	0.32	0.60	7.37
T ₃	1.21	0.41	0.22	0.62	7.13
T ₄	1.38	0.42	0.24	0.59	8.14
T ₅	1.19	0.50	0.29	0.68	6.96
T ₆	1.35	0.45	0.26	0.65	7.96
T ₇	1.14	0.37	0.21	0.56	6.72
CD (P= 0.05)	0.04	0.03	0.03	0.04	0.04

Potassium

Maximum potassium content i.e. 0.32 % in wheat grain was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Treatment recommended NPK (T₅) was at par with the treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was higher than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and

unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment recommended NPK (T₅). Treatment unfortified compost + 50% recommended NPK (T₄) gave lowest potassium content i.e. 0.24% among these three treatments. Minimum potassium content i.e. 0.21% was recorded in treatment control (T₇) as compared to rest of the treatments.

Sulphur

Maximum sulphur content i.e. 0.68 % in wheat grain was recorded in treatment recommended NPK (T₅). Treatment unfortified compost only (T₆) was at par with treatment recommended NPK (T₅). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments i.e. unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment recommended NPK (T₅). Treatment unfortified compost + 50% recommended NPK (T₄) gave lowest sulphur content i.e. 0.59% among these three treatments. Minimum sulphur content i.e. 0.56% was recorded in treatment control (T₇) as compared to rest of the treatments.

Crude Protein

Maximum crude protein content i.e. 8.14% in wheat grain was recorded in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was statistically higher than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost +

5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was statistically higher 8.14% (crude protein) than treatment unfortified compost only (T₆) followed by treatment recommended NPK (T₅). Minimum crude protein content i.e. 6.72% was recorded in treatment control (T₇) as compared to rest of the treatments.

4.3.2.2 Effect on nutrient content and quality of wheat straw

Nitrogen

The data presented in Table 4.10 revealed that maximum nitrogen content i.e. 0.88% in wheat straw was recorded in treatment unfortified compost + 50% recommended NPK (T₄). Treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Treatment recommended NPK (T₅) gave lowest sulphur content (0.81%) among these three treatments. Minimum nitrogen content i.e. 0.72% was recorded in treatment control (T₇) as compared to rest of the treatments.

Phosphorus

Maximum phosphorus content i.e. 0.33% in wheat straw was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatments fortified compost + 5 ml bioinoculants (T₁) and recommended NPK (T₅) was at par with treatment fortified compost + 5 ml

bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) gave lowest phosphorus content i.e. 0.25% among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment recommended NPK (T₅). Minimum phosphorus content i.e. 0.27% was recorded in treatment unfortified compost + 50% recommended NPK (T₄) among these three treatments. Minimum phosphorus content i.e. 0.22% was recorded in treatment control (T₇) as compared to rest of the treatments.

Potassium

Maximum potassium content i.e. 0.50% in wheat straw was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Treatment recommended NPK (T₅) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was higher i.e. 0.50% than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment recommended NPK (T₅). Minimum potassium content i.e. 0.42% was recorded in treatment unfortified compost + 50% recommended NPK (T₄) among these three treatments. Minimum potassium content i.e. 0.29% was recorded in treatment control (T₇) while comparing to rest of the treatments.

Table 4.10: Effect of different treatments on N, P, K, S content (%) and crude protein (%) in wheat straw

Treatments	N	P	K	S	Crude Protein
T ₁	0.84	0.30	0.45	0.20	4.95
T ₂	0.83	0.33	0.50	0.18	4.89
T ₃	0.82	0.25	0.39	0.19	4.84
T ₄	0.88	0.27	0.42	0.17	5.13
T ₅	0.81	0.32	0.47	0.24	4.77
T ₆	0.85	0.28	0.44	0.22	5.01
T ₇	0.72	0.22	0.29	0.15	4.24
CD (P= 0.05)	0.03	0.04	0.04	0.04	0.03

Sulphur

Maximum sulphur content i.e. 0.24% in wheat straw was recorded in treatment recommended NPK (T₅). Treatments fortified compost + 5ml bioinoculants (T₁) and unfortified compost only (T₆) were at par with treatment recommended NPK (T₅). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) were at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment recommended NPK (T₅). Minimum sulphur content i.e. 0.17% was recorded in treatment unfortified compost + 50% recommended NPK (T₄) among these three treatments. Minimum sulphur content i.e. 0.15% was recorded in treatment control (T₇) among rest of the treatments.

Crude Protein

Maximum crude protein content i.e. 5.13% in wheat straw was recorded in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) gave higher i.e. 4.95% crude protein content than fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) gave statistically higher i.e. 5.13% protein content than treatment unfortified compost only (T₆) followed by recommended NPK (T₅). Minimum crude protein content i.e. 4.24% was recorded in treatment control (T₇) as compared to rest of the treatments.

Nitrogen content in grain and straw was highest where integrated use of organic and inorganic sources was done because both sources gave nitrogen to the soil. Addition of rock phosphate in the compost increases the nitrogen and phosphorus content of compost due to this reason N and P content was higher where rock phosphate was used. Similar results were reported by Rasal *et al.* (2002). Potassium content was higher where fortified compost and bioinoculants were applied might be because of microbial action it was easily taken up by the plants. With increase in rates of N and P fertilizers through urea and SSP, respectively, there was an increase in S supply and hence the S content in wheat grain was increased. Setia and Sharma (2004) also reported that the combined effect of N and P significantly increased the S contents in the plants. Nitrogen content was highest where integrated use of organic and inorganic sources was done due to this reason protein content was also highest in this treatment because N content of plant is directly related with protein content of plant. Similar results were reported by Behera *et al.* (2007).

4.3.2.3 Effect on nutrient uptake by wheat grain

Nitrogen

The data presented in Table 4.11 revealed that maximum nitrogen uptake i.e. 38.72 mg plant⁻¹ by wheat grain was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was significantly higher than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Minimum nitrogen uptake i.e. 16.76% was recorded in treatment recommended NPK (T₅) among these three treatments. Minimum nitrogen uptake i.e. 14.82 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.11: Effect of different treatments on N, P, K and S uptake (mg plant⁻¹) by wheat grain

Treatments	N	P	K	S
T ₁	35.62	12.88	7.39	17.26
T ₂	26.12	10.87	6.48	12.54
T ₃	38.72	13.12	7.04	19.52
T ₄	25.67	7.81	4.46	10.97
T ₅	16.76	7.10	4.12	9.66
T ₆	25.51	8.50	4.91	12.28
T ₇	14.82	4.81	2.60	7.28
CD (P= 0.05)	1.96	1.78	1.80	1.97

Phosphorus

Maximum phosphorus uptake i.e. 13.12 mg plant⁻¹ by wheat grain was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment fortified compost + 5 ml bioinoculants (T₁) was at par with the treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Minimum phosphorus uptake i.e. 10.87% was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatments unfortified compost + 50% recommended NPK (T₄) and recommended NPK (T₅) were at par with treatment unfortified compost only (T₆). Minimum phosphorus uptake i.e. 4.81 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Potassium

Maximum potassium uptake i.e. 7.39 mg plant⁻¹ by wheat grain was recorded in treatment fortified compost + 5 ml bioinoculants (T₁). Treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) were at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) were at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only

(T₆); treatments unfortified compost + 50% recommended NPK (T₄) and recommended NPK (T₅) were at par with treatment unfortified compost only (T₆). Minimum potassium uptake i.e. 2.60 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Sulphur

Maximum sulphur uptake i.e. 19.52 mg plant⁻¹ by wheat grain was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was significantly higher i.e. 19.52 mg plant⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was at par with treatment unfortified compost only (T₆). Minimum sulphur uptake i.e. 9.66% was recorded in treatment recommended NPK (T₅) among these three treatments. Minimum sulphur uptake i.e. 7.28 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

The uptake of N, P, K and S were higher by wheat grain due to the highest grain yield and nutrient concentration. The nitrogen uptake was also increased due to the addition of urea. Uptake of N, P, K and S increased with the addition of organic and inorganic fertilizers in soil. Similar results were reported by Pandey *et al.* (2009) and Vyas *et al.* (1997). Uptake of P is synergistic to uptake of N and higher uptake could be due to solubilization effect of organic acids produced during decomposition of compost, improved aeration and better root proliferation. The maximum values of uptake under phosphocompost treatment could be due to improved inherent nutrient supplying capacity of materials, complexing of nutrients particularly micronutrients. The total uptake of these nutrients by plant is the combined effect of higher nutrient content in plant as well as total yield.

4.3.2.4 Effect on nutrient uptake by wheat straw

Nitrogen

The data presented in Table 4.12 revealed that maximum nitrogen uptake i.e. 28.98 mg plant⁻¹ by wheat straw was recorded in treatment fortified compost + 5 ml bioinoculants (T₁) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was significantly higher i.e. 28.98 mg plant⁻¹ than the treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was higher i.e. 21.38 mg plant⁻¹ than treatment unfortified compost + 50% recommended NPK (T₄) followed by treatment unfortified compost only (T₆). Minimum nitrogen uptake i.e. 7.56 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Phosphorus

Maximum phosphorus uptake i.e. 10.49 mg plant⁻¹ by wheat straw was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Minimum phosphorus uptake i.e. 7.55% was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) among these three treatments. Among the treatments unfortified

compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was higher i.e. 8.18% than treatment unfortified compost only (T₆) followed by treatment unfortified compost + 50% recommended NPK (T₄). Minimum phosphorus uptake i.e. 2.20 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.12: Effect of different treatments on N, P, K and S uptake (mg plant⁻¹) by wheat straw

Treatments	N	P	K	S
T ₁	28.98	10.35	33.46	6.90
T ₂	26.39	10.49	32.75	5.72
T ₃	24.76	7.55	26.87	5.74
T ₄	19.49	6.04	21.06	3.81
T ₅	21.38	8.18	26.13	6.34
T ₆	18.78	6.18	21.21	4.86
T ₇	7.56	2.20	8.40	1.57
CD (P= 0.05)	1.72	1.79	1.83	1.99

Potassium

Maximum potassium uptake i.e. 33.46 mg plant⁻¹ by wheat straw was recorded in treatment fortified compost + 5 ml bioinoculants (T₁). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with the treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost +

5 ml bioinoculants + 5% cow urine (T₂) was at par with the treatment fortified compost + 5 ml bioinoculants (T₁). Minimum potassium uptake i.e. 26.87% was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was statistically higher i.e. 26.13% than treatment unfortified compost only (T₆) followed by treatment unfortified compost + 50% recommended NPK (T₄). Minimum potassium uptake i.e. 8.40 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Sulphur

Maximum sulphur uptake i.e. 6.90 mg plant⁻¹ by wheat straw was recorded in treatment fortified compost + 5 ml bioinoculants (T₁). Treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂), fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) and recommended NPK (T₅) were at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) were at par with treatment fortified compost + 5 ml Bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) were at par with treatment recommended NPK (T₅). Minimum sulphur uptake i.e. 3.81% was recorded in treatment unfortified compost + 50% recommended NPK (T₄) among these three treatments. Minimum sulphur uptake i.e. 1.57 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

The uptake of N, P, K and S were higher by wheat straw due to the highest straw yield and nutrient concentration. Addition of fortified compost in the soil increased the nitrogen and phosphorus uptake by plants. Similar results were

reported by Manna *et al.* (2003). K content was higher where fortified compost and bioinoculants were applied because of microbial action it was easily taken up by the plants. Sulphur content was also highest where fortified compost and bioinoculants were applied.

4.3.2.5 Effect on total nutrient uptake by wheat plant (grain + straw)

Nitrogen

The data presented in Table 4.13 revealed that maximum nitrogen uptake i.e. 64.16 mg plant⁻¹ by wheat plant (grain + straw) was recorded in treatment fortified compost + 5 ml bioinoculants (T₁). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with the treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with the treatment fortified compost + 5 ml bioinoculants (T₁). Minimum nitrogen uptake i.e. 52.81% was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Minimum nitrogen uptake i.e. 38.14% was recorded in treatment recommended NPK (T₅) among these three treatments. Minimum nitrogen uptake i.e. 22.38 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Phosphorus

Maximum phosphorus uptake i.e. 23.23 mg plant⁻¹ by wheat plant (grain + straw) was recorded in treatment fortified compost + 5 ml bioinoculants (T₁). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5ml bioinoculants (T₁). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants

(T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Minimum phosphorus uptake i.e. 20.67% was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment recommended NPK (T₅). Treatment unfortified compost + 50% recommended NPK (T₄) gave minimum phosphorus uptake i.e. 13.85 mg plant⁻¹ among these three treatments. Minimum phosphorus uptake i.e. 7.01 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.13: Effect of different treatments on total N, P, K and S uptake (mg plant⁻¹) by wheat plant (grain + straw)

Treatments	N	P	K	S
T ₁	64.16	23.23	40.85	24.16
T ₂	52.81	21.36	39.23	18.26
T ₃	63.48	20.67	33.91	25.28
T ₄	45.16	13.85	25.52	14.78
T ₅	38.14	15.28	30.25	16.00
T ₆	44.29	14.68	26.12	17.14
T ₇	22.38	7.01	11.00	8.85
CD (P= 0.05)	1.75	2.00	1.78	1.91

Potassium

Maximum potassium uptake i.e. 40.85 mg plant⁻¹ by wheat plant (grain + straw) was recorded in treatment fortified compost + 5 ml bioinoculants (T₁). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments

in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Minimum potassium uptake content i.e. 33.31% was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) at par with treatment recommended NPK (T₅). Treatment unfortified compost + 50% recommended NPK (T₄) gave minimum potassium uptake i.e. 25.52 mg plant⁻¹ among these three treatments. Minimum potassium uptake i.e. 11.00 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

Sulphur

Maximum sulphur uptake i.e. 25.28 mg plant⁻¹ by wheat plant (grain + straw) was recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) gave minimum sulphur uptake i.e. 18.26 mg plant⁻¹ among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was at par with treatment unfortified compost only (T₆). Treatment unfortified compost + 50% recommended NPK (T₄) gave minimum sulphur uptake i.e. 14.78 mg plant⁻¹ among these three treatments. Minimum sulphur uptake i.e. 8.85 mg plant⁻¹ was recorded in treatment control (T₇) as compared to rest of the treatments.

The uptake of N, P, K and S were higher by wheat plant (grain + straw) due to the highest grain and straw yield and nutrient concentration. The total uptake of these nutrients by plant is the combined effect of higher nutrient content in plant as well as total yield. Addition of compost in the soil increased the nitrogen and phosphorus uptake by plants. Similar results were reported by Manna *et al.* (2003). Potassium content was higher where fortified compost and bioinoculants were applied may be because of microbial action in soil it was easily taken up by the plants. Integrated use of organic and inorganic fertilizers increases the S uptake by plant because they get S from both the sources.

4.3.3 Effect of organic, inorganic and integrated sources of nutrients on chemical properties of soil at different growth stages of wheat

4.3.3.1 Available nitrogen

The data presented in Table 4.14 revealed that the available nitrogen at CRI stage (25 DAS) was maximum i.e. 154.1 mg kg⁻¹ in treatment recommended NPK (T₅). Treatment fortified compost + 5ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with treatment recommended NPK (T₅). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment fortified compost + 5 ml bioinoculants (T₁) gave lowest i.e. 145.2 mg kg⁻¹ available nitrogen among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was statistically higher i.e. 154.1 mg kg⁻¹ than treatment unfortified compost only (T₆) followed by treatment unfortified compost + 50% recommended NPK (T₄). Minimum available nitrogen i.e. 140.8 mg kg⁻¹ at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.14: Effect of different treatments on available nitrogen content of soil at different stages of wheat growth

Treatments	Available nitrogen (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	142.2	142.9	140.4
T ₂	147.5	143.9	145.4
T ₃	152.0	145.7	147.4
T ₄	143.0	141.6	138.6
T ₅	154.1	148.5	146.6
T ₆	143.8	140.9	139.1
T ₇	140.8	138.5	132.0
CD (P= 0.05)	5.71	5.78	4.64
Initial soil	138.5	-	-

Available nitrogen at grain filling stage (85 DAS) was maximum i.e. 148.5 mg kg⁻¹ in treatment recommended NPK (T₅). Treatments fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5ml bioinoculants + 5% cow urine + 1% urea (T₃) were at par with treatment recommended NPK (T₅). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) were at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was statistically higher i.e. 148.5 mg kg⁻¹ than treatment

unfortified compost + 50% recommended NPK (T₄) followed by treatment unfortified compost only (T₆). Minimum available nitrogen i.e. 138.5 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Available nitrogen after harvest was maximum i.e. 147.4 mg kg⁻¹ in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and recommended NPK (T₅) were at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Treatment fortified compost + 5 ml bioinoculants (T₁) gave lowest i.e. 140.4 mg kg⁻¹ available nitrogen among these three treatments. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was statistically higher i.e. 146.6 mg kg⁻¹ than treatment unfortified compost only (T₆) followed by treatment Unfortified compost + 50% recommended NPK (T₄). Minimum available nitrogen i.e. 132.0 mg kg⁻¹ after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

The application of recommended dose of NPK increased the available N in soil at CRI stage. At grain filling stage application of recommended dose of fertilizer increased the available N due to slow or less mineralization. The application of fortified compost increased the available nitrogen content in the soil over the recommended dose of fertilizers. Also compost along with other organic and inorganic fertilizers might have helped in improvement of nitrogen fixation. The nitrogen was slowly released by the composts which increased its content in the soil. Also addition of larger biomass to soil provided opportunity to free living organisms to fix atmospheric nitrogen. Similar results were reported by Dinesh and Dubey (1999).

4.3.3.2 Available phosphorus

The data presented in Table 4.15 revealed that the available phosphorus at CRI stage (25 DAS) was maximum i.e. 14.0 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄). Treatments recommended NPK (T₅) and unfortified compost only (T₆) were at par with treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) were at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% Urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatments recommended NPK (T₅) and Unfortified compost only (T₆) were at par with treatment unfortified compost + 50% recommended NPK (T₄). Minimum available phosphorus i.e. 8.6 mg kg⁻¹ at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.15: Effect of different treatments on available phosphorus content of soil at different stages of wheat growth

Treatments	Available phosphorus (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	10.5	6.9	6.1
T ₂	11.5	7.5	6.3
T ₃	11.6	7.9	6.7
T ₄	14.0	12.3	11.3
T ₅	13.7	11.8	11.0
T ₆	12.6	9.6	8.7
T ₇	8.6	6.6	5.6
CD (P= 0.05)	2.09	2.13	2.18
Initial soil	8.3	-	-

Available phosphorus at grain filling stage (85 DAS) was maximum i.e. 12.3 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄). Treatment recommended NPK (T₅) was at par with treatment treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) were at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was at par with treatment treatment unfortified compost + 50% recommended NPK (T₄). Treatment unfortified compost only (T₆) has minimum available phosphorus i.e. 9.6 mg plant⁻¹ among these three treatments. Minimum available phosphorus i.e. 8.6 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of treatments.

Available phosphorus after harvest was maximum i.e. 11.3 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄). Treatment recommended NPK (T₅) was at par with treatment treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) were at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% Urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment recommended NPK (T₅) was at par with treatment treatment unfortified compost + 50% recommended NPK (T₄). Treatment unfortified compost only (T₆) has minimum available phosphorus i.e. 8.7 mg plant⁻¹ among these three treatments. Minimum available phosphorus i.e. 5.6 mg kg⁻¹ after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Integrated nutrient management practices found to be significantly superior than inorganic treatment. On decomposition of organic matter by various microorganisms, the organic phosphorus is converted slowly to inorganic form. Anwar *et al.* (2005) also reported higher values of available P in the pots receiving organic manures in addition to mineral fertilizer compared to those pots treated with chemical fertilizers alone.

4.3.3.3 Available potassium

The data presented in Table 4.16 revealed that the available potassium at CRI stage (25 DAS) was maximum i.e. 96.5 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄). Treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) were at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Treatment recommended NPK (T₅) has minimum available potassium i.e. 85.8 mg kg⁻¹ among these three treatments. Minimum available potassium i.e. 75.0 mg kg⁻¹ at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Available potassium at grain filling stage (85 DAS) was maximum i.e. 93.8 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄). Treatment Unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost +

5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) were at par with fortified compost + 5 ml bioinoculants + 5% cow urine + 1% Urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄). Treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Treatment recommended NPK (T₅) has minimum available potassium i.e. 81.2 mg kg⁻¹ among these three treatments. Minimum available potassium i.e. 69.0 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.16: Effect of different treatments on available potassium content of soil at different stages of wheat growth

Treatments	Available potassium (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	83.9	78.0	76.6
T ₂	84.4	77.0	76.1
T ₃	85.1	79.1	78.3
T ₄	96.5	93.8	92.2
T ₅	85.8	81.2	80.3
T ₆	94.8	92.6	88.8
T ₇	75.0	69.0	68.3
CD (P= 0.05)	3.71	3.85	3.66
Initial soil	74.5	-	-

Available potassium after harvest was maximum i.e. 92.2 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄). Treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50%

recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) were at par with fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Treatment recommended NPK (T₅) has minimum available potassium i.e. 80.3 mg kg⁻¹ among these three treatments. Minimum available potassium i.e. 68.3 mg kg⁻¹ after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Application of fortified compost increased the available potassium content of soil. Similar were reported by Chettri *et al.* (2004). Likewise significant improvement in fertility status of the soils due to the addition of FYM or crop residues has also been reported by Roy *et al.* (2001).

4.3.3.4 Available sulphur

The data presented in Table 4.17 revealed that available sulphur at CRI stage (25 DAS) was maximum i.e. 20.2 mg kg⁻¹ in treatment recommended NPK (T₅). Treatments fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) and unfortified compost + 50% recommended NPK (T₄) were at par with treatment recommended NPK (T₅). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 18.1 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified

compost + 50% recommended NPK (T₄) was at par with treatment recommended NPK (T₅). Treatment unfortified compost only (T₆) has minimum available sulphur i.e. 15.5 mg plant⁻¹ among these three treatments. Minimum available sulphur i.e. 12.6 mg kg⁻¹ at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.17: Effect of different treatments on available sulphur content of soil at different stages of wheat growth

Treatments	Available sulphur (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	14.4	12.2	10.9
T ₂	13.7	12.9	11.7
T ₃	18.1	13.2	12.8
T ₄	18.8	14.5	14.3
T ₅	20.2	15.7	14.7
T ₆	15.5	14.9	13.2
T ₇	12.6	12.9	11.8
CD (P= 0.05)	3.63	2.34	2.15
Initial soil	12.4	-	-

Available sulphur at grain filling stage (85 DAS) was maximum i.e. 15.7 mg kg⁻¹ in treatment recommended NPK (T₅). Treatments unfortified compost + 50% recommended NPK (T₄) and Unfortified compost only (T₆) were at par with treatment recommended NPK (T₅). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml

bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatments unfortified compost + 50% recommended NPK (T₄) and unfortified compost only (T₆) were at par with treatment recommended NPK (T₅). Minimum available sulphur i.e. 12.4 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Available sulphur after harvest was maximum i.e. 14.7 mg kg⁻¹ in treatment recommended NPK (T₅). Treatments fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃), unfortified compost + 50% recommended NPK (T₄) and Unfortified compost only (T₆) were at par with treatment recommended NPK (T₅). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatments fortified compost + 5 ml bioinoculants (T₁) and fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatments unfortified compost + 50% recommended NPK (T₄) and unfortified compost only (T₆) were at par with treatment recommended NPK (T₅). Minimum available sulphur i.e. 11.8 mg kg⁻¹ after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Addition of N fertilizers resulted in significant increase in available sulphur as compared to control. The increase in available sulphur may be due to the synergistic effect of N and S. Chaube and Dwivedi (1995) reported positive interaction between N and S. Addition of organic and inorganic fertilizers also significantly increased the available sulphur in the soil. Similar results were reported by Sharma *et al.* (2000).

4.3.3.5 Total nitrogen

The data presented in Table 4.18 revealed that total nitrogen at CRI stage (25 DAS) was the maximum i.e. 632.3 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 607.7 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher i.e. 632.3 mg kg⁻¹ than treatment recommended NPK (T₅) followed by unfortified compost only (T₆). Minimum available nitrogen i.e. 517.9 mg kg⁻¹ at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.18: Effect of different treatments on total nitrogen content of soil at different stages of wheat growth

Treatments	Total nitrogen (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	592.1	563.6	561.0
T ₂	585.8	557.4	554.6
T ₃	607.7	581.1	578.9
T ₄	632.3	602.0	599.2
T ₅	623.5	575.1	571.9
T ₆	580.0	553.6	529.1
T ₇	517.9	492.7	491.2
CD (P= 0.05)	5.72	5.91	5.67
Initial soil	516.4	-	-

Total nitrogen at grain filling stage (85 DAS) was maximum i.e. 602.0 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 607.7 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total nitrogen i.e. 492.7 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Total nitrogen after harvest was maximum i.e. 599.2 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 607.7 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment Unfortified compost + 50% recommended NPK (T₄) was significantly higher i.e. 599.2 mg kg⁻¹ than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total nitrogen i.e. 491.2 mg kg⁻¹ after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Integrated use of organic and inorganic fertilizers gave highest amount of total nitrogen in soil because both the sources have contributed to total nitrogen in the soil. Microorganisms present in compost might have converted unavailable form of nitrogen to available form of nitrogen and inorganic fertilizers also gave nitrogen to the soil due to this reason total nitrogen was higher where integrated use of organic and inorganic materials was done. It might be attributed to the fact that the application of organic and inorganics increase organic form of nutrients in soil and increase the activity of microbes. Similar results reported by Bedi and Dubey (2009).

4.3.3.6 Total phosphorus

The data presented in Table 4.19 revealed that the total phosphorus at CRI stage (25 DAS) was maximum i.e. 134.3 mg kg^{-1} in treatment unfortified compost + 50% recommended NPK (T_4) it was significantly higher i.e. 134.3 mg kg^{-1} than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3) was statistically higher i.e. 104.5 mg kg^{-1} than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) followed by treatment fortified compost + 5 ml bioinoculants (T_1). Among the treatments unfortified compost + 50% recommended NPK (T_4), recommended NPK (T_5) and unfortified compost only (T_6); treatment unfortified compost + 50% recommended NPK (T_4) was significantly higher i.e. 134.3 mg kg^{-1} than treatment recommended NPK (T_5) followed by treatment unfortified compost only (T_6). Minimum total phosphorus i.e. 134.3 mg kg^{-1} at CRI stage was recorded in treatment control (T_7) as compared to rest of the treatments.

Total phosphorus at grain filling stage (85 DAS) was maximum i.e. 129.6 mg kg^{-1} in treatment unfortified compost + 50% recommended NPK (T_4) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost +

5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 97.2 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher i.e. 129.6 mg kg⁻¹ than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total phosphorus i.e. 85.7 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.19: Effect of different treatments on total phosphorus content of soil at different stages of wheat growth

Treatments	Total phosphorus (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	98.7	90.7	89.1
T ₂	99.7	93.9	92.1
T ₃	104.5	97.2	95.6
T ₄	134.3	129.6	128.0
T ₅	127.1	124.1	122.5
T ₆	106.6	102.0	100.7
T ₇	89.5	85.7	84.4
CD (P= 0.05)	3.98	3.84	3.93
Initial soil	88.6	-	-

Total phosphorus after harvest was maximum i.e. 128.0 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost +

5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 95.6 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher i.e. 128.0 mg kg⁻¹ than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total phosphorus i.e. 84.4 mg kg⁻¹ after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Integrated use of organic and inorganic fertilizers gave highest amount of total phosphorus in soil. It might be attributed to the fact that the application of organic and inorganics increase organic form of nutrients in soil and increase the activity of microbes. Similar results reported by Bedi and Dubey (2009).

4.3.3.7 Total potassium

The data presented in Table 4.20 revealed that the total potassium at CRI stage (25 DAS) was maximum i.e. 1434.9 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 1273.4 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total potassium i.e. 990.4 mg kg⁻¹ at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.20: Effect of different treatments on total potassium content of soil at different stages of wheat growth

Treatments	Total potassium (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	1189.7	1185.4	1183.9
T ₂	1092.1	1087.6	1086.2
T ₃	1273.4	1268.7	1267.5
T ₄	1434.9	1431.2	1430.1
T ₅	1417.0	1413.5	1412.1
T ₆	1315.3	1312.3	1311.0
T ₇	990.4	987.9	986.6
CD (P= 0.05)	8.76	9.12	7.01
Initial soil	989.5	-	-

Total potassium at grain filling stage (85 DAS) was maximum i.e. 1431.2 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 1268.7 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher than treatment

recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total potassium i.e. 987.9 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Total potassium after harvest was maximum i.e. 1430.1 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 1267.5 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants (T₁) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total potassium i.e. 986.6 mg kg⁻¹ after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Application of fortified compost increased the total potassium content of soil. Similar findings were reported by Chettri *et al.* (2004). Likewise significant improvements in fertility status of the soils due to the addition of FYM or crop residues have also been reported by Roy *et al.* (2001).

4.3.3.8 Total sulphur

The data presented in Table 4.21 revealed that the total sulphur at CRI stage (25 DAS) was maximum i.e. 255.3 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine

+ 1% urea (T₃) was statistically higher i.e. 95.6 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher i.e. 255.3 mg kg⁻¹ than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total sulphur i.e. 180.6 mg kg⁻¹ at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.21: Effect of different treatments on total sulphur content of soil at different stages of wheat growth

Treatments	Total potassium (mg kg ⁻¹)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	192.4	182.7	180.2
T ₂	198.7	190.2	188.1
T ₃	201.7	193.6	191.6
T ₄	255.3	248.0	245.9
T ₅	231.8	225.7	223.1
T ₆	217.2	210.4	208.6
T ₇	180.6	175.4	172.8
CD (P= 0.05)	4.83	4.66	5.02
Initial soil	179.3	-	-

Total sulphur at grain filling stage (85 DAS) was maximum i.e. 248.0 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost +

5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 196.6 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and Unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher i.e. 248.0 mg kg⁻¹ than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total sulphur i.e. 175.4 mg kg⁻¹ at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Total sulphur after harvest was maximum i.e. 245.9 mg kg⁻¹ in treatment unfortified compost + 50% recommended NPK (T₄) and it was significantly higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 191.6 mg kg⁻¹ than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was significantly higher i.e. 245.9 mg kg⁻¹ than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum total sulphur i.e. 172.8 mg kg⁻¹ at after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Integrated use of organic and inorganic fertilizers gave highest amount of total sulphur in soil than control because more availability of sulphur from both the nutrient sources. Similar results were reported by Basumatary and Talukdar (1999).

4.3.4 Effect of organic, inorganic and integrated sources of nutrients on the microbiological properties of soil at different growth stages of wheat

4.2.4.1 Total microbial count

Bacterial population

The data presented in Table 4.22 revealed that the bacterial population at CRI stage (25 DAS) was maximum i.e. 27.6×10^5 cfu g^{-1} soil in treatment fortified compost + 5 ml bioinoculants (T_1) and it was statistically higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3); treatment fortified compost + 5 ml bioinoculants (T_1) was statistically higher i.e. 27.6×10^5 cfu g^{-1} soil than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3). Among the treatments unfortified compost + 50% recommended NPK (T_4), recommended NPK (T_5) and unfortified compost only (T_6); treatment unfortified compost + 50% recommended NPK (T_4) was statistically higher i.e. 24.3×10^5 cfu g^{-1} soil than treatment unfortified compost only (T_6) followed by treatment recommended NPK (T_5). Minimum bacterial population i.e. 20.5×10^5 cfu g^{-1} soil at CRI stage was recorded in treatment control (T_7) as compared to rest of the treatments.

Bacterial population at grain filling stage (85 DAS) was maximum i.e. 5.8×10^5 cfu g^{-1} soil in treatment fortified compost + 5 ml bioinoculants (T_1). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) was at par with treatment fortified compost + 5 ml bioinoculants (T_1). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) was at par with treatment fortified compost + 5 ml bioinoculants (T_1). Among these three treatments, treatment

fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) gave minimum bacterial population i.e. 4.7×10^5 cfu g⁻¹ soil. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among these three treatments, treatment recommended NPK (T₅) gave minimum bacterial population i.e. 3.9×10^5 cfu g⁻¹ soil. Minimum bacterial population i.e. 3.0×10^5 cfu g⁻¹ soil at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.22 : Effect of different treatments on bacterial population of soil at different stages of wheat growth

Treatments	Bacteria ($\times 10^5$ cfu g ⁻¹ soil)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	27.6	5.8	5.4
T ₂	26.3	5.5	5.2
T ₃	25.9	4.7	4.5
T ₄	24.3	4.4	4.2
T ₅	22.9	3.9	3.5
T ₆	23.7	4.2	4.0
T ₇	20.5	3.0	2.6
CD (P= 0.05)	0.43	0.34	0.36
Initial soil	18.9	-	-



Plate 4.5 Bacterial count in soil at crown root initiation (CRI) stage of wheat

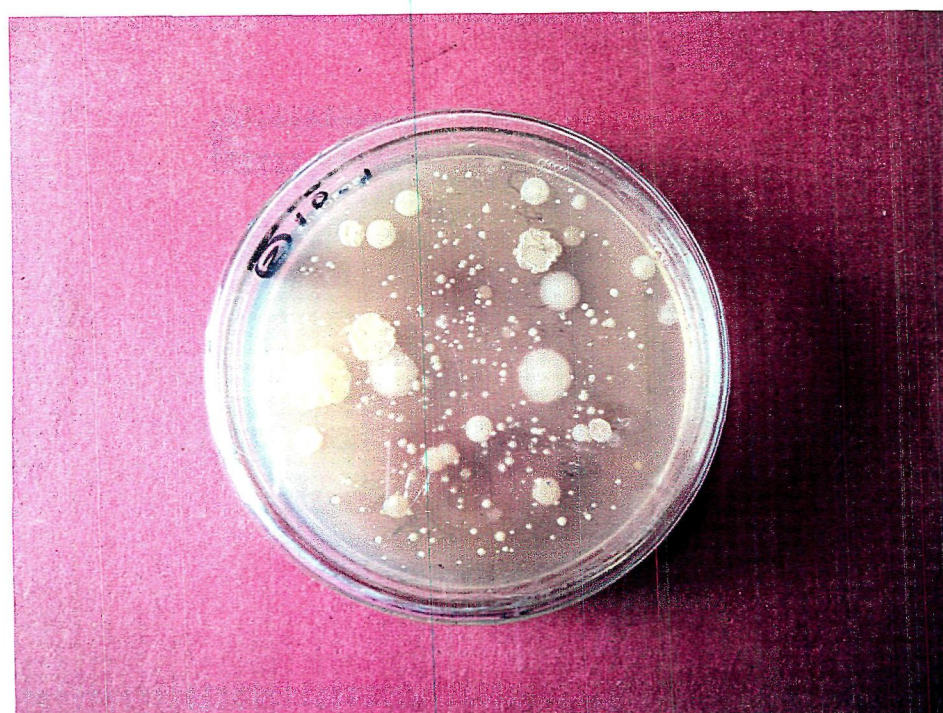


Plate 4.6 Bacterial count in soil at grain filling stage of wheat

Bacterial population after harvest was maximum i.e. 5.4×10^5 cfu g⁻¹ soil in treatment fortified compost + 5 ml bioinoculants (T₁). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost + 5 ml bioinoculants (T₁). Among these three treatments, treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) gave minimum bacterial population i.e. 4.5×10^5 cfu g⁻¹ soil. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among these three treatments, treatment recommended NPK (T₅) gave minimum bacterial population i.e. 3.5×10^5 cfu g⁻¹ soil. Minimum bacterial population i.e. 32.6×10^5 cfu g⁻¹ soil after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

The fortified compost contains higher count of bacteria which would have increased bacterial population in soil. It might be due fact that proper and continuous mineralization of nutrients from organic to inorganic pool resulted in maintaining the continuous supply of food as well as energy for the growth of microorganisms. Similar results were reported by Bedi (2004) and due to microbiological changes during decomposition of organic matter in the soil brought the highest proliferation of bacteria in soil. Similar results were reported by Mukherjee *et al.* (1999).

Fungal population

The data presented in Table 4.23 revealed that the fungal population at CRI stage (25 DAS) was maximum i.e. 18.4×10^3 cfu g⁻¹ soil in treatment fortified compost + 5 ml bioinoculants (T₁). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment fortified compost +

5 ml bioinoculants (T_1). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3); treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) was at par with treatment fortified compost + 5 ml bioinoculants (T_1). Among these three treatments, treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3) gave minimum fungal population i.e. 17.0×10^3 cfu g^{-1} soil. Among the treatments unfortified compost + 50% recommended NPK (T_4), recommended NPK (T_5) and unfortified compost only (T_6); treatment Unfortified compost only (T_6) was at par with treatment unfortified compost + 50% recommended NPK (T_4). Among these three treatments, treatment recommended NPK (T_5) gave minimum fungal population i.e. 15.5×10^3 cfu g^{-1} soil. Minimum bacterial population i.e. 14.3×10^3 cfu g^{-1} soil at CRI stage was recorded in treatment control (T_7) as compared to rest of the treatments.

Table 4.23: Effect of different treatments on fungal population of soil at different stages of wheat growth

Treatments	Fungi ($\times 10^3$ cfu g^{-1} soil)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T_1	18.4	5.8	5.6
T_2	17.9	5.2	5.1
T_3	17.0	4.9	4.7
T_4	16.8	4.7	4.6
T_5	15.5	3.3	3.2
T_6	16.4	4.6	4.3
T_7	14.3	2.6	2.5
CD (P= 0.05)	0.41	0.35	0.32
Initial soil	12.9	-	-



Plate 4.7 Fungal count in soil at crown root initiation (CRI) stage of wheat



Plate 4.8 Fungal count in soil at grain filling stage of wheat

Fungal population at grain filling stage (85 DAS) was maximum i.e. 5.8×10^3 cfu g⁻¹ soil in treatment fortified compost + 5 ml bioinoculants (T₁) and it was statistically higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was statistically higher i.e. 5.8×10^3 cfu g⁻¹ soil than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among these three treatments, treatment recommended NPK (T₅) gave minimum fungal population i.e. 3.3×10^3 cfu g⁻¹ soil. Minimum fungal population i.e. 2.6×10^3 cfu g⁻¹ soil at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Fungal population after harvest was maximum i.e. 5.6×10^3 cfu g⁻¹ soil in treatment fortified compost + 5 ml bioinoculants (T₁) and it was statistically higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was statistically higher i.e. 5.6×10^3 cfu g⁻¹ soil than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments Unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among these three treatments, treatment recommended NPK (T₅) gave minimum fungal population i.e. 3.2×10^3 cfu g⁻¹ soil. Minimum fungal population i.e. 2.5×10^3 cfu g⁻¹ soil after harvest stage was recorded in treatment control (T₇) as compared to rest of the treatments.

The fortified compost contains higher count of fungi which would have increased fungal population in soil. Due to microbiological changes during decomposition of organic matter in the soil brought the highest proliferation of fungi in soil. Similar results were reported by Mukherjee *et al.* (1999).

Actinomycetes population

The data presented in Table 4.24 revealed that the actinomycetes population at CRI stage (25 DAS) was maximum i.e. 43×10^4 cfu g⁻¹ soil in treatment fortified compost + 5 ml bioinoculants (T₁) and it was statistically higher than treatment all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was statistically higher i.e. 43×10^4 cfu g⁻¹ soil than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was statistically higher i.e. 34×10^4 cfu g⁻¹ soil than treatment unfortified compost + 50% recommended NPK (T₄) followed by treatment recommended NPK (T₅). Minimum actinomycetes population i.e. 22×10^4 cfu g⁻¹ soil at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Actinomycetes population at grain filling stage (85 DAS) was maximum i.e. 58×10^4 cfu g⁻¹ soil in treatment fortified compost + 5 ml bioinoculants (T₁) and it was statistically higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants (T₁) was statistically higher i.e. 58×10^4 cfu g⁻¹ soil than

treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost only (T₆) was statistically higher i.e. 42×10^4 cfu g⁻¹ soil than treatment unfortified compost + 50% recommended NPK (T₄) followed by treatment recommended NPK (T₅). Minimum actinomycetes population i.e. 29×10^4 cfu g⁻¹ soil at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.24: Effect of different treatments on actinomycetes population of soil at different stages of wheat growth

Treatments	Actinomycetes ($\times 10^4$ cfu g ⁻¹ soil)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	43	58	63
T ₂	39	51	52
T ₃	36	46	49
T ₄	31	39	42
T ₅	26	32	35
T ₆	34	42	43
T ₇	22	29	30
CD (P= 0.05)	2.62	2.89	2.98
Initial soil	20	-	-



Plate 4.9 Actinomycetes count in soil at crown root initiation (CRI) stage of wheat



Plate 4.10 Actinomycetes count in soil at grain filling stage of wheat

Actinomycetes population after harvest was maximum i.e. 63×10^4 cfu g^{-1} soil in treatment fortified compost + 5 ml bioinoculants (T_1) and it was statistically higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3); treatment fortified compost + 5 ml bioinoculants (T_1) was statistically higher i.e. 63×10^4 cfu g^{-1} soil than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) followed by fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3). Among the treatments unfortified compost + 50% recommended NPK (T_4), recommended NPK (T_5) and unfortified compost only (T_6); treatment unfortified compost + 50% recommended NPK (T_4) was at par with treatment unfortified compost only (T_6). Among these three treatments, treatment recommended NPK (T_5) gave minimum actinomycetes population i.e. 35×10^3 cfu g^{-1} soil. Minimum actinomycetes population i.e. 30×10^4 cfu g^{-1} soil after harvest was recorded in treatment control (T_7) as compared to rest of the treatments.

The fortified compost contains higher count of actinomycetes which would have increased actinomycetes population in soil. Due to microbiological changes during decomposition of organic matter in the soil brought the highest proliferation of actinomycetes in soil. Similar results were reported by Mukherjee *et al.* (1999).

4.3.4.2 Microbial biomass carbon

The data presented in Table 4.25 revealed that the microbial biomass carbon at CRI stage (25 DAS) was maximum i.e. $102.36 \mu g g^{-1}$ soil in treatment unfortified compost + 50% recommended NPK (T_4). Treatments fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3) were at par with treatment unfortified compost + 50% recommended NPK (T_4). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3); Treatment fortified compost +

5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among these three treatments, treatment fortified compost + 5 ml bioinoculants (T₁) gave minimum microbial biomass carbon i.e. 91.48 $\mu\text{g g}^{-1}$ soil. Among the treatment unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was statistically higher i.e. 102.36 $\mu\text{g g}^{-1}$ soil than treatment unfortified compost only (T₆) followed by treatment recommended NPK (T₅). Minimum microbial biomass carbon i.e. 56.24 $\mu\text{g g}^{-1}$ soil at CRI stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.25: Effect of different treatments on microbial biomass carbon of soil at different stages of wheat growth

Treatments	Microbial biomass carbon ($\mu\text{g g}^{-1}$ soil)		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	91.48	89.04	87.34
T ₂	99.54	95.38	92.48
T ₃	98.92	92.59	89.65
T ₄	102.36	97.46	93.67
T ₅	68.51	70.57	67.27
T ₆	90.46	86.62	83.72
T ₇	56.24	57.73	55.78
CD (P= 0.05)	3.53	3.56	3.55
Initial soil	54.8	-	-

Microbial biomass carbon at grain filling stage (85 DAS) was maximum i.e. 97.4 $\mu\text{g g}^{-1}$ soil in treatment unfortified compost + 50% recommended NPK (T₄). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment unfortified compost + 50%

recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among these three treatments, treatment fortified compost + 5 ml bioinoculants (T₁) gave minimum microbial biomass carbon i.e. 89.04 $\mu\text{g g}^{-1}$ soil. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was statistically higher i.e. 97.4 $\mu\text{g g}^{-1}$ soil than treatment unfortified compost only (T₆) followed by treatment recommended NPK (T₅). Minimum microbial biomass carbon i.e. 57.7 $\mu\text{g g}^{-1}$ soil at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Microbial biomass carbon after harvest was maximum i.e. 93.6 $\mu\text{g g}^{-1}$ soil in treatment unfortified compost + 50% recommended NPK (T₄). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) was at par with treatment unfortified compost + 50% recommended NPK (T₄). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was at par with treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Among these three treatments, treatment fortified compost + 5 ml bioinoculants (T₁) gave minimum microbial biomass carbon i.e. 87.3 $\mu\text{g g}^{-1}$ soil. Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was statistically higher i.e. 93.67 $\mu\text{g g}^{-1}$ soil than treatment unfortified compost only (T₆) followed by treatment recommended NPK (T₅). Minimum microbial biomass carbon i.e. 55.7 $\mu\text{g g}^{-1}$ soil after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

Microbial biomass carbon in integrated nutrient management was higher than the other treatments might be due to more microbial population and organic carbon in the integrated nutrient management which resulted in more biomass carbon due to increased in chemical nitrogen with organic material application. Results are corroborated with the finding of Santhy *et al.* (2004).

4.3.4.3 Urease enzyme

The data presented in Table 4.26 revealed that the urease activity at CRI stage (25 DAS) was maximum i.e. $5.2 \mu\text{g g}^{-1} \text{soil min}^{-1}$ in treatment unfortified compost + 50% recommended NPK (T_4). Treatment recommended NPK (T_5) was at par with treatment unfortified compost + 50% recommended NPK (T_4). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3) was significantly higher i.e. $4.6 \mu\text{g g}^{-1} \text{soil min}^{-1}$ than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) followed by treatment fortified compost + 5 ml bioinoculants (T_1). Among the treatments unfortified compost + 50% recommended NPK (T_4), recommended NPK (T_5) and unfortified compost only (T_6); treatment recommended NPK (T_5) was at par with treatment unfortified compost + 50% recommended NPK (T_4). Among these three treatments, treatment Unfortified compost only (T_6) gave minimum urease activity i.e. $4.2 \mu\text{g g}^{-1} \text{soil min}^{-1}$. Minimum urease activity i.e. $1.7 \mu\text{g g}^{-1} \text{soil min}^{-1}$ at CRI stage was recorded in treatment control (T_7) as compared to rest of the treatments.

Urease activity at grain filling stage (85 DAS) was maximum i.e. $6.2 \mu\text{g g}^{-1} \text{soil min}^{-1}$ in treatment unfortified compost + 50% recommended NPK (T_4). Treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3) was at par with treatment Unfortified compost + 50% recommended NPK (T_4). Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T_1), fortified compost + 5 ml bioinoculants + 5% cow urine (T_2) and fortified compost + 5 ml bioinoculants + 5% cow urine + 1%

urea (T₃); treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) was significantly higher i.e. 5.8 $\mu\text{g g}^{-1}$ soil min^{-1} than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was statistically higher i.e. 6.2 $\mu\text{g g}^{-1}$ soil min^{-1} than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum urease activity i.e. 1.9 $\mu\text{g g}^{-1}$ soil min^{-1} at grain filling stage was recorded in treatment control (T₇) as compared to rest of the treatments.

Table 4.26: Effect of different treatments on urease activity in soil at different stages of wheat growth

Treatments	Urease activity ($\mu\text{g g}^{-1}$ soil min^{-1})		
	CRI stage (25 DAS)	Grain filling stage (85 DAS)	After harvest
T ₁	3.0	3.3	3.6
T ₂	3.3	3.7	4.0
T ₃	4.6	5.8	5.7
T ₄	5.2	6.2	6.4
T ₅	4.8	5.5	5.6
T ₆	4.2	5.2	5.4
T ₇	1.7	1.9	2.0
CD (P= 0.05)	0.39	0.42	0.44
Initial soil	1.6	-	-

Urease activity after harvest was maximum i.e. 6.4 $\mu\text{g g}^{-1}$ soil min^{-1} in treatment unfortified compost + 50% recommended NPK (T₄) and it was statistically higher than all the treatments. Among the treatments in which enriched compost was used i.e. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) and fortified compost +

5 ml bioinoculants + 5% cow urine + 1% urea (T₃); treatment fortified compost + 5ml bioinoculants + 5% cow urine + 1% urea (T₃) was statistically higher i.e. 5.7 $\mu\text{g g}^{-1}$ soil min^{-1} than treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂) followed by treatment fortified compost + 5 ml bioinoculants (T₁). Among the treatments unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) and unfortified compost only (T₆); treatment unfortified compost + 50% recommended NPK (T₄) was statistically higher i.e. 6.4 $\mu\text{g g}^{-1}$ soil min^{-1} than treatment recommended NPK (T₅) followed by treatment unfortified compost only (T₆). Minimum urease activity i.e. 2.0 $\mu\text{g g}^{-1}$ soil min^{-1} after harvest was recorded in treatment control (T₇) as compared to rest of the treatments.

The maximum urease activity was found in the combined application of organics and inorganics together than organics and inorganics alone, might be due to the application of organic source and inorganic source together which maintain the continuity of conversion of nutrients from organic to inorganic form because it act on C-N bonds other than peptide bonds in linear amides and thus belongs to a group of enzymes that include glutaminase and amidase. The results are corroborated with the findings of Jaun *et al.* (2008) and Kadlag *et al.* (2007).



SUMMARY
AND
CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

The present study entitled, "Fortification and mineralization studies in compost under controlled conditions" was carried out with the objectives to prepare nutrient enriched compost and its fortification with organic and inorganic agents and to evaluate fortified compost for mineralization of different nutrients in synchronization with crop growth.

Preparation and analysis of biocomposts

Compost was prepared by using farm residue and available weed plants (*Eupatorium*) in the surrounding area and fortified with rock phosphate (5 and 10%) in the pits of size (1x0.7x0.61) metres in the Farm area of Soil Microbiology. The preparation of compost started on 26th of March, 2011 and the compost matured on 5th of August, 2011. The biocomposts were analysed for moisture content, pH, CEC, EC, total carbon, total NPK, micronutrients, C:N ratio, microbial biomass C, N and S. Three biocomposts were evaluated for nutrient mineralization under incubation studies. Among three biocomposts prepared, best one i.e. [cowdung + *Eupatorium* weed + 5% rock phosphate (compost-II)] was selected on the basis of moisture content (49.46%), pH (6.7), CEC (201.4 cmol (p⁺) kg⁻¹), EC (0.09 dS m⁻¹), total carbon (32.4%), NPK content (1.82% N, 0.64% P, 1.04% K), micronutrients (21.6 mg kg⁻¹ Cu, 992.0 mg kg⁻¹ Fe, 44.5 mg kg⁻¹ Zn, 396.0 mg kg⁻¹ Mn), C:N ratio (18:1) and microbial biomass (308 µg g⁻¹ C, 256 µg g⁻¹ N, 6.1 µg g⁻¹ S) for the evaluation of wheat in growth chamber experiment.

Incubation studies on nutrient mineralization

An incubation study was conducted with sixteen treatments at 30° C laid in completely randomised design with three replications in the Soil Microbiology laboratory of the Department of Soil Science during 31st Oct, 2011 to 26th Dec, 2011.

The soil samples of incubation study were analysed for CO₂ evolution, mineralization of ammonical nitrogen, nitrate nitrogen, phosphorus and potassium at weekly interval. Total CO₂ evolution of eight weeks was highest i.e. 211.3 mg kg⁻¹ in the treatment 400 g soil + 10 g compost-I + 5 ml bioinoculants + 5% cow urine (T₄). Mineralization of nitrogen measured as ammonium and nitrate nitrogen was highest in treatment 400 g soil + 10 g compost-II + 5 ml bioinoculants + 5% cow urine + 1% urea (T₁₀) during 2nd week of incubation. Mineralization of phosphorus was highest in treatment 400 g soil + 10 g compost-II + 1% urea (T₆) and mineralization of potassium was highest in treatment 400 g soil + 10 g compost-II + 5% cow urine (T₇).

Growth chamber studies

A pot experiment was conducted by taking Wheat crop (cv. HS 295) in growth chamber of the Department of Organic agriculture, CSKHPKV, Palampur during *rabi* 2011. Seven treatments viz. fortified compost + 5 ml bioinoculants (T₁), fortified compost + 5 ml bioinoculants + 5% cow urine (T₂), fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃), unfortified compost + 50% recommended NPK (T₄), recommended NPK (T₅) unfortified compost only (T₆) and control i.e. no compost and no fertilizers (T₇) were laid in completely randomised design with four replications. Each pot had size 0.01584 m³ dimensions. Wheat was grown by applying organic, inorganic and integration of organic and inorganic sources of nutrients as per the treatment.

Before sowing of crop a representative soil samples was taken and was analyzed for physical, chemical and microbiological properties. The results indicated that the soil was having texture silty clay loam, pH 5.4, organic carbon 10.6 g kg⁻¹, available N, P, K and S 138.5 mg kg⁻¹, 8.3 mg kg⁻¹, 74.5 mg kg⁻¹ and 12.4 mg kg⁻¹ respectively, total N, P, K and S 516.4 mg kg⁻¹, 88.6 mg kg⁻¹, 989.5 mg kg⁻¹ and 179.3 mg kg⁻¹ respectively, microbial biomass carbon 54.8 µg g⁻¹, microbial count as 18.9x10⁵ cfu g⁻¹ bacteria, 12.9x10³ cfu g⁻¹ fungi and 20x10⁴ cfu g⁻¹ actinomycetes and urease activity 1.6 µg g⁻¹ min⁻¹.

Growth observations and yield

The growth observations viz. plant height, number of effective tillers per plant and number of grains per ear were recorded. Maximum plant height (95.05 cm), number of effective tillers per plant (4) and number of grains per ear (49) were recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃).

Maximum plant biomass per plant i.e. 6.27g and grain yield per plant i.e. 3.24 g were recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) and maximum straw yield per plant i.e. 3.45 g was recorded in treatment fortified compost + 5 ml bioinoculants (T₁).

Nutrient content and crop quality

Grain samples and straw samples were processed and analyzed for N, P, K and S contents and N, P, K and S uptakes were calculated. Grain and straw samples were also analyzed for protein content. In grain samples the maximum nitrogen content i.e. 1.38% was recorded in treatment unfortified compost + 50% recommended NPK (T₄). Maximum P and K content i.e. 0.52% and 0.32%, respectively were recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Maximum S content i.e. 0.68% was recorded in treatment recommended NPK (T₅). Maximum crude protein content i.e. 8.14% was recorded in treatment unfortified compost + 50% recommended NPK (T₄).

In straw samples the maximum nitrogen content i.e. 0.88% was recorded in treatment unfortified compost + 50% recommended NPK (T₄). Maximum P and K content i.e. 0.33% and 0.50%, respectively were recorded in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T₂). Maximum S content i.e. 0.24% was recorded in treatment recommended NPK (T₅). Maximum crude protein content i.e. 5.13% was recorded in treatment unfortified compost + 50% recommended NPK (T₄).

Nitrogen, phosphorus and sulphur uptake by wheat grain was recorded highest i.e. 38.72 mg kg⁻¹, 13.12 mg kg⁻¹ and 19.52 mg kg⁻¹ respectively in the treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃)

and potassium uptake was highest i.e. 7.39 mg kg^{-1} in the treatment fortified compost + 5 ml bioinoculants (T_1). Nitrogen, potassium and sulphur uptake by wheat straw was recorded highest i.e. 28.98 mg kg^{-1} , 33.46 mg kg^{-1} and 6.90 mg kg^{-1} respectively in the treatment fortified compost + 5 ml bioinoculants (T_1) and phosphorus uptake was highest i.e. 10.49 mg kg^{-1} in treatment fortified compost + 5 ml bioinoculants + 5% cow urine (T_2).

Total N, P and K uptake (grain + straw) was recorded highest i.e. 64.16 mg kg^{-1} , 23.23 mg kg^{-1} and 40.85 mg kg^{-1} respectively in treatment fortified compost + 5 ml bioinoculants (T_1), total sulphur content was recorded highest i.e. 25.28 mg kg^{-1} in treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T_3).

Soil analysis

Soil samples were taken at CRI stage, at grain filling stage and after harvest of the wheat and were analysed for available and total N, P, K and S, total microbial count, microbial biomass carbon and urease activity.

The maximum available N i.e. 154.1 mg kg^{-1} , 148.5 mg kg^{-1} and 146.6 mg kg^{-1} respectively was recorded in treatment recommended NPK (T_5) at CRI stage, grain filling stage and after harvest soil samples. Maximum available P i.e. 14.0 mg kg^{-1} , 12.3 mg kg^{-1} and 11.3 mg kg^{-1} respectively was recorded in the treatment unfortified compost + 50% recommended NPK (T_4) at CRI stage, grain filling stage and after harvest soil samples. At CRI stage, grain filling stage and after harvest soil samples the maximum available K i.e. 96.5 mg kg^{-1} , 93.8 mg kg^{-1} and 92.2 mg kg^{-1} respectively was recorded in treatment unfortified compost + 50% recommended NPK (T_4). At CRI stage, grain filling stage and after harvest soil samples the maximum available S i.e. 20.2 mg kg^{-1} , 15.7 mg kg^{-1} and 14.7 mg kg^{-1} respectively were recorded in treatment recommended NPK (T_5).

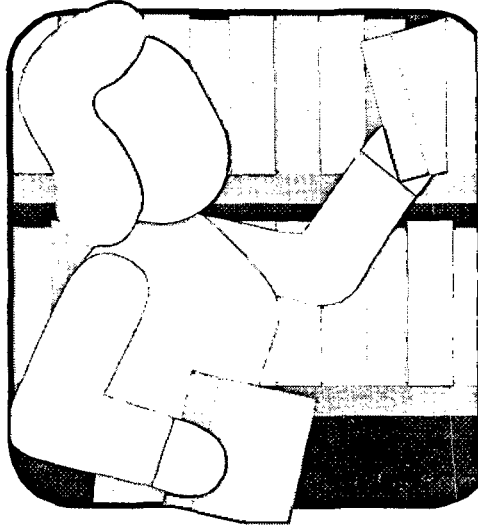
At CRI stage, grain filling stage and after harvest soil samples; the maximum total N contents i.e. 632.3 mg kg^{-1} , 602.0 mg kg^{-1} and 599.2 mg kg^{-1} respectively were recorded in treatment unfortified compost + 50% recommended NPK (T_4). At CRI stage, grain filling stage and after harvest soil

samples the maximum total P i.e. 134.3 mg kg⁻¹, 129.6 mg kg⁻¹ and 128.0 mg kg⁻¹ respectively were recorded in treatment unfortified compost + 50% recommended NPK (T₄). At CRI stage, grain filling stage and after harvest soil samples the maximum total S i.e. 255.3 mg kg⁻¹, 248.0 mg kg⁻¹ and 245.9 mg kg⁻¹ respectively were recorded in treatment unfortified compost + 50% recommended NPK (T₄).

At CRI stage, grain filling stage and after harvest soil samples; the highest bacterial population, fungal population and actinomycetes population were recorded in treatment fortified compost + 5 ml bioinoculants (T₁). At CRI stage, grain filling stage and after harvest soil samples the microbial biomass carbon was recorded highest i.e. 102.36 µg g⁻¹, 97.46 µg g⁻¹ and 93.67 µg g⁻¹ respectively in treatment unfortified compost + 50% recommended NPK (T₄). At CRI stage, grain filling stage and after harvest soil samples the urease activity was recorded highest i.e. 5.2 µg g⁻¹ min⁻¹, 6.2 µg g⁻¹ min⁻¹ and 6.4 µg g⁻¹ min⁻¹ respectively in treatment unfortified compost + 50% recommended NPK (T₄).

Conclusion

1. On the basis of yield contributing characters, grain and straw yield of wheat treatment fortified compost + 5 ml bioinoculants + 5% cow urine + 1% urea (T₃) proved significantly better than rest of the treatments.
2. On the basis of nutrient contents, crude protein and soil properties except microbial count treatment unfortified compost + 50% recommended NPK (T₄) found significantly better than rest of the treatments



LITERATURE CITED

LITERATURE CITED

- Adhikari C, Bronson KF, Panuallah GM, Regmi AP, Saha PK, Dobermann A, Olk DC, Hobbs PR and Pasuquin E. 1999. On-farm soil N supply and N nutrition in the rice-wheat system of Nepal and Bangladesh. *Field crops Research* 64(3): 273-286
- Adhikari T, Manna MC and Biswas AK. 1997. Organic matter improves soil health- An overview. *Indian Farming* 47(8): 11-14
- Ahmad R, Naveed M, Alslam M, Zahir ZA, Arshad M and Jilani G. 2008. Economizing the use of nitrogen fertilizer in wheat production through enriched compost. *Renewable Agriculture and Food Systems* 23(3): 243-249
- Allison LE. 1960. Organic carbon. In : C.A. Black et al. (Eds.) Method of soil analysis, part 2. *Agronomy* 9:-1367-1378. American Society of Agronomy, Inc., Publisher Madison, Wisconsin, USA
- Alvarez CR and Alvarez R. 2000. Nitrogen balance in a soil-wheat system under plow and no-tillage in the Argentine Humid Pampa. *Communications in Soil Science and Plant Analysis* 31(7/8): 1043-1050
- Anwar M, Patra DD, Chand S, Alpesh K, Naqvi AA and Khanuja SPS. 2005. Effect of organic manures and inorganic fertilizer on growth, herb and oil yield, nutrient accumulation, and oil quality of French Basil. *Communications in Soil Science and Plant Analysis* 36(13-14): 1737-1746
- AOAC. 1970. Official method of analysis of the Association, Analytical Chemist, Benjamin Franklin Station, Washington, DC (USA)
- Arunachalam K and Arunachalam A. 1999. Effect of soil pH on N mineralization in regrowing humid sub-tropical forests of Meghalaya. *Journal of the Indian Society of Soil Science* 48(1): 98-101

- Bangar KC, Shanker S, Kapoor KK, Kukreja K and Mishra MM. 1989. Preparation of nitrogen and phosphorus-enriched paddy straw compost and its effects on yield and nutrient uptake by wheat. *Biol Fertil Soils* 8: 339-342
- Bangar SG and Patil PL. 1980. Effect of C/N ratio and phosphatic fertilizers on the decomposition of wheat straw. *Journal of the Indian Society of Soil Science* 28: 543-546
- Banta B and Dev SP. 2009. Field evaluation of nitrogen enriched phosphocompost prepared from green biomass of *Lantana camara* in wheat. *Indian Journal of Ecology* 36(1): 39-44
- Bartal A, Yermiyahu U, Beraud J, Keinan M, Rosenberg R, Zohar D, Rosen V and Fine P. 2004. Nitrogen, phosphorus and potassium uptake by wheat and their distribution in soil following successive, annual compost applications. *Journal of Environmental Quality* 33(5): 1856-1865
- Basumatary A and Talukdar MC. 2011. Integrated effect on sulphur and farmyard manure on yield, quality of crops and nutrient status under rapeseed-rice cropping system in Fluventic Dystrochrept. *Journal of the Indian Society of Soil Science* 59(4): 397-400
- Bedi MK, Jaitly MK and Kanwar K. 2009. Studies on CO₂ evolution in soils from green manure, compost and nitrogen fertilizer under aerobic and anaerobic conditions. *Crop Research Hisar* 37(1/7): 78-82
- Bedi P. 2004. Long-term influence of organic and inorganic fertilizers on nutrient build-up and their relationship with microbial properties under a rice-wheat cropping sequence in an acid Alfisol. *M Sc Thesis*. Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.
- Bedi P and Dubey YP. 2009. Long-term influence of organic and inorganic fertilizers on nutrient build-up and their relationship with microbial properties under a rice-wheat cropping sequence in an acid Alfisol. *Biomedical and Life Sciences* 57(3): 297-306

- Bedi P, Dubey YP and Datt N. 2009. Microbial properties under Rice-Wheat cropping sequence in an acid Alfisol. *Journal of the Indian Society of Soil Science* 57(3): 373-377
- Behera VK, Pradhan S and Sharma AR. 2007. Effect of integrated nutrient management practices on productivity of durum wheat (*Triticum durum*) in the vertisols of central india. *Indian Journal of Agricultural Sciences* 77(10): 635-638
- Bernal MP, Navarro AF, Sanchez-monederero MA, Roig A and Cegarra J. 1998. Influence of sewage sludge compost stability and maturity on carbon and nitrogen mineralization in soil. *Soil Biol. Biochem.* 30(3): 305-313
- Bhardwaj KKR and Dev SP. 1985. Production and decomposition of *Sesbania cannabina* (Retz.) Pers. In relation to its effect on the yield of wet land rice. *Trop. Agric.* 62: 233-236
- Bhardwaj KKR and Kanwar K.1991 . Utilization of wildsage (*Lantana camara*) as green manure and raw material for composting. *Indian Journal of Agricultural Sciences* 61: 890-903
- Bhardwaj SK, Sharma IP and Sharma SD. 2010. Effect of integrated nutrient management on soil fertility, yield and quality of tomato and frenchbean crops in the mid Himalayas. *Journal of the Indian Society of Soil Science* 58(4): 464-466
- Black CA. 1965. Methods of soil analysis Part-I; American Society of Agronomy. Madison, Wisconsin, USA
- Bohne H, Daum T and Schuh C. 1996. Influence of biocompost and farmyard manure on soil properties and on growth of *Acer pseudoplatanus*. *Gartenbauwissenschaft* 61(2): 53-59

- Brookes, P. C., A. Landman, G. Pruden, and D. S. Jenkinson. 1985. Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method to measure microbial biomass nitrogen in soil. *Soil Biol. Biochem.* 17:837-842
- Buchgraber K. 2000. Use of biocompost in agriculture. *Bericht-uber-das-6- Alpenlandische-Expertenforum-Gumpenstein*: 61-77
- Buchgraber K. 2003. Use of biocompost as fertilizer in agriculture and horticulture. *Verroffentlichungen – Bundesanstalt – fur – lpenlandische – Landwirtschaft -Gumpenstein* 39: 86
- Cambardella CA, Richard TL and Russell A. 2003. Compost mineralization in soil as a function of composting process conditions. *European Journal of Soil Biology* 39(3): 117-127
- Ceccanti B and Ganni A. 1992. Hydrolases in the organic matter fractions of sewage sludge: Changes with composting. *Bioresource Technology* 45: 47-52
- Celaya M, Chittoori B, Saride S, Nazarian S and Puppala A. 2009. Determination of total potassium. Design manual and test protocols to accelerate mix design of stabilized subgrades 20-21
- Chand S, Somani LL and Bhandari SC. 2010. Effect of fertilizer, farmyard manure and biofertilizer on the population of *Azotobacter* and phosphate solublising bacteria in the soil. *Journal of the Indian Society of Soil Science* 58(4): 460-463
- Chaube AK and Dwivedi KN. 1995. Effect on N, P and S application on oil content, iodine value and lipoxygenase activity of linseed oil. *Journal of the Indian Society of Soil Science* 43: 75-77
- Chesti MH and Ali T. 2012. Rhizospheric micro flora, nutrient availability and yield of green gram (*Vigna radiata* L.) as influenced by organic manures, phosphate solublizers and phosphorus levels in Alfisols. *Journal of the Indian Society of Soil Science* 60(1): 25-29

- Chesnin L and Yien CH. 1950. Turbimetric determination of available sulphate. *Soil Science Society America Proceedings* 15: 149-151
- Chettri M, Mondal SS and Konar A. 2004. Integrated nutrient management for enhancing productivity and sustaining soil fertility under potato (*Solanum tuberosum*)-based cropping system in West Bengal. *Indian Journal of Agricultural Sciences* 74(4): 210-212
- Christensen BT. 1986. Barley straw decomposition under field conditions: Effect of placement and initial soil content. *Soil Biol. Biochem* 18:523-529
- Conti ME, Arrigo NM and Marelli. 1997. Relationship of soil carbon light fraction, microbial activity, humic acid production and nitrogen fertilization in the decaying process of corn stubble. *Biol Fertil Soils* 25: 75-78
- Darwinkel A and Titulaer HHH. 2000. Nitrogen in high-yielding winter wheat: effects of high nitrogen rates on nitrogen balance in the crop and the soil. *PAV Bulletin Akkerbouw* (2): 11-15
- Dinesh R and Dubey RP. 1999. Nitrogen mineralization rates and kinetics in soils amended with organic manures. *Journal of the Indian Society of Soil Science* 47(3): 421-425
- Eghball B, Wienhold BJ, Gilley JE and Eigenberg RA. 2002. Mineralization of manure nutrients. *Journal of Soil and Water Conservation Ankeny* 57(6): 470-473
- Eswaran H, Paul R and Vearasilp. 2005. A global assessment of land quality in the anthropocene. In: Proceedings of International conference on soil, water and environmental quality-issues and strategies. *Indian Society of Soil Science*, IARI, New Delhi
- Gaind S, Pandey AK and Lata. 2006. Microbial biomass, P nutrition and enzymatic activities of wheat soil in response to phosphorus-enriched organic and inorganic manures. *Journal of Environmental Science and Health part-B, Pesticides, Food Contaminants and Agricultural Wastes* 41(2): 177-187

- Gaur AC.1992. *In: Fertilizers, Organic Manures, Recyclable Wastes and Bio-fertilizers.* (Eds. Tandon, H.L.S.) Fertilizer Development and Consultation Organization, New Delhi, 110048, 36
- Gaur AC. 1998. Integrated plant nutrient supply system blending organic, bio and chemical resources. Proceedings – Summer school on Soil-Plant microbe interaction in relation to Integrated Nutrient Management from June 17-July 8,1998. Division of Microbiology. *Indian Agricultural Research Institute.*14-27
- Gaur AC. 1999. Enrichment of compost. *Microbial technology for composting of agricultural residues by improved methods* 32
- Ghoshal SK, Hazara GC, Mandal B, Majindar D, Mishra AK and Samantarai RN.2005. Assessing biological soil quality for a 34 years old long term fertility experiment with rice-rice cropping system. In International Conference on soil, water and environmental quality issues and strategies: Abstracts 20 I SSS, New Delhi
- Ghuman BS and Sur HS. 2006. Effect of manuring on soil properties and yield of rainfed wheat. *Journal of the Indian Society of Soil Science* 54(1): 6-11
- Gogoi B, Barna NG and Baruah TC. 2010. Effect of Integrated supply of nutrients on soil microbial biomass carbon in an Inceptisol of Assam.
- Gomez KA and Gomez Aa. 1984. Statistical procedure for agricultural Research, John Wiley and sons, New York
- Goyal S, Mishra MM, Hooda IS and Singh R.1992. Organic matter-microbiological biomass relationship in field experiment under tropical conditions: Effects of inorganic fertilization and organic amendments. *Soil Biol. and Biochem.* 24: 1081-1084
- Goyal S, Singh D, Suneja S and Kapoor KK. 2009. Effect of rice straw compost on soil microbiological properties and yield of rice. *Indian Journal of Agricultural Research* 43(4): 263-268

- Gupta RK, Sharma KN, Singh B, Singh Y and Arora BR. 2005. Effect of urea and manure addition on changes in mineral-N content in soil profile at various growth stages of wheat. *Journal of the Indian Society of Soil Science* 53(1): 74-80
- Hadas A, Kautsky L and Portnoy R. 1996. Mineralization of composted manure and microbial dynamics in soil as affected by long-term nitrogen management. *Soil Biol. Biochem.* 28(6): 733-738
- Hartz TK, Mitchell JP and Giannini C. 2000. Nitrogen and carbon mineralization dynamics of manures and composts. *Hort Science* 35(2):209-212
- He ZL, Alva AK, Yan P, Li YC, Calvert DV, Stofella PJ and Banks DJ. 2000. Nitrogen mineralization and transformation from composts and biosolids during field incubation in a sandy soil. *Soil Science* 165(2): 161-169
- Heller WE. 1999. Nitrogen mineralization of composts in an incubation assay. *Agrarforschung* 6(2): 75-77
- Henrikson TM and Breland TA. 1999. Nitrogen availability effects on carbon mineralization, fungal and bacterial growth and enzyme activities during decomposition of wheat straw in soil. *Soil Biol. and Biochem.* 31(8): 1121-1134
- Hioki M and Kitamura H. 2000. The estimation of the amount of nitrogen mineralization from the animal manure compost in the paddy soil condition. *Research Bulletin of the Aichi ken Agricultural Research Center* (32): 81-86
- Horwath WR and Elliott LF. 1996. Ryegrass straw component decomposition during mesophilic and thermophilic incubations. *Biol Fertil Soils* 21: 227-233
- Jackson ML. 1967. Soil chemical analysis. Prentice Hall of India Limited, New Delhi

- Jamriska P. 1996. Effect of biocompost on yield of selected crops. *Vedecke Prace Vyskumneho Ustavu Rastlinnej Vyroby -v- Piest'-any* 28:13-20. 2007.
- Jatav MK, Sud KC and Trehan SP. 2010. Effect of organic and inorganic sources of phosphorus and potassium on their different fractions under potato-radish cropping sequence in a brown hill soil. *Journal of the Indian Society of Soil Science* 58(4): 388-393
- Jaun L, Bingqiang Z, Xiuyiny L, Ruibo J and Hwat bing S. 2008. Effects of long term combined application of organic and mineral fertilizers on microbial biomass, soil enzyme activities and soil fertility. *Agricultural Science in China* 7(3): 336-343
- JenHshuan C, JengTzung W and WeiTin H. 2001. Effects of compost on the availability of nitrogen and phosphorus in strongly acidic soils. *Technical Bulletin Food and Fertilizer Technology Center* (155): 10
- Johnson CM and Nitisha H. 1952. Micro estimation of sulphur in plant materials, soils and irrigated water. *Analytical Chemistry* 24: 736-742
- Kadlag AD, Jadhav AB and Vyavahare MT. 2007. Soil urease and acid phosphate enzyme activity as influenced by rock phosphate. *Assam Journal of Soil Science* 2(2): 6-12
- Kahle P and Belau L. 2001. Incubation experiment on the turnover of biocomposts after application to agriculturally utilized soil. *Landnutzung und Landentwicklung* 42(4): 173-178
- Kanwar K and Paliyal SS. 2004. Influence of phosphorus management and organic manuring on uptake and yield of chickpea (*Cicer arietinum*). *Himachal Journal of Agricultural Research* 30(1): 38-43
- Kanwar K and Paliyal SS and Bedi MK. 2006. Integrated management of green manure, compost and nitrogen fertilizer in a rice-wheat cropping sequence. *Crop Research Hisar* 31(3): 334-338

- Kapoor KK and Goyal S. 2005. Effect of application of different phosphorus sources on degrading fungi on wheat yield under rice (*Oryza sativa* L.)- wheat (*Triticum aestivum*) sequence. *Journal of Research Birsa Agricultural University* 18(1): 119-121
- Kar S, Majumdar R, Chatterjee P and Gupta Sk. 2007. Nitrogen mineralization of some added organic manures in soils. *Indian Agriculturist* 51(3/4): 165-172
- Khamis MA and Metwally SM. 1998. Utilization of organic materials inoculated with microbial decomposers as a nitrogen source for wheat in presence of *Azotobacter* in a sandy soil. *Egyptian Journal of Soil Science* 38(1/4): 81-99
- Khind CS, Maskina MS and Meelu OP. 1987. Effect of time of application of *Sesbania aculeata* green manure and fertilizer nitrogen on yield of wetland rice. *Journal of the Indian Society of Soil Science* 35:143
- Kumarjitsingh RK, Athokpam, Herojitsingh, Changte, Zoliana and Singh GN. 2005. Integrated management of Azolla, vermicompost and urea on yield and nutrient uptake by rice and soil fertility. *Journal of Indian Society of Soil Science* 53(1): 107-110
- Kumar V and Singh AP. 2010. Long-term effect of green manuring and farmyard manure on yield and soil fertility status in rice-wheat cropping system. *Journal of the Indian Society of Soil Science* 58(4): 409-412
- Kumari G, Mishra B, Kumar R, Agarwal BK and Singh BP. 2011. Long-term effect of manure, fertilizer and lime application on active and passive pools of soil organic carbon under maize-wheat cropping system in an alfisol. *Journal of the Indian Society of Soil Science* 59(3): 245-250
- KyungHwa H, WooJung C, GwangHyun H, SeokIn Y, SunHo Y and HeeMyong R. 2004. Urea-nitrogen transformation and compost-nitrogen mineralization in three different soils as affected by the interaction between both nitrogen inputs. *Biology and Fertility of Soils* 39(3): 193-199

- Lakaria BL, Mukherjee A, Jha P and Biswas AK. 2012. Soil carbon mineralization as affected by land use systems and water regimes. *Journal of the Indian Society of Soil Science* 60(1) 71-73
- Li H, Han Y and Cai Z. 2003. Nitrogen mineralization in paddy soils of the taihu region of China under anaerobic conditions: dynamics and model fitting. *Geoderma* 115: 161-175
- Liang BC, Gregorich EG, Schnitzer and Voroney RP. 1996. Carbon mineralization in soils of different textures as affected by water-soluble organic carbon extracted from composted dairy manure. *Journal of the Indian Society of Soil Science* 21: 10-16
- Lindsay WL and Norvell WA. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal* 42: 421-428
- Mankotia BS, Shekhar J, Thakur RC and Negi SC. 2008. Effect of organic and inorganic sources of nutrients on rice (*Oryza sativa*)- wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* 53(1): 32-36
- Manna MC and Ganguly TK. 1999. Composting, an enrichment technology. *Indian Farming* 49(1): 14-16
- Manna MC, Ghosh PK and Ganguly TK. 2003. Comparative performance of four sources of enriched phosphocompost and inorganic fertilizer application of yield, uptake of nutrients and biological activity of soil under soybean-wheat rotation. *Journal of Food, Agriculture and Environment* 1(2):203-208
- Manna MC, Ganguly TK and Ghosh BN. 2000. Evaluation of compost maturity and mineral enrichment quality through simple chemical parameters. *Journal of the Indian Society of Soil Science* 48(4): 781-786
- Manna MC, Hazra JN, Sinha NB and Ganguly TK. 1997. Enrichment of compost by bioinoculate and mineral treatments. *Journal of Indian Society of Soil Science* 45(4): 831-833

- Mukherjee D, Das AC, Chakravarty A, Das SK and Mukhopadhyay PK. 1999. Carbon mineralization and microbiological changes during decomposition of organic matter in soil. *Indian Agriculture* 43(3/4): 191-201
- Murata T, Tanaka H, Sakagami K, Asaka D and Hanada R. 1997. The influence of wheat straw and manure application on microbial biomass, available soil N and nuptial sugar composition induced by wheat straw and manure application. *Japanese Journal of Soil Science and Plant Nutrition* 68: 249-256
- Nagumo T, Fueki N and Hatano R. 2001. Utility of livestock excreta chemically treated with slaked lime in regard to paddy rice production. *Memorandum of the Graduate School of Agriculture* 23(4): 403-413
- Nannipieri P, Falchini L, Landi L, Benedetti A, Canali S, Tittarelli F, Ferri Convertini G, Badalucco L, Grego S, Antisari VL, Raglione M and Barraclough D. 1999. Nitrogen uptake by crops, soil distribution and recovery of urea-N in a sorghum-wheat rotation in different soils under Mediterranean conditions. *Plant and Soil* 208(1): 43-56
- Nath DJ, Ozah B, Baruah R, Barroah RC, Borah DK and Gupta M. 2012. Soil enzymes and microbial biomass carbon under Rice-Toria sequence as influenced by nutrient management. *Journal of the Indian Society of Soil Science* 60(1): 20-24
- Nasir NM, Qureshi SA and Afghan S. 1994. Effect of biocompost on sugarcane crop. *Pakistan Sugar Journal* 8(3): 13-16
- Nass HG, Ivany JA and MacLeod JA. 2003. Agronomic performance and quality of spring wheat and soybean cultivars under organic cultivation. *American Journal of Alternative Agriculture* 18(3): 164-170
- Nira R and Nishimune A. 1998. Accumulation of fertilizer nitrogen applied at different times into grain and uptake of soil nitrogen by winter wheat in Hokkaido. *Japanese Journal of Soil Science and Plant Nutrition* 69(6): 604-611

- Nishanth D and Biswas DR. 2008. Kinetics of phosphorus and potassium release from rock phosphate and waste mica enriched compost and their effect on yield and nutrient uptake by wheat (*Triticum aestivum*). *Bioresource Technology* 99(9): 3342-3353
- Olsen SR, Cole CV, Watanabe FS and Dean LA. 1954. Estimation of available phosphorus in soil by extraction method with NaHCO_3 , USDA Circ. No. 939: 19-33
- Pandey AK, Singh SK and Prasad R. 2009. Long term influence of organic and inorganic fertilizers on nutrient uptake by rice and wheat in calcareous soil. *Environment and Ecology* 27(4B): 1903-1906
- Pape H and Steffens D. 1998. Estimation of N-supply of biowaste composts in laboratory and field investigations. *Einflüsse von Erzeugung und Verarbeitung auf die Qualität landwirtschaftlichen Produkte Vorträge zum Generalthema des* 147-150
- Piper CS. 1966. Soil and Water analysis. (Asian edition) Hans Publication, Bombay, India) 223-237
- Pramar D and Schmidt EL. 1964. Experimental soil microbiology. *Burgess Publishing Co. Minneapolis, U.S.A.*
- Prasad B and Prasad J. 1994. Balanced and efficient fertilization of wheat for its specific yield through soil testing and integrated nutrient management in calcareous soil. *Annual Agricultural Research* 15(3): 291-296
- Prasad SS, Nanda KK, Sinha SK and Ram H. 2010. Effect of organic/inorganic amendments on nutrient uptake by rice-wheat cropping system in salt-affected soil. *Environment and Ecology* 28(1B): 543-546

- Purnomo E, Black AS, Smith CJ and Conyers MK. 2000. The distribution of net nitrogen mineralization within surface soil and field studies under a wheat crop. *Australian Journal of Soil Research* 38(1): 129-140
- Qureshi AA, Narayanasamy G, Chhonkar PK and Balasundaram VR. 2005. Direct and residual effect of phosphate rocks in presence of phosphate solublizers and FYM on the available P, organic carbon and viable counts of phosphate solublizers in soil after soybean, mustard and wheat crops. *Journal of the Indian Society of Soil Science* 53(1): 97-100
- Ramasamy C. 2005. Inaugural address by chief guest 70th annual convention of the Indian society of soil science. *Journal of the Indian Society of Soil Science* 53: 430-432
- Rao KJ and Ramalaxmi CS. 2009. Soil nutrient status and enzyme activity in post harvest soils treated with urban and agricultural waste composts. *Journal of Environment Science and Engineering* 51(4): 239-246
- Rasal PH, Jadhav BR, Nazirkar RB, Kalbhor HB and Pawar KB. 2002. Quantitative assessment of phosphocompost and their efficiency in groundnut-wheat cropping system and soil health. *Journal of Maharashtra Agricultural Universities* 27(2): 156-160
- Richards LA. 1954. Diagnosis and improvement of saline and alkali soils. *USDA Agric. Handbook* 60. Washington, D.C.
- Rout KK, Sahoo S, Mukhi SK and Mohanty GP. 2012. Assessment of quality of different organic manures used by the farmers of Khurda district in Orissa and their effect on microbial activity of an acid soil. *Journal of the Indian Society of Soil Science* 60(1): 30-37
- Roy SK, Sharma RC and Trehan SP. 2001. Integrated nutrient management by using farm yard manure and fertilizers in potato-sunflower-paddy rotation in Punjab. *Journal of Agricultural Sciences* 137(3): 271-278

- Ruhe I. 2002. Winter wheat cultivation in nitrogen-limited production systems under particular consideration of yield formation, organic fertilizing and mechanical weed control. *Schriftenreihe des Instituts für Pflanzenbau und Pflanzenzüchtung der Christian Albrechts Universität zu Kiel* (13): 181
- Saliha BB, Krishnakumar S and Natarajan SK. 2005. Response of rice crop to organic manuring in high pH soil. *Asian Journal of Plant Sciences* 4(5): 524-526
- Santhy P, Selvi D, Dhakshinamoorthy M and Maheshwari M. 2004. Microbial population and biomass in rhizosphere as influenced by continuous intensive cultivation and fertilization in an Inceptisol. *Journal of the Indian Society of Soil Science* 52(3): 254-257.
- Scherer HW. 2001. Sulphur in crop production. *European Journal of Agronomy* 14(2): 81-111
- Schulz R, Alnazar H, Breuer J and Romheld V. 2001. The effect of biocompost application on crop yield and nitrogen dynamics in the soil. *Plant Nutrition: food security and sustainability of agro ecosystems through basic and applied research Fourteenth International Plant Nutrition Colloquium* 986-987
- Setia RK and Sharma KN. 2004. Effect of long-term differential fertilization on depth-distribution of forms of sulphur and their relationship with sulphur nutrition of wheat under maize-wheat sequence. *Journal of the Indian Society of Soil Science* 53: 91-96
- Sharma AR and Mittra BN. 1990. Effect of organic materials and NPK levels on growth and yield of rice. *Indian Agriculturist* 34(3): 169-175
- Sharma CM and Bhardwaj SK. 2005. Direct and residual effect of rock phosphate enriched organics on yield in maize-wheat cropping in an acid soil. *Journal of the Indian Society of Soil Science* 53(2): 264-266

- Sharma MP, Bali SV and Gupta DK. 2000. Crop yield and properties of Inceptisol as influenced by residue management under Rice-Wheat cropping sequence. *Journal of the Indian Society of Soil Science* 48: 506-509
- Sharma V, Pandher JK and Kanwar K. 2008. Biomanagement of lantana (*Lantana camara* L.) and congress grass (*Parthenium hysterophorus* L.) through vermicomposting and its response on soil fertility. *Indian J. Agric. Res.* 42(4): 283-287
- Siebert S, Leifeld J and Kogel KI. 2000. Use of fresh and old compost on a recultivated soil. *Mitteilungen der Deutschen Bodenkundlichen Gesellschaft* 93: 335-338
- Sieling K, Gunther Borstel O, Teebken T and Hanus H. 1999. Soil mineralization N and N net mineralization during autumn and winter under an oilseed rape-winter wheat-winter barley rotation in different crop management systems. *Journal of Agricultural Science* 132(2): 127-137
- Sikora LJ and Enkiri NK. 2000. Efficiency of compost-fertilizer blends compared with fertilizer alone. *Soil Science* 165(5): 444-451
- Singh A, Nehra BK, Khurana SC and Singh N. 1997. Influence of plant density and fertility level on growth and yield in seed crop of potato. *Journal of Indian Potato Association* 24(1-2): 17-23
- Singh AB and Ganguly TK. 2005. Quality comparison of conventional compost, vermicompost and chemically – enriched compost. *Journal of the Indian Society of Soil Science* 53(3): 352-355
- Singh J, Rani N, Sidhu BS and Beri V. 2009. Effect of phosphocompost on rice-wheat system in a non-calcareous typic Haplustept. *Journal of the Indian Society of Soil Science* 57(3): 338-344
- Singh P and Singh H. 2010. Nitrogen mineralization of pressmud in sub-tropical riparian Zone of Punjab. *Journal of the Indian Society of Soil Science* 58(4): 455-459

- Singh RD and Chauhan VS. 2002. Impact of fertilizers and organic manures on soil productivity under wheat-ragi system. *Journal of the Indian Society of Soil Science* 50(1): 62-63
- Smith DC, Beharee and Hughes JC. 2001. The effects of composts produced by a simple composting procedure on the yields of swiss chard and common bean (*Phaseolus vulgaris* L. var. *nanus*). *Scientia Horticulturae* 91(3-4): 393-406
- Sreenivas CH and Narayanasamy G. 2003. Phosphate release characteristics of phosphor-compost in a typic Haplustept. *Journal of the Indian Society of Soil Science* 51(3): 305-308
- Sridevi S, Katyal JC, Srinivas K and Sharma KL. 2003. Carbon mineralization and microbial biomass dynamics in soil amended with plant residues and residue fractions. *Journal of the Indian Society of Soil Science* 51(2): 133-139
- Srinivas K, Singh HP, Vanaja M, Raju S and Sharma KL. 2006. Effect of chemical composition of plant residues on nitrogen mineralization. *Journal of the Indian Society of Soil Science* 54(3): 300-306
- Steffens D, Haas R and Jahn-Deesbach W. 1992. Influence of biocompost on yield, heavy metal transfer and nitrogen dynamics under field conditions. *Proceedings-Second Congress of the European Society for Agronomy, Warwick University*: 428-429
- Subbiah BV and Asija GL. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* 25: 259-260
- Swain AK, Pattanayak SK, Jena MK and Nayak RK. 2003. Effect of integrated use of bio-inoculants and fertilizer nitrogen on growth, yield and nitrogen economy of okra. *Journal of the Indian Society of Soil Science* 51(2): 145-150
- Tabatabai MA and Bremner JM. 1969. Use of p-nitrophenyl phosphatase for assay of soil phosphatase activity. *Soil Biol. and Biochem.* 1: 301-307

- Tiwari KN. 2002. Nutrient management for sustainable agriculture- The 9th Dr. D.P. Motiramani memorial lecture. *Journal of the Indian Society of Soil Science* 50(4): 374-397.
- Vance ED, Brookes PC and Jekinson DS. 1987. An extraction method for measuring soil microbial biomass carbon. *Soil Biology and Biochemistry* 19: 703-707
- Varalakshmi BR, Srinivasamurthy CA and Bhaskar S.2005. Effect of integrated use of organic manures and inorganic fertilizers on organic carbon, available N, P and K in sustaining productivity of groundnut-finger millet cropping scheme. *Journal of the Indian Society of Soil Science* 53(3): 315-318
- Vyas SH, Modhwadia MM and Khanpara VD. 1997. Integrated nutrient management in wheat (*Triticum aestivum* L.). *Gujrat Agricultural University Research Journal* 23(1): 12-18
- Walkley A and Black CA. 1934. An examination of wet acid method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37: 29-38
- Wieczorek W, Klimach A and Kubica-Sokoowska K. 2002. Influence of biocompost on salubrity of replanted tomato and cucumber seedlings. *Pestycydy* (1/4): 71-79
- Wollum AG. 1982. Cultural methods for souil microorganisms. In: *Methods of Soil Analysis part II. Chemical and Microbiological Properties*. American Society of Agronomy. Inc. Publisher Madison. Wisconsin, USA. 781-802
- Wu J, O'Donnell AG, He ZL, Syers JK. 1994. Fumigation-extraction method for the measurement of soil microbial biomass-S. *Soil Biol Biochem* 26: 117-125

- Yadav DS and Kumar A. 2000. Integrated nutrient management in rice-wheat cropping system under eastern Uttar Pradesh conditions. *Indian Farming* 50(1): 28-30
- Zachariah AS and Chhonkar PK .2004. Biochemical properties of compost as influenced by earthworms and feed material. *Journal of the Indian Society of Soil Science* 52(2): 155-159

Errata

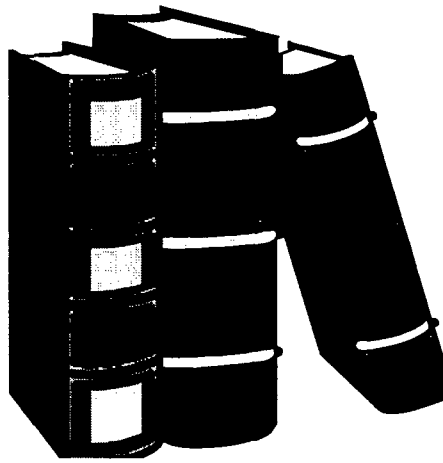
Khan AK, Jilani G, Akhtar MS, Naqvi SMS and Rasheed M. 2009. Phosphorus solubilizing bacteria: Occurrence, mechanisms and their role in crop production. *Journal of Agric. Biol. Sci.* 1(1): 48-58

*

Sitangshu S and Mondal SS. 2004. Nutrient management of potato and its after effect on the soil fertility build up in lower gangetic plains of west Bengal. *Res. On Crops* 5(1): 108-112

Thakur S and Sharma CR. 1998. Effect of rock phosphate enrichment and Azotobacter inoculation on the transformation of nitrogen during composting. *Journal of the Indian Society of Soil Science* 46: 228-231

*Kumar B, Mishra B and Shahi DK. 2006. Effect of residue management using cellulose degrading fungi on wheat yield under rice -wheat sequence. *Journal of Research* 18(1): 119-121



APPENDICES

Appendix-1

Composition of media used for microbial population determination

➤ Bacteria : Soil Extract Agar (Lochhead. 1940)

Glucose	1.0 g
Dipotassium hydrogen phosphate	0.5 g
Potassium nitrate (KNO ₃)	0.1 g
Soil extract	100 ml
Distilled Water	1000 ml
pH	6.5-7.0
Agar	18 g

➤ Fungi : Rose Bengal Streptomycin Agar (Martin 1950)

Dextrose	10 g
Peptone	5 g
Potassium hydrogen phosphate	1 g
Magnesium sulphate	0.5 g
pH	7.0
Agar	18 g
Rose Bengal	0.033g
Distilled water	1000 ml
Streptomycin	30 µg/ml of autoclaved media

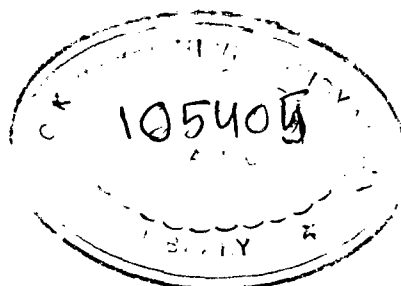
➤ **Actinomycetes : Dextrose nitrate agar (Ken knight and Munice, 1939)**

Dextrose	1 g
Potassium dihydrogen phosphate	0.1 g
Sodium nitrate	0.1 g
Magnesium sulphate	0.1 g
Potassium chloride	0.1 g
Distilled water	1000 ml
pH	7.0
Agar	18 g

➤ **Soil extract**

Soil extract was prepared by mixing 1 kg of fertile soil with 1.5 lt of water. The mixture was autoclaved for 30 minutes at 15 pounds pressure per square inch pressure. After cooling and settling, the suspension was filtered using a medium grade filter paper.

➤ **Wollum A.G (1982)**



Brief Biodata of student

Name : Arti
Father's Name : Mr. Ashok Kumar Sandal
Mother's Name : Mrs. Krishna Sandal
Date of Birth : 09 September, 1987
Permanent Address : House no. 24/2, V.P.O. Rajpur
Tehsil. Palampur, District. Kangra (H.P.),
Pin code - 176061

Academic Qualifications:

Examination passed	Month	Year	School/Board/University	Marks (%)	Division
10 th	March	2004	CBSE	59.8	2 nd
10+2	March	2006	CBSE	61.3	1 st
B.Sc. Agriculture	June	2010	CSKHPKV, Palampur	67.8	1 st