STUDIES ON NITROGEN USE EFFICIENCY IN IRRIGATED RICE AS INFLUENCED BY VARIOUS SOURCES OF NITROGEN

M.Sc. (Ag.) Thesis

by

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE

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STUDIES ON NITROGEN USE EFFICIENCY IN IRRIGATED RICE AS INFLUENCED BY VARIOUS SOURCES OF NITROGEN

Thesis

Submitted to

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

MOOD CHAWAN JOSHNA DEVI

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in

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CERTIFICATE - II

This is to certify that the thesis entitled **"Studies on Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen"** submitted by **Mood Chawan Joshna Devi** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the Department of Soil Science and Agricultural Chemistry has been approved by the external examiner and Student's Advisory Committee after oral examination.

Date: 11/08/2017 Signature External Examiner

(Name)

Major Advisor ____________ 11/8/2017

Head of the Department /Section ____________

Dean Faculty ____________

Approved/Not approved

Director of Instructions ____________

CERTIFICATE - I

This is to certify that the thesis entitled **"Studies on Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture of** the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Mood Chawan Joshna Devi** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

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

K. Surekha
Co-Chairman

Chairman

Date:

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Date :

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LIST OF ABBREVIATIONS

%	Percent
@	At the rate
℃	Degree Celsius
CD	Critical difference
cm	Centimeter
UA	Urease Activity
DHA	Dehydrogenase Activity
$dS\ m^{-1}$	Deci -Simens per metre
EC	Electrical Conductivity
et al.	And co- worker/ and other
Fig.	Figure
VC	Vermicompost
RDN	Recommended Dose of Nitrogen
ha-1	Per hectare
i.e.	That is
NUE	Nitrogen use efficiency
kg	Kilogram
m3	Cube metre
m2	Square metre
mg	Milligram
Mg	Mega gram
ml	Millilitre
NCU	Neem Coated Urea
PCU	Polymer Coated Urea
RS	Rice Straw
No.	Number
NPK	Nitrogen, Phosphorus, Potassium
NS	Non- Significant
pH	Potentiality of hydrogen
Q	Quintal
SEm±	Standard Error of means
T	Tonne
TPF	Triphenyl Formazan
TTC	Triphenyl Tetrazolium Chloride
Y	Yield
TPF	Triphenyl Formazan
TTC	Triphenyl Tetrazolium Chloride
Y	Yield
THAM	Tris-hydroxymethyl amine methane
viz.,	Namely
ZnSO4	Zinc sulphate
K	Potassium
KCl	Potassium Chloride
KCl-Ag2SO4	Potassium chloride silver sulphate

kg ha^{-1}	kilogram per hectare
KMnO4	Potassium permanganate
L	Litre
mg kg^{-1}	milligrams per kilogram
ug of NH4+ released g^{-1} soil	Micrograms of ammonium released per gram soil
h^{-1}	per hour
NUE	Nitrogen Use Efficiency
PUE	Phosphorous Use Efficiency
KUE	Potassium Use Efficiency
DAT	Days after transplanting
AT	Active Tillering
PI	Panicle initiation
MT	Maximum tillering

THESIS ABSTRACT

a)	Title of the Thesis	:	Studies on Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen
b)	Full Name of the Student	:	Mood Chawan Joshna devi
c)	Major Subject	:	Soil Science & Agricultural Chemistry
d)	Name and address of the	:	Dr. Anurag, Professor,
	Major Advisor	:	Department of Soil Science & Agricultural Chemistry , IGKV,Raipur (C.G.)
e)	Degree to be awarded	:	M.Sc. (Ag.) Soil Science & Agricultural Chemistry

Signature of the Student

Signature of the Major Advisor

Date ______________________ Signature of the Head of the Department

ABSTRACT

Present investigation entitled " Studies on Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen ' was carried out under field conditions during *kharif* season of 2016 at the research farm of the ICAR - Indian Institute of Rice Research (IIRR) (formerly DRR), Hyderabad, Telangana state. The soil of the experimental field was clay loam in texture, low in available nitrogen and high in phosphorus and potassium content. Rice variety "Varadhan" was used as a test crop. The experiment was laid out in randomized block design with sixteen treatments and each one replicated thrice. The treatments comprised of T_1: Control; T_2 :50% RDN from Prilled urea (PU); T_3 : 50% RDN from Neem

coated urea (NCU); T_4 : 50% RDN from Polymer coated urea (PCU); T_5 : 50% RDN from Vermi compost (VC); T_6 : 50% RDN from Rice straw (RS); T_7 : 75% RDN from (PU); T_8 : 75% RDN from (NCU); T_9 : 75% RDN from (PCU); T_{10} : 75% RDN from (VC); T_{11} : 75% RDN from (RS); T_{12} : 100% RDN from (PU); T_{13} : 100% RDN from (NCU); T_{14} : 100% RDN from (PCU);T_{15} : 100% RDN from (VC); T_{16} : 100% RDN from (RS).

The results revealed that the rice plant height was significantly influenced by nutrient management practices and the highest value (97.83 cm) was recorded under $T_{13:}$100% RDN from (NCU). Similarly, Yield attributing characters of rice were significantly affected by different treatments. The highest value for number of tillers m^{-2} (399), number of panicles m^{-2} (331), number of grains per panicle (128), Panicle length (20. cm) and filled grain percentage (97.45%) were found in treatment $T_{13:}$100% RDN from (NCU). Likewise, treatment $T_{13:}$100% RDN from (NCU) has also recorded maximum rice grain yield (41.0 q/ha) and straw yield (54.0q/ha) and was followed by T_{14} : 100% RDN from (PCU). Significantly lowest Grain and straw yield of rice were obtained under T_1: control. The grain test weight was found non-significant.

Influence of different applied nitrogen treatments showed significant effect on N, P and K content and uptake by rice plant. The highest value for total nitrogen (85.05 kg ha^{-1}), phosphorous (15.91 kg ha^{-1}) and potassium uptake (87.18 kg ha^{-1}) by rice were recorded highest under $T_{13:}$100% RDN from (NCU). Nitrogen use efficiency (46.30%), Phosphorous use efficiency (24.00%) and Potassium use efficiency (97.00%) were recorded significantly highest underT_{13}:100% RDN from (NCU) was followed by T_{14}:100% RDN from (PCU). The lowest NPK content and uptake as well as the lowest NUE, PUE and KUE were recorded under control (T_1).

Soil nutrient status after harvesting, were also varied under different treatments. The highest value for available nitrogen (246 kg ha^{-1}), available phosphorous (93 kg ha^{-1}) and available potassium (484 kg ha^{-1}) content were observed under treatment T_{13} : 100% RDN from (NCU) .Maximum urease enzyme activity was recorded under treatment T_{13} : 100% RDN from (NCU) while, dehydrogenase activity was maximum under treatment T_{15} : 100% RDN from Vermi compost (VC).

As per the above findings, application of 100% RDN from neem coated urea among different sources of fertilizer nitrogen was found the most suitable for irrigated rice cultivation system.

शोध सारांश

(अ) शोधग्रंथ शीर्षक : सिंचित धान के नत्रजन के विभिन्न श्रोतो का नत्रजन उपयोग दक्षता पर प्रभाव का अध्ययन

(ब) विद्यार्थी का नाम : मूड चव्हाण जोशना देवी

(स) मुख्य विषय : मृदा विज्ञान एवं कृषि रसायन

(द) प्रमुख सलाहकार का नाम एवं पता : डॉ.अनुराग प्रोफेसर इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर, छत्तीसगढ़

(इ) सम्मानित डिग्री : कृषि विज्ञान मे परास्नातक– मृदा विज्ञान एवं कृषि रसायन

छात्र के हस्ताक्षर

प्रमुख सलाहकार के हस्ताक्षर

दिनांक ....

विभाग के प्रमुख के हस्ताक्षर

सारांश

वर्तमान शोध अनुसंधान प्रक्षेत्र भारतीय कृषि अनुसंधान संस्थान (नई दिल्ली) के भारतीय धान अनुसंधान संस्थान हैदराबाद तेलंगाना में खरीफ 2016 में किया गया। जिसका शीर्षक "सिंचित धान के नत्रजन के विभिन्न श्रोतो का नत्रजन उपयोग दक्षता पर प्रभाव का अध्ययन "प्रायोगिक प्रक्षेत्र के कन्हार मृदा पर अध्ययन किया गया। इसमें उपलब्ध नत्रजन , फास्फोरस और पोटेशियम सामग्री क्रमशः कम, उच्च और उच्च थी।

इस प्रयोग के अंतर्गत यादाच्छिक ब्लॉक रूप में रखा गया जिसके तीन प्रतिकृति के साथ 16 उपचार में किया गया जो इस प्रकार है। उपचार प्रयोग में टी 1 नियंत्रण टी 2 50 प्रतिशत नत्रजन का निर्धारित दर के साथ सामान्य यूरिया : टी 3 50 प्रतिशत नत्रजन का निर्धारित दर के साथ बहुलक यूरिया : टी 4 50 प्रतिशत नत्रजन का निर्धारित दर के साथ नीम लेपित यूरियाः टी 5 50 प्रतिशत नत्रजन का निर्धारित दर के साथ केंचुआ खाद्य : टी

6 50 प्रतिशत नत्रजन का निर्धारित दर के साथ धान का पुआल : टी 775 प्रतिशत नत्रजन का निर्धारित दर के साथ सामान्य यूरिया : टी 8 75 प्रतिशत नत्रजन का निर्धारित दर के साथ बहुलक यूरिया : टी 9 75 प्रतिशत नत्रजन का निर्धारित दर के साथ नीम लेपित यूरिया : टी 10 75 प्रतिशत नत्रजन का निर्धारित दर के साथ केंचुआ खाद्य : टी 1175 प्रतिशत नत्रजन का निर्धारित दर के साथ धान का पुआल से टी 12100 प्रतिशत नत्रजन का निर्धारित दर के साथ सामान्य यूरिया : टी 13 100प्रतिशत नत्रजन का निर्धारित दर के साथ बहुलक यूरिया : टी 14 100 प्रतिशत नत्रजन का निर्धारित दर के साथः नीम लेपित यूरिया : टी 15 100 प्रतिशत नत्रजन का निर्धारित दर के साथ केंचुआ खाद्य : टी 16100 प्रतिशत नत्रजन का निर्धारित दर के साथ

इस प्रयोग मे परिणाम स्परूप पौधे की ऊंचाई (सेमी) के रूप में फसल की व्यवस्था और पोषक प्रबंधन से काफी प्रभावित है।टी 13 100 प्रतिशत नत्रजन का निर्धारित दर के साथ नीम लेपित यूरिया के तहत उच्चतम मूल्य दर्ज किया गया है। इसके बाद टी 14 100 प्रतिशत नत्रजन का निर्धारित दर के साथः बहुलक यूरिया के 100ः नत्रजन का निर्धारित दर के साथ (एनसीयू) के बाद टी 14–100ः नत्रजन का निर्धारित दर के साथ से (पीसीयू) के बाद किया गया। चावल की उपज गुण, अर्थात कंसे की संख्या मी^{2}, बाली की संख्या मी^{2}, प्रतिबाली अनाज की संख्या, कंसे की लंबाई, भरे हुए अनाज प्रतिशत, फसल की व्यवस्था और पोषक प्रबंधन पर प्रभाव पढा। सभी उपचारों में टेस्ट वजन पाया गया, जिस पर प्रभाव नहीं पढा। उपचार टी 13 के तहत अनाज और पुआल की पैदावार सबसे ज्यादा पाया गया। 100 प्रतिशत नत्रजन का निर्धारित दर के साथः नीम लेपित यूरिया (एनसीयू) के बाद उपचार टी 14 100ः प्रतिशत नत्रजन का निर्धारित दर के साथ बहुलक यूरिया (पीसीयू) मे पाया गया। सबसे कम अनाज और पुआल की पैदावार उपचार टी 1 मे प्राप्त की गई।

धान की कटाई के बाद मृदा पोषक तत्व स्थिति, उच्चतम उपलब्ध नाइट्रोजन, उपलब्ध फास्फोरस और उपलब्ध पोटेशियम को उपचारटी 13 100 प्रतिशत नत्रजन का निर्धारित दर के साथ नीम लेपित यूरिया (एनसीयू)उपचार मे प्राप्त कियागया। नाइट्रोजन उपयोग दछता, फास्फोरस उपयोग दछता और पोटेशियम उपयोग दछता उपचार टी 13 100 प्रतिशत नत्रजन का निर्धारित दर के साथ नीम लेपित यूरिया (एनसीयू) में दर्ज किया गया सबसे कम नाइट्रोजन उपयोग दछता, फास्फोरस उपयोग दछता और पोटेशियम उपयोग दछता उपचारटी 1 नियंत्रण के तहत रिकॉर्ड किया गया नाइट्रोजन का उपयोग दक्षता, फॉस्फोरस उपयोग दक्षता और पोटेशियम उपयोग दक्षता दर्ज की गई थी। उपचार टी 13 100 प्रतिशत नत्रजन का निर्धारित दर के साथ बहुलक यूरिया के तहत उच्चतम

मूल्य दर्ज किया गया। इसके बाद उपचार टी 14 100 प्रतिशत नत्रजन का निर्धारित दर के साथ नियंत्रण (टी 1) के तहत दर्ज किया गया था। अधिकतम उत्प्रेरक100 प्रतिशत नत्रजन का निर्धारित दर के साथ नीम लेपित यूरिया (एनसीयू)। डीहाइड्रोजनेज को उपचार टी 15 100 प्रतिशत नत्रजन का निर्धारित दर के साथ केंचुआ खाद्य के तहत अधिकतम दर्ज किया गया ।

CHAPTER 1
INTRODUCTION

Rice is India's pre- eminent crop, and is the staple food of the people of the eastern and southern parts of the country. Rice is one of the chief grains of India. Moreover, this country has the largest area under rice cultivation, as it is one of the principal food crops. It is infact the dominant crop of the country. India is one of the leading producers of this crop. Rice is the basic food crop and being a tropical plant, it flourishes comfortably in hot and humid climate. It is estimated that by 2018 the demand for fertilizer N is predicted to increase by 29.1% in East Asia and by 24.5 % in Southeast Asia (FAO, 2015). However, it is worth mentioning that the nitrogen levels and sources of applied fertilizer N, either expressed as crop N recovery or agronomic efficiency, in rice is very low.

Several strategies have been tried to enhance nitrogen use efficiency (NUE) in rice including split N application, the use of slow release N fertilizers and nitrification inhibitors (NIs). Although, most of the NIs such as nitrapyrin, dicyandiamide and ammonium thiosulphate remain still unpopular with most of the Asian farmers due to their high cost and limited availability Kumar *et al.* (2010). Hence, need is being increasingly felt to develop some enhanced efficiency fertilizers for increasing NUE and reduced inputs of N fertilizers. The ICAR-Indian Agricultural Research Institute pioneered the discovery and development of neem products as fertilizer urea adjuvants. In this direction, use of neem oil coated urea (NOCU) holds a great promise in India. Kumar *et al.* (2010) reported that neem (*Azadirachta indica)* coated urea increased NUE (N recovery and AE) in rice substantially. It is possible that the coated oil assists the plant in capturing N or may provide additional growth benefits. A recent study Kashiri and Kumar (2016) concluded that citronella oil has nitrification inhibiting properties, and has a potential to substitute the neem oil, if coated onto prilled urea.

Indian rice productivity is still well below the world's average yield of 4.36 t ha^{-1} (FAO, STAT, 2014). It demands temperature of around 25 ^{0}C and above and rainfall of more than100 cm. Rice is also grown through irrigation in those areas that receive comparatively less rainfall. Rice can be cultivated by different methods based on the type of region. But in India, the traditional methods are still in use for harvesting rice. The fields are initially ploughed and then fertiliser is applied which typically consists of cow dung and then the field is smoothed. The seeds are transplanted by hand and then through proper irrigation, the seeds are cultivated. Rice grows on a variety of soils like silts, loams and gravels. It can also tolerate alkaline as well as acid soils. However, clayey loam is well suited to the raising of this crop. Actually the clayey soil can be easily converted in to mud in which rice seedlings can be transplanted easily. Proper care has to be taken as this crop thrives if the soil remains wet and is underwater during its growing years.

Rice fields should be level and should have low mudwalls for retaining water. In the plain areas, excess rainwater is allowed to inundate the rice fields and flow slowly. Rice raised in the well watered lowland areas is known as lowland or wet rice. In the hilly areas, slopes are cut into terraces for the cultivation of rice. Thus, the rice grown in the hilly areas is known as dry or upland rice. Interestingly, per hectare yield of upland rice is comparatively less than that of the wet rice. The regions cultivating this crop in India is distinguished as the western coastal strip, the eastern coastal strip, covering all the primary deltas, Assam plains and surrounding low hills, foothills and Terai region- along the Himalayas and states like West Bengal, Bihar, eastern Uttar Pradesh, eastern Madhya Pradesh, northern Andhra Pradesh and Odisha. India, being alando feternal growing season, and the deltas of Kaveri River, Krishna River, Godavari River, Indravati River and Mahanadi River with a thick set-up of canal irrigation like Hirakud Dam and Indravati Dam, permits farmers to raise two, and in some pockets, even three crops a year. Irrigation has made even three crops a year possible. Irrigation has made it feasible even for Punjab and Haryana, known for their baked climate, to grow rice. They even export their excess to other states. Punjab and Haryana grow prized rice for export purposes. The hilly terraced fields from Kashmir to Assam are idyllically suited for rice farming, with age-old hill irrigational conveniences. High yielding kinds, enhanced planting methods, promised irrigation water supply and mounting use of fertilizers have together led to beneficial and quick results. It is the rain fed area that cuts down average yields per hectare. In some of the states like West Bengal, Assam and Orissa two crops of rice are raised in a year. Winter season in the north western India are extremely cold for rice.

Rice is considered as the master crop of coastal India and in some regions of the eastern India where during the summer monsoon rainy season both high temperature and heavy rainfall provide ideal conditions for the cultivation of rice. Almost all parts of India are suitable for raising rice during the summer season provided that the water is available. Thus, rice is also raised even in those parts of western Uttar Pradesh, Punjab and Haryana where low level areas are waterlogged during the summer monsoon rainy season. Rice is the staple food for about 50% of the population that resides in Asia, where 90% of the world's rice is grown and consumed. In Asia, India has the largest area under rice (44.6mha) accounting for 29.4% of the global rice area and record in terms of production (104.3mt) during 2014-15 and it stood next only to china in the world. The yield levels in India are low at 2.1t per ha compared to other major rice producing countries. Rice is produced under both upland and lowland ecosystems with about 76% of the global rice produced from irrigated-lowland rice systems (Fageria *et al.*, 2003).

Nitrogen is one of the most important and essential nutrients which directly influences the growth and development, yield and quality of rice. Nitrogen is universally deficient in majority of the agricultural soils and successful arable and flooded farming is impossible without the use of nitrogen fertilizers. Moreover, nitrogen fertilization aims at a high economic return of the investment through optimized crop yield and quality.

Now a day's consumption of N fertilizer is in increasing trend, but the fertilizer use efficiency is low in most of the fertilizer management practices. This cause to decrease in the yield of the rice, this may be due to low input use efficiency. The most limiting nutrient in irrigated rice is nitrogen and N recovery efficiency is only about 25-40% of applied N in most farmers' field mostly by leaching gaseous loss volatilization loss, surface run off. For control of declining yield and there is a need to achieve increased input-use efficiency

Nitrogen is the largest yield limiting nutrient in rice cropping. Therefore, efficient N fertilizer management is critical for rice production. Nevertheless, the complex nature of N transformation in soils, has led to low N use efficiency. The lower N use efficiency of fertilizers is a result of multiple loss mechanisms such as volatilization and denitrification and it is a major problem in rice crops. Low efficiency of N is not only responsible for higher cost of crop production, but also a major threat to environmental quality. The use of specially formulated form of fertilizer by supplemented with inhibitors have a great prospect to reduce N losses, improve fertilize N efficiency and produce positive impact to the environment. Nitrogen use efficiency (NUE) is a term used to indicate the relative balance between the amount of fertilizer N taken up and used by the crop versus the amount of fertilizer N lost. Nitrogen use efficiency represents the response of rice plant in terms of grain yield to N fertilizer.

Slow-release fertilizers (SRF) are often used to increase nitrogen-use efficiency and to allow for the provision of N over extended periods of time. As compared to “quick release” fertilizers, SRFs are designed to release N over an extended period of time, rather than all at once, in an attempt to better match plant N needs throughout the growing season and to reduce time of exposure for N losses to the environment. Slow release fertilizers release through a variety of methods including: microbial processes, chemical reactions, or bursting of a coating due to water vapor infiltration resulting in high internal pressures.Once a point of the coating breaks, the urea becomes exposed and left accessible to be hydrolyzed and further converted to other N forms. This process is relatively more unpredictable compared to Control release Fertilizers, making additional applications necessary during growing seasons and decreasing N use efficiency (Ellison*et al.*, 2013). This group of fertilizers includes 5 denitrification /nitrification inhibitors, long chain molecules requiring microbial decomposition, and granules coated in a substance to restrict water movement through hydrophobic or hydrophilic attractions (Aviv 2001).

Organic matters (OMs) are beneficial to soils with respect to their productivity as well as to remediation purposes. There has been significant growth enhancement of rice plants grown under the experimental condition with respect to the addition of OMs to the growing medium. Inorganic nitrogen released immediately after the application, fulfils the initial N requirement of the crop while the organic N mineralizes gradually at a steady rate catering the later requirement thus assuming continuous N supply throughout the growth period. Such situation promotes adequate N absorption by rice at different stages.

Although nutrient use efficiency mainly depends on the efficient fertilizer management, the existing N use efficiency pattern and the factors responsible for N use efficiency in existing popular fertilization methods need to be well understood for further improvement in N use efficiency.

In view of above, theexperiment entitled **" Studies on Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen ''**was conducted during *Kharif* 2016 at Research farm, ICAR - Indian institute of Rice Research (IIRR) (formerly DRR), Hyderabad, Telangana State with the following objectives.

OBJECTIVES:

1. To study the responses of rice crop at graded levels of Nitrogen.
2. To determine the influence of slow releasing N –fertilizers at graded N levels on growth and yield of Rice.
3. To determine the nutrient concentration, uptake and Nutrient use efficiency of the Rice crop
4. To study the influence of slow releasing N fertilizers on soil properties, under graded levels of slow releasing N – fertilizers.

CHAPTER- II

REVIEW OF LITERATURE

In this chapter, a review of literature pertaining to present investigation entitled **"Studies on various sources of Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen in irrigated rice"** especially with reference to its effect on growth, yield, nutrient uptake and soil properties carried out by various researchers in India and abroad has been briefly mentioned. The literature on the aspects is reviewed under following heads:

2.1 Influence of different nitrogen levels and sources on growth and yield attributes in irrigated rice.

2.2 Influence of different nitrogen levels and sources on nutrient content and their uptake and nutrient use efficiency by plant.

2.3 Influence of different nitrogen levels and sources on physico-chemical properties of soil.

2.4 Influence of different nitrogen levels and sources on enzymatic activities of soil.

2.1 Influence of different nitrogen levels on growth and yield attributes in irrigated rice

Prasad *et al*. (1999) conducted a field study made with rice at the Indian Agricultural Research Institute, New Delhi, which showed that coating urea with neem oil, neem cake or neem oil microemulsion improved rice growth and resulted in more grain and straw than commercial prilled urea. They further observed that nitrification inhibitor significantly increased the number of productive tillers, panicle length and weight, 1000-grain weight, and grain and straw yield of rice. Further as regards to sources of N, NCU recorded the highest number of productive tillers per hill and all neem-coated materials produced more grain and straw of rice than prilled urea.

Shivay *et al.* (2000) reported a significant increase in yield attributes with an increase in the level of fertilizer nitrogen.

Xu *et al.* (2000) reported that higher SCMR means greater nitrogen and chlorophyll and thus these values can be taken as an index for evaluation of

Sorghum genotypes for drought tolerance. Sudhakar *et al.* (2006) also reported the similar findings.

Fageria and Baligar (2001) reported that application of N in adequate amount accounted about 91% variation in panicles perm^2, about 75% variation in spikelet sterility, and about 73% variation in 1000-grainweight. Since N application significantly increased all the above three yield attributes, hence, a significant increase in grain yield was obtained due to application of N.

Ottis and Talbert (2005) reported a high correlation (R2 > 0.85) between yield and panicle density.

Tarikul (2007) conducted a field experiment at Shcr-e- Bangla Agricultural University. Dhaka during, 2008 to observe the effect of Nimin coated nitrogen (N) fertilizer over primed nitrogenous fertilizer on the yield and yield contributing characters of BRR1 dhan-29. The experiment was laid out in randomized block design with three replications with three levels of nitrogen (60, 90 and 120 kg N ha^{-1}) each from urea and nimin coated nitrogen fertilizer and one nitrogen control treatment. He found that the highest plant height, number of effective tillers and straw yield were found in nimin coated nitrogen at 120 kg ha^{-1}, which was statistically identical with nimin coated nitrogen 90 kg ha^{-1}. Also maximum yield (4.84 t ha^{-1}) and filled grain (146 Panical^{-1}) were observed from nimin coated nitrogen 90 kg ha^{-1} which was statistically similar with nimin coated nitrogen 120 kg ha^{-1}. Therefore Nimin coated nitrogen at 90 kg ha^{-1} is more economic and nitrogen use efficiency was higher than other treatments for BRRI dhan-29 cultivation. He found that different nitrogen levels significantly influenced uptake of nitrogen by BRR1 dhan 29. Between the two N sources as, the highest N uptake by BRRI dhan- 29 was recorded in 120 kg nimin coated ha^{-1}. Further in all cases the uptakes of nitrogen i.e. from grain and from soil were affected by different nitrogen fertilizers, nimin coated nitrogen at 120 kg ha^{-1} performed the highest results.

Bhalla and Prasad (2008) recorded significant increase in the growth of paddy plant parts by halving the urea used and pelleting the remaining with neem cake prior to application. Their results on an averaged data set showed significant increase in leaf length, number of leaves, number of panicles, number of tillers and greenness of leaves. The results indicated higher availability of nitrogen in the treatment. They commented that this could be attributed to inhibition of de-nitrifying bacteria by neem as well as a slower continuous release of nitrogen when urea is pelleted with neem than when it is applied directly. There statement made a strong case for cutting down on nitrogen application in paddy using low-cost, readily available materials, without compromising on the yield.

2.2 Influence of different nitrogen levels and sources and on nutrient content and their uptake

Bains *et al.* (1971) reported that neem extractants are very effective in terms of increasing grain yield and protein content of rice. Simiar findigs were reported by Ketkar (1974), Thomas and Prasad (1983), Chakravorti (2006).

Reddy and Prasad (1977) reported that the increase in rice yield due to neem cake coated urea over uncoated has ranged from11.1% to 54.2% at 100kg N ha^{-1}. Similar findigs were reported by Surve and Daftardar (1985).

Subbiah *et al*. (1979) conducted a field trial in 1978-9 rice cv. IR20 in the wetlands of Tamil Nadu on a sandy clay loam soil with nutrient levels of 60, 90 or 120 kg urea ha^{-1} with or without a coating of neem cake in addition to 60 kg P_2O5 and 60 kg K_2O ha^{-1}. Results revealed that application of neem cake-coated urea increased grain and straw yields by 19-21% and 19-24%, respectively when compared with applications of urea alone. They further reported that application of neem cake-coated urea also increased N and P uptake in the grain and straw. However K uptake decreased with increasing N application.

Bawasakar *et al.* (1980) observed that split applications (total amount of N divided into four applications) of neem cake blended urea give a higher yield than a single basal application (all N applied before planting). However, trials with neem oil have produced better results than with neem cake (Indian Agricultural Research Institute 1983).

Thomas and Prasad (1987) studied the performance of NCU in five different soils and found that NCU was inferior to that of nitrapyrin. Agarwal *et al.* (1990) reported that in wheat at 80 kg N ha^{-1} neem cake coated urea produced 5.4% more grain than uncoated urea.

Geethadevi *et al.* (1991) obtained larger rice yields in field experiments with NCU than with prilled urea. De *et al.* (1992) concluded that more than 30 kg N ha^{-1} can be saved in rice with Nimin coated urea in comparison to untreated urea.

Jena *et al*. (1993) conducted a field experiment on clay loam during the *kharif* season of 1989 at Chiplima, Orissa; rice grain yields increased with increase in N rate (0, 30 or 60 kg ha^{-1}). They recorded highest grain yield of 3.45 t ha^{-1} obtained from applying 60 kg N as neem coated urea in 2 equal splits (basal + tillering). They further added that at both N rates, prilled urea produced lower yields than coated urea fertilizers.

Kumar and Thakur (1993) also obtained larger yields of rice with NCU.

Mutanal *et al*. (1997) conducted a field experiment during 1992-94 rainy seasons at Sirsi in Karnataka to study the response of transplanted rice cv. IET 7191 to urea forms and nitrogen levels (50, 75 or 100 kg N ha^{-1}). They reported that application of nitrogen through nimin (neem seed extract)-coated urea gave better results than prilled urea.

Shukla and Chouhan (1998) conducted a field experiments during the 1993 rainy season. They observed that NCU significantly increased the mean rice grain yield compared with prilled urea. Further straw yields increased significantly with all of the indigenous urea coating materials, especially with NCU. They observed that N uptake and recovery of applied urea were significantly greater with coated urea materials than with prilled urea. N uptake and urea recovery were greatest after application of NCU. Available N in the soil increased up to 60 DAT of rice and decreased thereafter in all treatments, but soil available N was highest in plots given NCU at each growth interval. They concluded that neem cake-coated urea is superior to prilled urea in respect of rice yield, N uptake and nutrient recovery.

Kumar (1999) conducted a field experiment during the rainy season (*kharif*) 1996-97 at Faizabad, Uttar Pradesh, India with transplanted rice cv. NDR 359. which was given N fertilizer as prilled urea, urea coated with neem cake, mahuwa cake or coal tar, urea form, or urea mixed with farmyard manure or clay. They recorded that yield; N uptake and N use efficiency were highest with urea coated with neem cake as compared to prilled urea.

Prasad *et al.* (1999) and Shivay *et al.* (2000) have also observed the superior eff ects of modified urea fertilizers on yield attributes as compared to polyurethane-urea (PU).

Rao *et al*. (2000) carried out at field experiment at Bangalore, Karnataka, during summer 1995 on alfisols to study the relative efficiency of neem-coated and prilled urea for lowland rice under two irrigation regimes. They recorded that nimin-coated urea gave significantly higher grain yield (6237 kg ha^{-1}) and increased the nitrogen use efficiency (94.93 kg grain kg^{-1} N) as compared to prilled urea (grain yield: 5203 kg^{-1}; NUE; 79.88 kg grain kg^{-1} N).

Prasad *et al.* (2001) reported that at New Delhi's research farm there was a increase from 6% to 12% higher in farmer's field due to coating of prilled urea at higher neem-oil thickness (e.g. 2000 mg kg^{-1} PU), in general, was not advantageous, especially with respect to grain and straw yields, over PU.

Shivay *et al.* (2001) have also recorded the highest yield at 120kg Nha^{-1} over control.

Singh and Singh (2003)reported that increasing levels of nitrogen significantly increased the number of effective tillers $hill^{-1}$, panicle length, panicle weight, grain and straw yields and nitrogen uptake, by there revealing a significant decline in agronomic nitrogen use efficiency. They found that NCU was significantly superior to other sources with regards to panicle length, grain yield, N uptake, agronomic nitrogen use efficiency and apparent N recovery (%), indicating that coating urea with neem formulations not only increased the grain yield, NUE and apparent N recovery, but also helped to reduce the environmental hazards associated with the use of large amounts of urea.

Mangat and Narang (2004) conducted a study during *kharif* and *rabi* seasons of 2002-2003 in Punjab and Haryana, for evaluating agronomical efficiency of NCU using rice and wheat as test crops. At 80% level of recommended dose of urea application through NCU in paddy crop, the yield obtained were comparable when urea was applied at 100% level of recommended dose through normal prilled urea i.e., urea dose can be reduced by 50 kg ha^{-1} with marginal or non-significant reduction in yield when NCU was used. They reported that NCU, when applied at 100% level of recommended levels, gave significantly higher yield in wheat crop in Haryana but when NCU was applied at 80% level, the yield was reduced significantly.

Suganya *et al*. (2007) conducted a field experiment to assess the influence of neem coated urea products on yield and nitrogen use efficiency in rice grown in different soils at TNAU, Coimbatore (ADT 46) and SWMRI, Kattuthottam, Thanjavur (ADT 36). The results revealed that the highest per cent increase in grain yield over prilled urea was recorded under P4: 0.1% neem gold coated urea, (19.9) and P5: (0.2%) neem gold coated urea, P5 (20.4) in Noyyal and Madukkur soil series, respectively. Apparent nitrogen recovery was highest at P3, P4 and P5. Thus, the application of 0.3% neem oil coated urea, 0.1% and 0.2% neem gold coated urea at 125 kg N ha^{-1} to rice crop, increased the grain and straw yield and nitrogen use efficiency in Noyyal and Madukkur soil series in corporation to prilled urea.

Kumar *et al*. (2010) found that nitrogen fertilizer use efficiency (20–50%) is low in rice field in India. They conducted field experiments during *kharif* (rainy) season years, 2004 and 2005 at the Research Farm of Indian Agricultural Research Institute, New Delhi to find out the effect of neem coating on N-use efficiency and yield. The treatments comprised of three N levels (50, 100, and 150 kg N ha^{-1}) plus a no-N control. Application of urea coated with neem-oil resulted in significantly higher growth, yield parameters, grain yield, N uptake, and efficiency of aromatic rice (*Oryza* unsaturated fractions were coated on prilled urea with three loading capacities (500, 1000 and 5000 mg kg^{-1} prilled urea). The results of the field trials using standard protocols in terms of grain yields revealed that the meliacin fraction-coated urea outperformed over all other fractions which did not differ in performance. They found that the yield of paddy grains were 5.98-6.30 t ha^{-1} with meliacins coated urea treatment as compared to 4.92-5.13 t ha^{-1} with prilled urea alone in the biennial study. The other four fractions produced paddy grains yields in the range of 5.57-5.85 t ha^{-1} and this yield increase amounted to 0.65-0.72 t ha^{-1} over prilled urea.

Bhatt (2012) reported that the pattern in paddy yield was identical, with 100% N applied as NCU performed significantly better (7.3 t ha^{-1} and 6.6 t ha^{-1} in 2007 and 2008, respectively) than 80 % N applied either as ordinary urea (6.1 t ha^{-}

^{1}and 5.8 t ha^{-1}, respectively) or as NCU (6.2 t ha^{-1} and 5.9 t ha^{-1}, respectively) but being statistically at par with the treatment involving 100 % of N given as ordinary urea (7.2 t ha^{-1} and 6.5 t ha^{-1}, respectively).

2.3 Influence of different nitrogen levels and sources on physico-chemical properties of soil

Awasthi and Mishra (1987) reported that mineralization in the soil was delayed by 20 days by neem seed cake on silty clay loam soil at Pantnagar. Ammonical nitrogen gradually increased upto a period of 30 days and thereafter showed a decreasing trend on clay loam soil in Puna.

Vyas *et al.* (1991) noted that significantly lower trends of Nitrification (NO_2 + NO_3 - N content) atleast one month with nimin coated urea treated soils in comparision with uncoated urea. NH_4 - N content in soil was greatest at tillering stage of the crop and declined subsequently upto crop maturity. Its content increased with an increse in N levels from 15.4 ppm to 22.4 ppm, respectively.

2.4 Influence of different nitrogen levels and sources on enzymatic activities of soil

2.4.1 Urease

Determination of urease activty in soils provide a good index about the ability of soils to hydrolyse urea. Urease (urea amino hydrolase) is a unique enzyme because it catalysts of urea to ammonia (NH_3) which is subsequently transformed to ammonium (NH_4^+) and nitrate (NO_3^-) ions.

A study at Pantnagar showed that the urease activity reduced from 11.8 to 9.4 mg urea kg^{-1} soil hr^{-1} when neem cake (20% w/w) was incorporated in soil (Reddy and Mishra, 1983).

Reddy and Chhonkar (1991) observed that neem cake (2mg kg^{-1} soil) urease activity in the initial stages in sandy clay loam soil at Hyderabad.

NCU has consistently demonstrated its ability to inhibit the activity of the enzyme urease. Its urease inhibiting activity in the soil is associated with the activity of its derivative, the oxygen analogue, N-(n-butyl) phosphoric triamide, it prevents N losses by temporarily inhibiting urease activity (Gardner, 1995), slowing the urease-catalyzed transformation of urea to ammonium minimises ammonia losses and allows time for absorption or dissipation of the N forms into the soil.

2.4.2 Dehydrogenase

Manna *et al.* (2005) reported that dehydrogenase (µg TPF g^{-1} soil 24^{hr-1}) and phosphatase (µg P-nitro phenol g^{-1} soil h-1) activity significantly decreased under 100% N (50.8 and 120) and 100% NP (70.8 and 144) application while they increased with balanced fertilizer application i.e., 100% NPK (86 and 199) and integrated application of 100% NPK +FYM (118 and 223) under long term rice-rice cropping system at Barrackpore.

Shingha *et al.* (2014) observed the highest dehydrogenase activity as 2.09, 1.58 and 1.30 µg TPF g^{-1} hr^{-1} and the lowest as 0.92, 0.50 and 0.21 µg TPF g^{-1} hr^{-1} in 0-10, 10-20 and 20-30 cm depth, respectively. The results recognized that NPK application had a major role in dehydrogenase activity.

CHAPTER III

MATERIALS AND METHODS

The details of materials used and methodologies adopted during the course of present investigation are elucidated under appropriate heads in this chapter. The present investigation entitled **“Studies on Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen’’**was carried out under field conditions during *kharif* 2016 at the Research Farm of the ICAR - Indian Institute of Rice Research (IIRR) (formerly DRR), Hyderabad, Telangana state. The details of the research work carried out, materials used and methodologies adopted in this investigation are described here under.

3.1 Experimental site

The field experiment was conducted at the Research Farm of the Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad, Telangana state. The farm is geographically located at $17^{o}19'$ N latitude, $78^{o}23'$ E longitude with an altitude of 1719 ft.

3.2 Details of the field experiment

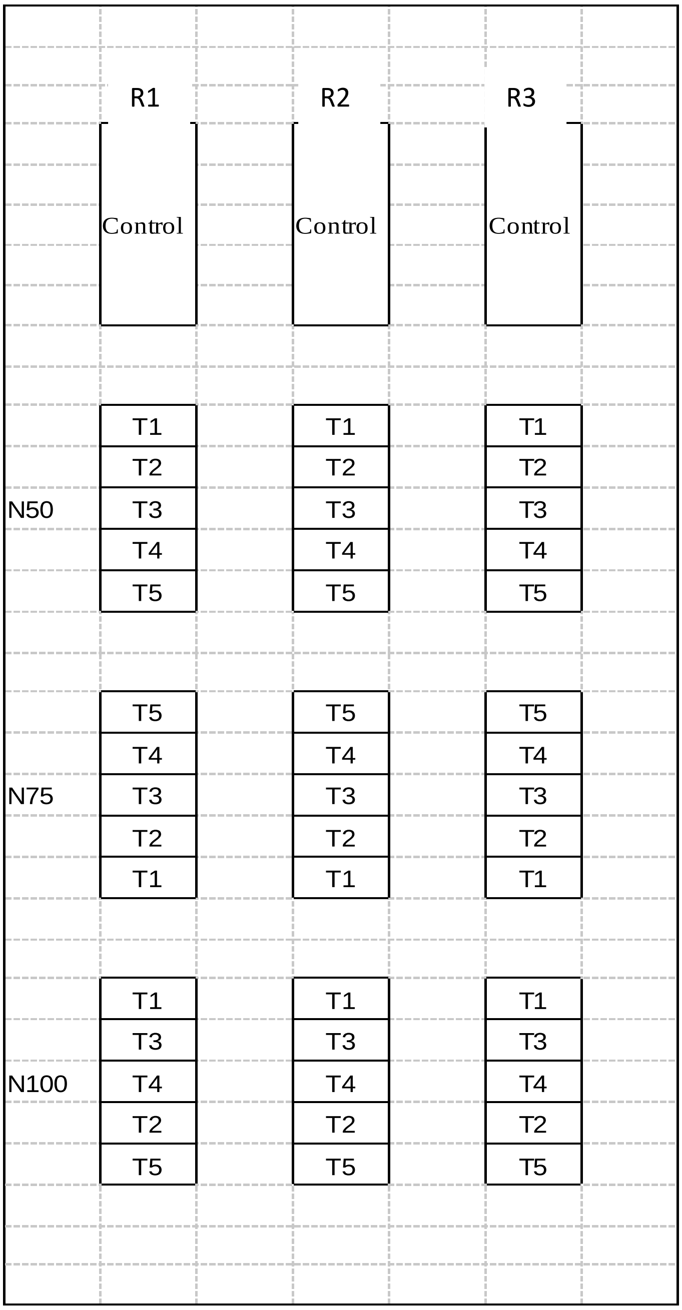
3.2.1 Soil characteristics

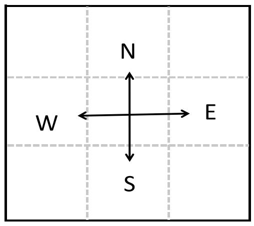
The present study was taken up in *kharif* 2016. Representive soil samples were collected before layout of the experiment and analyzed after processing.

Table 3.1: Properties of experimental soil at the initiation of the experiment

Particulars	Values	Status	Method followed
I. Physical properties			
1. Sand (%)	43	-	International pipette method (Black 1966)
2. Silt (%)	25	-	
3. Clay (%)	32	-	
4. Soil textural class	Clay loam		
7. Bulk density (Mg m^{-3})	1.45	-	Soil core method (Blake and Hartge,1986)
II. Chemical properties			
1. pH (1:2.5)	8.24	alkaline	Glass electrode pH meter (Piper 1967)
2. EC (1:2.5) (dS m^{-1})	0.74	Non saline	Solu bridge as described by Black(1965).
3. Organic carbon (%)	0.85	High	Wet oxidation method (Walkley and Black, 1934)
4. Available N (kg ha^{-1})	242	Low	Alkaline potassium permanganate method (Subbaiah and Asija, 1956)
5. Available P(kg ha^{-1})	41	high	Sodium bicarbonate (Olsen *et al.*, 1954)
6. Available K (kg ha^{-1})	376	High	Ammonium acetate soil method (Hanway and Heidel, 1952)

Fig- 3.1 :Layout of the experiment





Nitrogen Levels

N-50

N-75

N-100

Sources :

T1: Prilled Urea (PU)

T2: Neem Coated Urea (NCU)

T3: Polymer Coated Urea (PCU)

T4: Vermicompost (VC)

T5: Rice straw (RS)

Table 3.2 : Treatment details of experiment

Notation		Treatment
T1	:	Control
T2	:	50% RDN fromPrilled urea (PU)
T3	:	50% RDN fromNeem coated urea (NCU)
T4	:	50% RDN fromPolymer coated urea (PCU)
T5	:	50% RDN fromVermi compost (VC)
T6	:	50% RDN from Rice straw (RS)
T7	:	75% RDN from Prilled urea
T8	:	75% RDN from Neem coated urea
T9	:	75% RDN from Polymer coated urea
T10	:	75% RDN from Vermi compost
T11	:	75% RDN from Rice straw
T12	:	100% RDN from Prilled urea
T13	:	100% RDN from Neem coated urea
T14	:	100% RDN from Polymer coated urea
T15	:	100% RDN from Vermi compost
T16	:	100% RDN from Rice straw

Table 3.2.(a) Details of the variety and plot size

Variety	:	varadhan
Design	:	Randomized block design
Replications	:	3cm x 15cm
Plot size	:	7.1 x 4.2 m = 28.4
Spacing	:	20cm × 15 cm
Date of nursery	:	27-06- 2016
Date of transplanting	:	04-08- 2016
Date of Harvesting	:	01 - 11- 2016

3.3 Cultivation details

The details of field operations are given in Table 3.3.

3.3.1 Field preparation

The experimental field was ploughed twice with tractor drawn plough and finally with cultivator to get fine tilth. Later the stubbles were removed and the field was uniformly leveled. Soil was puddled for transplanting.

3.3.2 Nursery Sowing and transplanting

Rice variety Varadhan was the test crop. Healthy, matured and viable seeds were used for sowing. The seed bed was prepared and the seed was broadcast in seed bed for transplanting. Seedlings of 38 days old were transplanted in the puddled soil at 20×15 cm spacing.

3.3.3 Gap filling and thinning

Gap filling was done one week after sowing to maintain desired plant.

3.3.4 Irrigation management

First irrigation was given immediately after sowing and subsequent irrigations were given up to 3-5 cm of standing water was maintained until 2 weeks before harvest.

3.3.5 Weeding

The crop weed competition was kept at minimum by taking up manual weeding at 20 DAT and 45 DAT.

Table 3.3 : Calendar of operations (Rice, *kharif* 2016)

Field operation	Date
Initial soil samples collection	18-07-2016
Land preparation and leveling	20-07-2016
Field layout	20-07-2016
Date of sowing in Nursery	27-06-2016
Date of Transplanting	04-08-2016
Application of Herbicide	10-08-2016
Soil sampling for enzymes at maximum tillering stage	03-09-2016
Biometrical observation at maximum tillering stage	01-09-2016
SPAD meter reading	06-09-2016
Soil sampling for enzymes at panicle initiation stage	07-09-2016
Soil sampling for enzymes at harvest stage	02-1-2016
Date of Harvesting	01-11-2016
Soil samples collection (after harvest)	06-11-2016
Dry weight of straw and grain (plot wise)	06-11-2016

3.3.6 Fertilizer application

N, P, and K @ 100-40-40 kg^{-1}.Full quantity of Paddy Straw and Vermicompost were applied as basal dose only.

3.3.7 Plant Protection

The crop was not affected from pest and diseases. However, Monocrotophos @ 1.5% was sprayed at maximum tillering stage (45 DAT) and panicle initiation (90 DAT) stages to control stem borer damage at initial crop growth stage.Tricyclozole was added to control blast disease.

3.3.8 Harvesting

The crop was harvested at 125 days after DAT.The panicles from each plot were sun dried properly to facilitate easy threshing. Threshing and winnowing were done manually and grain was dried properly.

3.4 Growth and yield parameters

3.4.1 Plant height (cm)

The plant height (cm) was measured from randomly selected five hills selecting main shoot and recording plant height from ground level to the base of the fully opened leaf. The mean plant height was worked out and expressed in centimetres.

3.4.2 Number of tillers m^{-2}

Number of tillersrecorded from the randomly selected one metre row length from five places in each plot at harvest.They were pooled and average number of tillersm^{-2}was presented.

3.4.3 Number of panicles m^{-2}

Number of paniclesm^{-2}was counted from randomly selected one metre row length from five places in each plot at harvest and then converted in to m$^{-2.}$

3.4.4 Number of grains panicle^{-1}

Grains from randomly selected panicles were counted manually and average was taken.

3.4.5 Test weight (g)

Thousand grain counts was recorded by "NUMIGRAL" seed counter, a seed counting machine, which automatically stops after counting 1000 grains. The weight was recorded in grams.

3.4.6 Filled grains percentage

The five panicles from each plot were randomly selected and filled grains were counted then mean was calculated.

3.4.7 Grain and Straw yields (q ha^{-1})

Grain and straw yields were recorded (q ha^{-1}). Grain yield was recorded at 14 per cent moisture level. The straw was sun dried properly and the yield was recorded at about 14%.

3.5 Collection of samples

3.5.1 Plant samples

Plant samples were collected at harvest of rice crop and were oven dried. The dried samples were powdered and analyzed for N, P and K using standard procedures.

3.5.2 Soil samples

Initial and post-harvest surface soil samples 0-15 cm were collected, processed and analysed for pH, EC, organic carbon, available N, P and K.

3.5.3. Soil samples for enzymatic activity

Soil samples of each treatment were collected at maximum tillering stage, panicle initiation stage and at harvest stage, that was immediately stored in polythene bags. The soils were preserved and stored at 5 ^{o}C in a refrigerator until analysis. Soils were taken from refrigerator and incubated at 23+2 ^{o}C for 2 days before analysis. These samples were utilized for the determination of soil enzyme activities.

3.6 Analysis

3.6.1 Plant Analysis

Straw and grain samples, collected plot wise at harvest, were used for estimation of nitrogen, phosphorous, potassium and zinc contents. Straw and grain samples collected were first shade dried and then oven dried at 65 ^{o}C. The dried straw and grain samples were powdered and the finely ground material was used for chemical analysis. In these samples N, P and K were analyzed by adopting the standard procedures (Piper, 1966).

3.6.1.1 Nitrogen

The nitrogen content of grain and straw samples was estimated by digestion with conc. H_2SO_4 followed by distillation with NaOH using Kjeidahl distillation unit. 0.5g of finely powdered plant sample was weighed in to a 300 mL tube. 10 mL of conc. H_2SO_4 and 3-4 g of catalyst mixture (K_2SO_4 + $CuSO_4$ in a ratio of 5:1) were added. The tubes were placed in Kelplus digestion unit and heated at 410 ^{o}C for 1-2 hours till digestion was completed. The test tubes were removed from the digestion chamber and cooled to room temperature.

The tube with digested contents was placed in the distillation unit. 20 mL of 4% boric acid containing mixed indicator was taken in a 250 mL conical flask and placed it under the receiver tube (dipped the receiver tube end in the boric acid). Then 15 mL of 40% NaOH was added and distillation process (running steam) was carried out for 6 minutes. After completion of distillation for, conical flask was taken out. Titrated the contents of the flask against 0.02 *N* H_2SO_4 till the color changed from bluish green to pink colour (Piper, 1966). Nitrogen content was calculated from the titre value and expressed as percent.

3.6.1.2 Digestion of plant samples for P & K

One gram each of oven-dried and processed grain and straw samples were digested with a 9:4 mixture of nitric acid and perchloric acid on a hot plate. The clear digested residue was cooled, diluted to 100 mL distilled water and filtered to remove insoluble silica.

3.6.1.3 Phosphorus

In digested extract, phosphorus content was determined by Vanado–molybdo phosphoric yellow color method as described by Piper (1966) using Spectrophotometer (Elico SL – 177) at 420 nm and P content was expressed as percent.

3.6.1.4 Potassium

Potassium content in the diacid digest was determined using flame photometer (Elico CL 361) (Piper, 1966) and expressed as percent.

3.6.2 Soil analysis

The soil samples collected plot wise at different growth stages of the crop *viz.,* maximum tillering, panicle initiation and harvest stages were used for assay of enzyme activity in soil. The initial soil sample and plot wise samples collected at harvest. All the samples collected were analyzed for physico-chemical and chemical properties and contents of NPK following standard procedures as given below.

3.6.2.1 Soil reaction

Soil reaction (pH) was determined in 1:2.5 soil: water suspension using pH meter (Elico LI 610) after shaking the sample with water for 30 minutes (Jackson, 1967).

3.6.2.2 Total soluble salts

Total soluble salts were determined in 1:2.5 soil: water suspension using digital EC meter (Elico CM 183) (Jackson, 1967) and expressed as Electrical Conductivity (dS m^{-1}).

3.6.2.3 Organic carbon (%)

Organic carbon content was determined in 0.5 mm sieved soil samples by wet digestion method (Walkley and Black, 1934) and expressed in percentage.

3.6.2.4 Available nitrogen (kg ha^{-1})

Available nitrogen in the soil was determined by alkaline permanganate method as described by Subbaiah and Asija (1956) and expressed as kg ha^{-1}.

3.6.2.5 Available phosphorus (kg ha^{-1})

Available phosphorus was extracted from soil by Olsen's reagent as described by Olsen *et al.* (1954). The blue color was developed following ascorbic acid method of Watanabe and Olsen (1965) and the intensity of blue color was measured at 660 nm by using Spectrophotometer (Elico SL – 177). The available phosphorus content was calculated and expressed as kg P_2O_5 ha^{-1}.

3.6.2.6 Available potassium (kg ha^{-1})

Available potassium was extracted from soil using neutral normal ammonium acetate and was determined by using Flame photometer (Elico CL 361) as described by (Hanway and Heidel, 1952) and expressed as kg K_2O ha^{-1}.

3.6.3 Assay of Enzyme Activity in Soil

The soil samples collected at MT, PI and at harvest of crop were assessed for the activities of urease, dehydrogenase and phosphatase as per the procedures given below.

3.6.3.1 Assay of urease activity

Urease activity was assayed by quantifying the rate of release of NH_4^+ from the hydrolysis of urea as described by Tabatabai and Bremner (1972).

5 g of soil was taken in a 50-mL volumetric flask, 0.2 mL of toluene and 9 mL of THAM buffer were added, swirled the flask for a few seconds to mix the contents and added 1 mL of 0.2 *M* urea solution. Swirled the flask for a few seconds stoppered and placed it in an incubator at 37 ± 0.5^{o}C for 2 hr. Removed the stopper, added approximately 35 mL of KCl-Ag_2SO_4 solution, swirled the flask for a few seconds, and allowed the flask to stand until the contents cooled down to room temperature. Made up the volume to 50 mL by addition of KCl-Ag_2SO_4 solution, stoppered the flask and inverted it several times to mix the contents. NH_4^+-N was determined in the resulting soil suspension taking a 20 mL aliquot of the suspension into a 100mL distillation flask, and determined the NH_4^+-N released by steam distillation with 0.2 g of MgO for 4 minutes. The urease activity was calculated and

expressed as µg of NH_4^+ released g^{-1} soil hr^{-1} as described by Tabatabai and Bremner (1972) with slight modifications.

3. 6.3.2 Assay of dehydrogenase

Dehydrogenase activity was assayed by quantifying the 2,3,5-triphenyl formazon (TPF) produced and expressed as mg TPF producedg^{-1} soil hr^{-1} as described by Cassida *et al.* (1964) with slight modifications.

Thoroughly mixed 20 g of air dried soil and 0.2 g of $CaCO_3$ in a 50 mL beaker, and 6 g each of this mixture was taken in three test tubes. To each tube added 1 mL of 3% aqueous solution of Triphenyl Tetrazolium Chloride (TTC) and 2.5 mL of distilled water. Mixed the contents of each tube with a glass rod, and stoppered the tube and incubated it at 37 ^oC. After 24 h, removed the stopper, added 10mL of methanol, and stoppered the tube. Tube was shaken for 1 min and filtered the suspension through a glass funnel plugged with absorbent cotton, into a 100 mL volumetric flask. Washed the tube with methanol and quantitatively transferred the soil to the funnel. Then added more methanol to the funnel until the reddish color has disappeared from the cotton plug. Made up the volume with methanol and the red colour intensity in the filtrate was measured on a spectrophotometer (Elico SL 177) at 485 nm. The dehydrogenase activity was calculated with respect to the amount of TPF produced and expressed as µg of TPF produced g^{-1} soil h^{-1}.

3.7. Nutrient Uptake

Nutrient uptake (N, P & K) was calculated using the grain and straw yields and nutrient content.

Nutrient uptake (kg ha^{-1}) in seed and straw = Seed and straw yield × Nutrient content.

3.8. Nutrient use efficiency: - It was calculated by using the following formula for nitrogen, phosphorus and potassium nutrients

$$NUE\ (\%) = \frac{\text{Uptake from treated plot} - \text{Uptake from control plot}}{\text{Total nutrient applied}} \times 100$$

3.9 Statistical analysis

The experiment was laid out in Randomized Block Design (RBD). The data obtained from various characters under study were analyzed by the method of analysis of variance as described by Gomez and Gomez (1984). The level of significance used in “F” test was given at 5 per cent. Critical difference (CD) values are given in the table at 5 percent level of significance, wherever the “F” test was significant at 5 percent level. The skeleton of analysis of variance and formula used for various estimations are given below:

Table 3.4: The skeleton of the analysis of variance

Source of variation	DF	SS	MSS	Fcal	Ftab	SEm±	CD 5%
Replicati	(r-1) = 2 (t-	RSS	RMS	RMS/			
on(r)	1) = 15 (r-	TrSS	TrMS	EMS			
Treatmen	1) (t-1) =	ESS	EMS	TrMS/E			
t(t) Error	30			MS			
Total	rt-1= 47						

The following formula was used for standard error, critical difference and coefficient of variance estimation.

(a) SEm± = √ E R

(b) CD = SEm± x √2 x t7 DF at 5%

(c) CV (%) = √ EMS x 100GM

Where, R = Number of replication, DF = Degree of freedom T = Number of treatment, SS = Sum of square CD = Critical difference, CV = Coefficient of variance MSS = Mean sum of square, EMS = Error mean square SEm ± = Standard error of mean, GM = Grand mean

CHAPTER -IV

RESULTS AND DISCUSSION

The present investigation entitled**" Studies on Nitrogen use efficiency in irrigated rice as influenced by various sources of Nitrogen "** was carried in *kharif* 2016 at the ICAR- Indian Institute of Rice Reasearch, Rajendranagar, Hyderabad. The details of the results obtained during the experimental period (June to November 2016) pertaining to various crop and soil parameters during the growth and after the harvest of rice due to the effect of NUE through different sources of nitrogen have been analyzed and the salient findings emerging out of the study are presented and have been discussed in this Chapter.

4.1 Characterization of initial soil sample

The results of initial soil sample (soil before taking up the crop) analyzed are presented in Table 4.1. The soil (black soil) was clay loam in texture with alkaline pH (8.24). It was non-saline (EC 0.74 dS m^{-1}) and high in organic carbon content (0.85%). The soil was low in available nitrogen (242 kg ha^{-1}), high in available phosphorus (41 kg P ha^{-1}) and high in available potassium (376 kg Kha^{-1}). Available zinc content (1.0 mg kg^{-1}) was above the critical level (0.6 mg kg^{-1}).

Table 4.1 :Initial soil properties

S. No	Soil properties	Value
1	Soil type	Black soil
2	Sand (%)	43
3	Silt (%)	25
4	Clay (%)	32
5	Soil textural class	Clay loam
6	Bulk density (Mg m^{-3})	1.45
7	pH (1:2.5)	8.24
8	EC (1:2.5) (dS m^{-1})	0.74
9	Organic carbon (g kg^{-1})	0.85
10	Available N (kg ha^{-1})	242
11	Available P(kg ha^{-1})	41
12	Available K (kg ha^{-1})	376
13	Available Zn (mg kg^{-1})	1.0

4.2 Effect of different nitrogen levels and sources on plant growth, yield attributes and yield of irrigated rice

Among the several factors responsible for increase in rice production, adequate supply of essential nutrients in a balanced way are the important factors for getting higher yields. Initial vigour, vegetative and reproductive growth of the plant plays an important role in realizing the potential yield of the crop.

4.2.1 SPAD chlorophyll meter reading (SCMR)

The data on SPAD reading reveal significant differences among the treatments both at tillering and panicle initiation and the maximum SPAD readings were recorded at 100% RDN from NCU (40) at panicle initiation stage and the lowest SPAD reading was recorded under Control (T1) at tillering stage (Table 4.2). In general higher SCMR means greater Nitrogen and Chlorophyll.The results observed in the present study are in confirmity with the results of Xu *et al.* (2000) and Sudhakar *et al.* (2006).

4.2.2 Plant height (cm)

Data pertaining to plant height (cm) at tillering, panicle initiation and harvesting stages of rice ranged from 47.21 to 62.88 cm, 70.05 to 82.89 and82.89 to 97.83 cm (Table 4.2). At tillering, the different nitrogen levels and sources had significant influence on the plant height with maximum 100% RDN of Neem coated urea (T13). This may be ascribed to the increase in availability of nitrogen from Neem coated urea along with RDN that was responsible for increased vegetative growth. In case of panicle initiation, the maximum plant height was observed in 100% RDN of Neem coated urea (T13).At harvesting, maximum plant height was observed in 100 % RDN of Neem coated urea (T13). This may also be attributed to the increased availability of nitrogen in these treatments. This corroborates the findings of Tarikul (2007).

4.2.3 Number of tillers m^{-2}

Data pertaining to number of tillers m^{-2} at tillering, panicle initiation and harvesting stages of rice were given in Table 4.2. Tiller numbers m^{-2} ranged from 325 to 397, 350 to 399 and 350 to 399 respectively (Table 4.2). At different stages, the different nitrogen levels and sources had significant influenced the number of tillers $m^{-2}$with maximum in 100 % RDN from NCU over control. This may be due to maximum easy in availability of nitrogenresponsible for vegetative growth. This corroborates the findings of Bhalla and Prasad (2008).

4.2.4 Panicle length (cm) and filled grains (%)

Data pertaining to panicle length (cm) and filled grains percentage at harvesting of rice ranged from 19.45 to 20.86 cm and 68.16 to 97.45 percent, respectively (Table 4.3). Treatment 100% RDN from NCU (T13) registered significantly higher panicle length over control, which was at par with rest of nitrogen use efficiency management practices except in control (T1). In case of number of filled grains percentage, treatment 100% RDN from (T13) recorded significantly higher value as compared to rest of the treatments. Similar trend was reported by Shivay *et al.* (2000) .

4.2.5 Test weight (g)

The size and boldness of rice seed measured as 1000-grain weight as influenced by different nitrogen levels and sources have been presented in (Table 4.3.). The test weight of rice varied from 27 to 30 g. All the treatments failed to give significant impact on test weight of rice. The maximum value of test weight was recorded with 100% RDN from NCU (T13).

4.2.6 Number of grains panicle^{-1} and number of panicle m^{-2}

Data pertaining to number of grain per panicle and number of panicles per m-2 at harvesting of rice ranged from 80 to 127.75 and 303 to 331., respectively (Table 4.3). All the treatments failed to give significant impact on number of panicle per per m-2 of rice. Among the different nitrogen levels and sources, the highest number of panicles m-2 was recorded in treatment 100% RDN from NCU (T13).These findings were corroborated with the findings of Ottis and Talbert (2005) and Bhalla and Prasad (2008).

4.2.7 Grain and Straw yield (q ha^{-1})

The average grain and straw yield of rice was significantly affected by different nitrogen levels and sources. The yields of grain and straw of rice varied from 21(q ha^{-1})to 41and 32(q ha^{-1}) to 54(q ha^{-1})respectively, in various treatments (Table 4.4 and Fig. 4.1). The different nitrogen levels and sources influenced the grain yield significantly with maximum grain yield was recorded in treatment 100% RDN from NCU (T13) and minimum grain yield was observed in control

(T1). It may be due to increase in the availability of nitrogen.The maximum total yield was recorded in100% RDN from NCU (T13) treatment. Control (T1) treatment recorded significantly lower straw yield as compared to other treatments. NCU deactivate the ammonia monooxygenase enzyme responsible for the oxidation of ammonical nitrogen to nitrite form. NCU help to retain soil N in the ammonical form for a longer time and therefore provide more opportunities and time for its uptake by crop plants. Low yield was observed in the treatments having organic inputs (VC) and (RS) because they can not release N immediately for the current crop when they are applied first time and after repeated application, the nutrients will be accumulated and they will be provided in sufficient quantities to the succeeding crops. It may be due to increase in the availability of nitrogen, these results are in conformity with the findings of Bains *et al. (*1971), Ketkar (1974), Reddy and Prasad (1977), Surve and Daftardar (1985),Thomas and Prasad (1987), Geethadevi *et al.* (1991), Jena *et al*. (1993), Kumar and Thakur (1993), Prasad *et al.* (1999), Shivay *et al.* (2000),Shivay *et al.* (2001), Chakravorti (2006) and S.Mohapatra, S.K. Mukhi and P. Mishra (2015),

Table 4.2 : Effect of different nitrogen levels and sources on growth parameters

Treatment	SPAD values		Plant height (cm)			Number of Tillers m^2		
	A.T	P.I	A.T	P.I	Harvesting	A.T	P.I	Harvesting
Control	34	37	47.21	70.05	75.16	325	350	350
50% RDN from prilled urea(PU)	37	35	48.44	75.36	82.81	366	370	370
50% RDN from Neem coated urea(NCU)	37	37	54.1	77.41	85.22	375	376	376
50% RDN from Polymer coated urea(PCU)	37	36	48.88	76.9	84.51	373	374	374
50% RDN from Vermi compost	39	35	48.71	73.35	80.06	365	366	366
50% RDN from Rice Straw(RS)	36	36	49.21	72.41	79.52	361	363	363
75% RDN from PU	37	39	50.9	78.57	89.88	385	386	386
75% RDN from NCU	37	37	51.74	81.36	95.68	388	389	389
75% RDN from PCU	38	37	56.77	85.26	95.1	386	386	386
75% RDN from VC	39	36	50.1	76.62	83.4	369	373	373
75% RDN from RS	35	36	47.1	76.6	82.93	370	373	373
100% RDN from PU	32	36	54.32	84.48	96.32	395	396	396
100%RDN from NCU	35	40	62.88	82.89	97.83	397	399	399
100% RDN from PCU	31	37	54.6	83.34	96.62	395	397	397
100% RDN from VC	36	36	50.65	80.34	88.76	377	379	379
100% RDN from RS	34	37	53.2	77.4	85.41	376	378	378
SEm±	0.57	0.33	1.02	1.1	1.76	3.35	4.41	4.41
CD (P= 0.05)	1.73	1.01	3.09	3.32	5.32	10.1	13.29	13.29

Table 4.3 :Effect of different nitrogen levels and sources on plant yield attributes of irrigated rice

Treatment	Number of grains Panicle^{-1}	Panicle length (cm)	Filled grain percentage	Test weight (g)	Number of panicle m^{-2}
Control	80.00	19.45	68.16	27	303
50% RDN from prilled urea(PU)	92.00	20.26	81.5	27	310
50% RDN from Neem coated urea(NCU)	104.25	20.31	85	27.5	320
50% RDN from Polymer coated urea(PCU)	100.00	20.3	84.21	27.5	314
50% RDN from Vermi compost	90.00	20.26	80.56	27	295
50% RDN from Rice Straw(RS)	85.45	20.25	80.5	27	290
75% RDN from PU	112.00	20.4	88.43	27.5	310
75% RDN from NCU	114.50	20.56	92.58	27.8	318
75% RDN from PCU	114.00	20.45	92.5	27.7	316
75% RDN from VC	95.00	20.26	82.3	27.2	303
75% RDN from RS	93.50	20.25	81.5	27	302
100% RDN from PU	120	20.65	92.83	28	324
100%RDN from NCU	127.75	20.86	97.45	30	331
100% RDN from PCU	120.45	20.76	93.21	29.8	341
100% RDN from VC	108.75	20.36	87.39	27	321
100% RDN from RS	108	20.33	85.5	27	316
SEm±	3.45	0.07	1.77	0.23	3.27
CD (P= 0.05)	10.42	0.23	5.36	NS	9.87

Table 4.4 : Influence of different nitrogen levels and sources on grain and straw yield

Treatment		Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})
T1	Control	21.0	32.0
T2	50% RDN from prilled urea(PU)	28.0	41.0
T3	50% RDN from Neem coated urea(NCU)	32.0	45.0
T4	50% RDN from Polymer coated urea(PCU)	34.0	47.0
T5	50% RDN from Vermi compost	24.0	35.0
T6	50% RDN from Rice Straw(RS)	23.0	36.0
T7	75% RDN from PU	31 .0	44.0
T8	75% RDN from NCU	36 .0	47.0
T9	75% RDN from PCU	36 .0	47.0
T10	75% RDN from VC	26 .0	37.0
T11	75% RDN from RS	27 .0	38.0
T12	100% RDN from PU	34 .0	47.0
T13	100%RDN from NCU	41 .0	54.0
T14	100% RDN from PCU	41.0	54.0
T15	100% RDN from VC	30 .0	41.0
T16	100% RDN from RS	29 .0	40.0
SEm±		1.49	1.61
CD(P= 0.05)		4.5	4.58

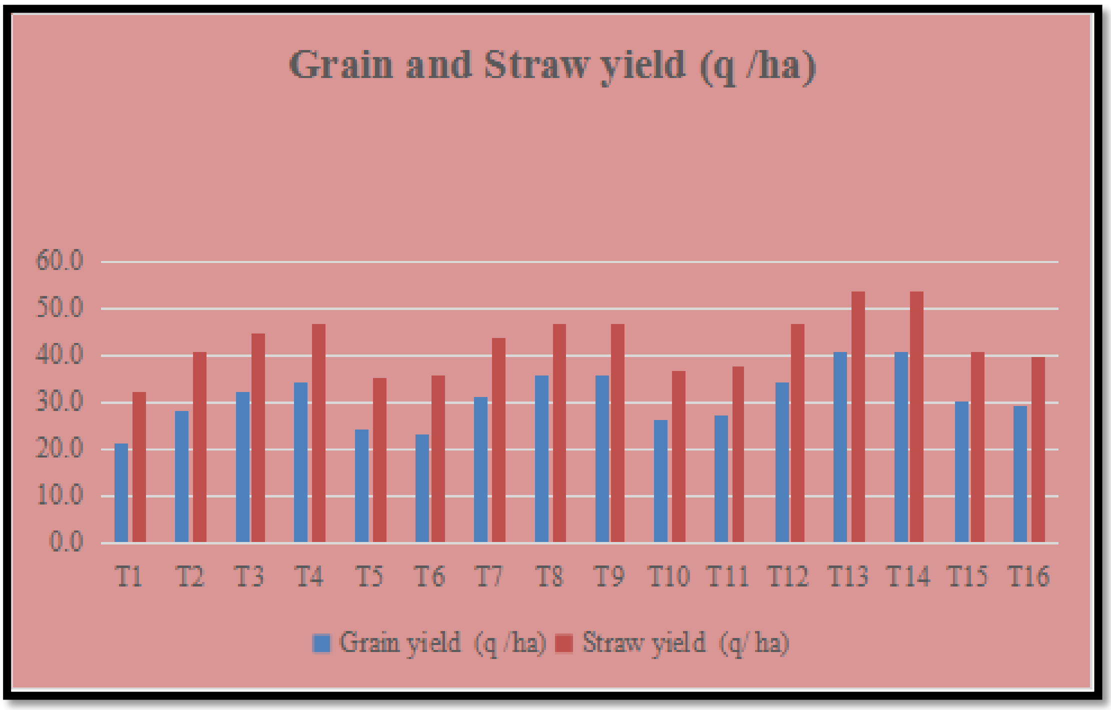


Fig 4.1: Influence of different nitrogen levels and sources on grain and straw yield

4.3 Influence of nitrogen levels and sources on NPK contents and their uptake

4.3.1 Nitrogen content (%) and uptake (kg ha^{-1})

Data recorded on N content in grain and straw at harvest ranged from 1.31 to 1.35 % and 0.35 to 0.55 %, respectively (Table 4.5 and Fig.4.2). At harvest stage, in case of grain, all the treatments showed significant increase in nitrogen content except in control (T1). Treatment 100% RDN from NCU (T13) recorded maximum nitrogen content.The uptake of N, as influenced by different nitrogen levels and sources by grain, straw and total uptake ranged from 27.51 to 55.35,11.2 to 29.7 and 38.71 to 85.05 kg ha^{-1}, respectively and the data are presented in Table (4.6 and Fig. 4.3). The maximum N uptake was observed in 100% RDN from NCU (T13) and minimum N uptake in grain was observed in control (T1). This may be due to higher yield of rice in respective treatments. The different nitrogen levels and sources had also significantly influenced the N uptake by straw with maximum N uptake in treatment 100% RDN from NCU (T13) and minimum N uptake in straw was observed under control (T1). The different nitrogen levels and sources also significantly influenced the total N uptake by grain and straw and maximum total N uptake was observed in 100% RDN from NCU (T13) and minimum total N uptake was observed under control (T1). This may be due to higher nitrogen use efficiency of rice in respective treatments. A critical observation of the data reveals that the performance of treatment 100%RDN from NCU (T13) and 100% RDN from PCU in general, was better over other treatments in increasing the uptake of N. Increasing levels of N increased the nitrogen uptake significantly and each successive increment of N resulted in a significant increase in N uptake over the preceding levels of N. This was true for grain, straw and total N uptake. Thus N had a distinct role in determining the nitrogen uptake in rice. As regards the sources of nitrogen, NCU resulted in significantly more grain, straw and total N uptake than PU, while the other sources were statistically at par.These findings were corroborated with the findings of Awasthi and Mishra (1987),De *et al.* (1992), Shukla and Chouhan (1998), Mohapatra *et al*. (2015).

Table 4.5 :Influence of different nitrogen levels and sources on nitrogen content in irrigated rice

Treatment		Nitrogen content (%)	
		Grain	Straw
T1	Control	1.31	0.35
T2	50% RDN from prilled urea(PU)	1.14	0.39
T3	50% RDN from Neem coated urea(NCU)	1.22	0.41
T4	50% RDN from Polymer coated urea(PCU)	1.19	0.40
T5	50% RDN from Vermi compost	1.22	0.45
T6	50% RDN from Rice Straw(RS)	1.21	0.46
T7	75% RDN from PU	1.28	0.48
T8	75% RDN from NCU	1.32	0.50
T9	75% RDN from PCU	1.31	0.49
T10	75% RDN from VC	1.28	0.46
T11	75% RDN from RS	1.28	0.42
T12	100% RDN from PU	1.23	0.51
T13	100%RDN from NCU	1.35	0.55
T14	100% RDN from PCU	1.34	0.53
T15	100% RDN from VC	1.26	0.47
T16	100% RDN from RS	1.23	0.43
SEm±		0.01	0.01
CD (P= 0.05)		0.04	0.04

Table 4.6 :Influence of different nitrogen levels and sources on nitrogen uptake by irrigated rice

Treatment		Nitrogen uptake (kg ha^{-1})		
		Grain	Straw	Total
T1	Control	27.51	11.20	38.71
T2	50% RDN from prilled urea(PU)	31.92	15.99	47.91
T3	50% RDN from Neem coated urea(NCU)	39.04	18.45	57.49
T4	50% RDN from Polymer coated urea(PCU)	40.46	18.80	59.26
T5	50% RDN from Vermi compost(VC)	29.28	15.75	45.03
T6	50% RDN from Rice Straw(RS)	27.83	16.56	44.39
T7	75% RDN from PU	39.68	21.12	60.8
T8	75% RDN from NCU	47.52	23.50	71.02
T9	75% RDN from PCU	47.16	23.03	70.19
T10	75% RDN from VC	33.28	17.02	50.3
T11	75% RDN from RS	34.56	15.96	50.52
T12	100% RDN from PU	41.82	23.97	65.79
T13	100%RDN from NCU	55.35	29.70	85.05
T14	100% RDN from PCU	54.94	28.62	83.56
T15	100% RDN from VC	37.8	19.27	57.07
T16	100% RDN from RS	35.67	17.20	52.87
SEm±		2.17	1.23	3.37
CD (P= 0.05)		6.56	3.72	10.17

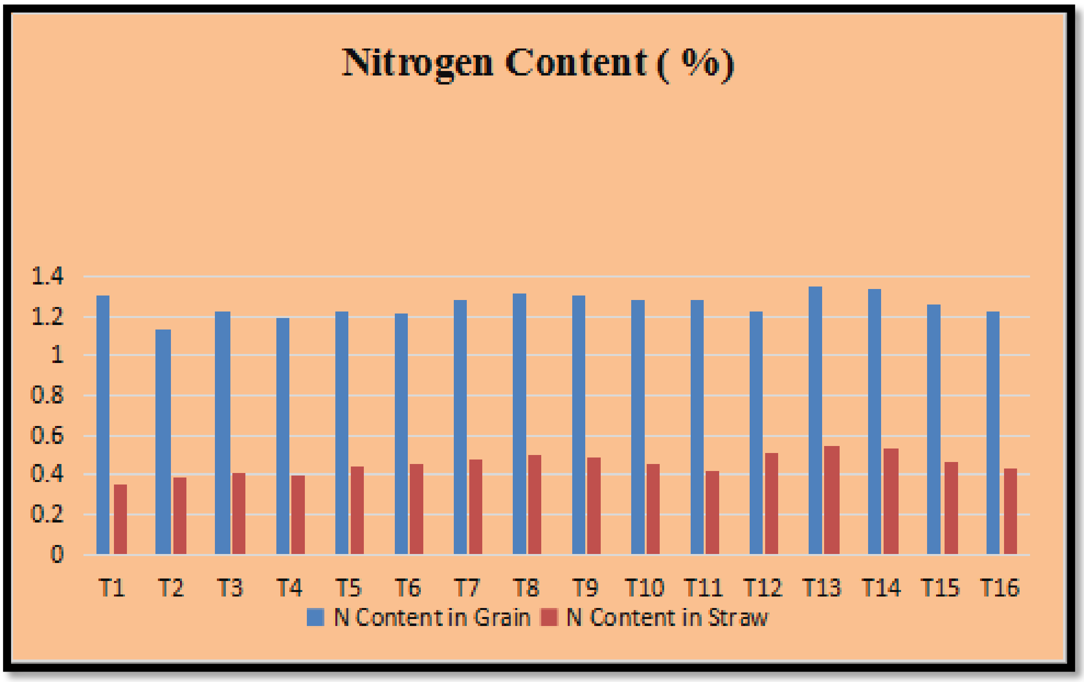


Fig 4.2 :Influence of different nitrogen levels and sources on nitrogen content in irrigated rice

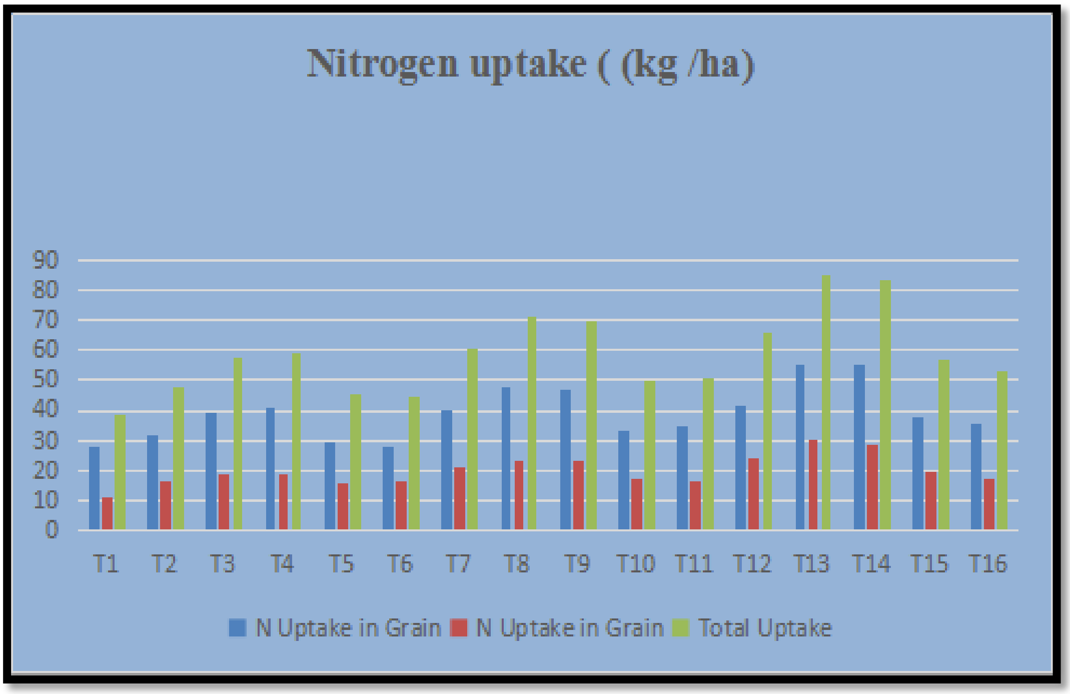


Fig 4.3 :Influence of different nitrogen levels and sources on nitrogen uptake by irrigated rice

4.3.2 Phosphorus content (%) and uptake (kg ha^{-1})

Data recorded on P contents in grain and straw at harvest ranged from 0.23 to 0.30 % and 0.05 to 0.067 %, respectively (Table 4.7 Fig. 4.4). The treatments significantly influenced the P content in grain with maximum P content in treatment 100% RDN from NCU(T13) which was at par with the 100 % RDN from PU (T12) and minimum P content in grain was observed in control (T1). The uptake of P, as influenced by different treatments, by grain, straw and total uptake ranged from 4.83 to 12.3,1.60 to 3.62 and6.43 to 15.91 kg ha^{-1}, respectively and the data are presented in(Table 4.8 and Fig. 4.5) The different nitrogen levels and sources had also significantly influenced the P uptake in grain with maximum P uptake in treatment 100% RDN from NCU (T13) which was at par with the 100 % RDN from PU (T12) and minimum P uptake in grain was observed in control (T1). This may be due to higher grain yield of rice intreatments. The nitrogen levels and sources had also significantly influenced the P uptake in straw with maximum P uptake in treatment 100 % RDN from NCU (T13) which was at par with the 100% RDN from PU (T12) and minimum under control (T1). The nitrogen levels and sources had also significantly influenced the total P uptake with maximum uptake in 100% RDN from NCU(T13) which was at par with the 100 % RDN from PU (T12) and minimum under control (T1).A critical observation of the data reveals that the performance of treatments 100% RDN from NCU (T13) and 100% RDN from PCU (T14), in general, was better over other treatments in increasing the uptake of P in rice. This might be due to the soil containing higher phosphorus level by the addition of P through fertilizerswhich are larger sources of P. Similar results were also reported bySubbiah *et al*. (1979).

Table 4.7 :Influence of different nitrogen levels and sources on phosphorous content (%) in irrigated rice

	Treatment	Phosphorous (%)	
		Grain	Straw
T1	Control	0.230	0.050
T2	50% RDN from prilled urea(PU)	0.210	0.055
T3	50% RDN from Neem coated urea(NCU)	0.230	0.060
T4	50% RDN from Polymer coated urea(PCU)	0.220	0.060
T5	50% RDN from Vermi compost	0.230	0.058
T6	50% RDN from Rice Straw(RS)	0.230	0.054
T7	75% RDN from PU	0.260	0.064
T8	75% RDN from NCU	0.270	0.057
T9	75% RDN from PCU	0.260	0.045
T10	75% RDN from VC	0.262	0.058
T11	75% RDN from RS	0.251	0.054
T12	100% RDN from PU	0.270	0.070
T13	100%RDN from NCU	0.300	0.067
T14	100% RDN from PCU	0.280	0.060
T15	100% RDN from VC	0.290	0.065
T16	100% RDN from RS	0.270	0.064
SEm±		0.06	0.001
CD (P= 0.05)		0.01	0.004

Table 4.8 :Influence of different nitrogen levels and sources on phosphorous uptake (kg ha^{-1}) in irrigated rice

Treatment		Phosphorous uptake (kg ha^{-1})		
		Grain	Straw	Total
T1	Control	4.83	1.60	6.43
T2	50% RDN from prilled urea(PU)	5.88	2.26	8.13
T3	50% RDN from Neem coated urea(NCU)	7.36	2.70	10.06
T4	50% RDN from Polymer coated urea(PCU)	7.48	2.82	10.30
T5	50% RDN from Vermi compost(VC)	5.52	2.03	7.55
T6	50% RDN from Rice Straw(RS)	5.29	1.94	7.23
T7	75% RDN from PU	8.06	2.82	10.87
T8	75% RDN from NCU	9.72	2.68	12.39
T9	75% RDN from PCU	9.36	2.12	11.47
T10	75% RDN from VC	6.81	2.15	8.95
T11	75% RDN from RS	6.77	2.05	8.82
T12	100% RDN from PU	9.18	3.29	12.47
T13	100%RDN from NCU	12.3	3.62	15.91
T14	100% RDN from PCU	11.48	3.24	14.72
T15	100% RDN from VC	8.70	2.67	11.36
T16	100% RDN from RS	7.83	2.56	10.39
SEm±		1.61	0.41	1.97
CD (P=0.05)		0.53	0.13	0.65

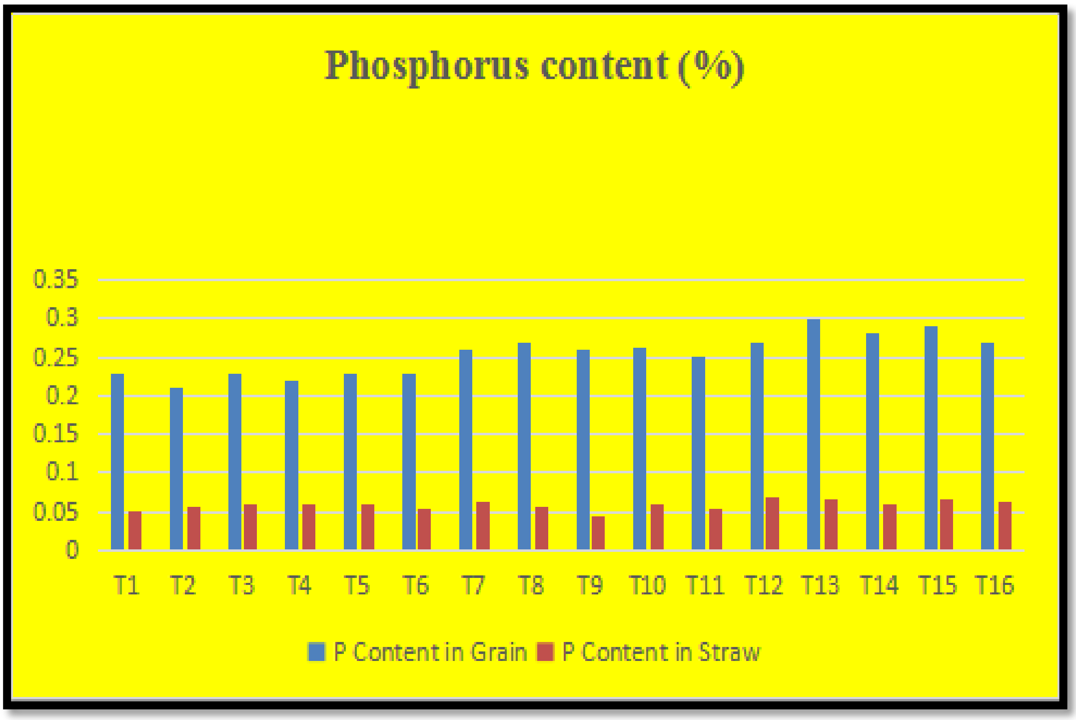


Fig 4.4 :Influence of different nitrogen levels and sources on phosphorous content in irrigated rice

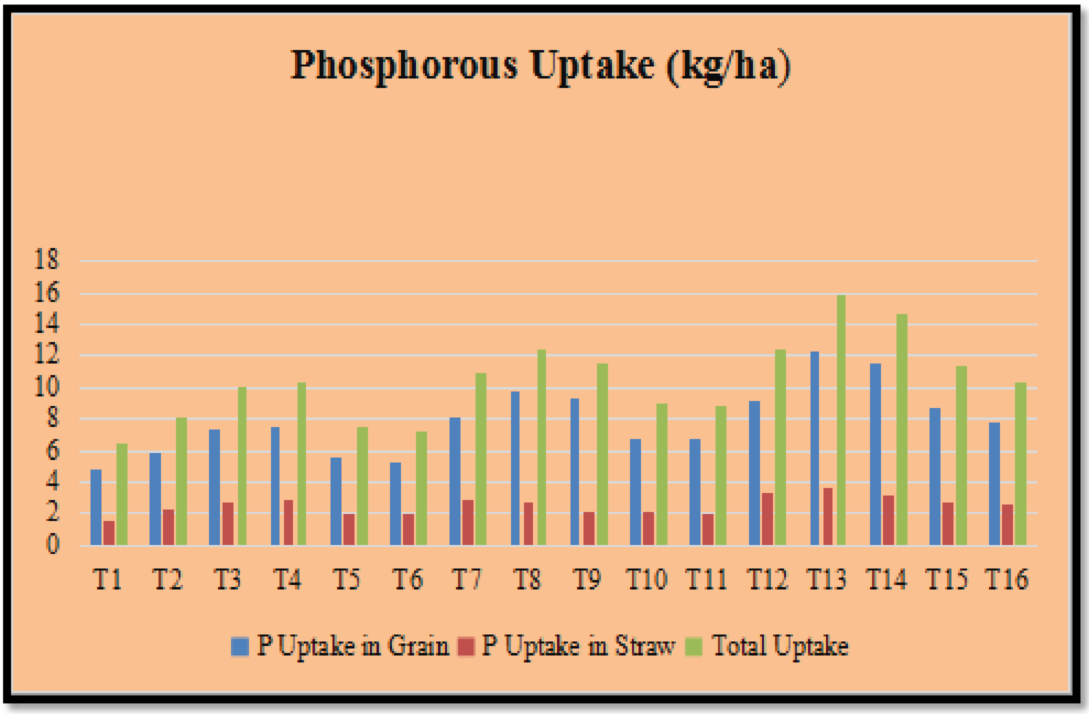


Fig 4.5 : Influence of different nitrogen levels and sources on phosphorous uptake by irrigated rice

4.3.3 Potassium content (%) and uptake (kg ha-1)

Data recorded on K contents in grain and straw at harvest ranged from 0.4 to 0.48 % and 1.25 to 1.36 %, respectively (Table 4.9 and Fig.4.6). Different Nitrogen use efficiency practices failed to show significant influence on potassium contents at any stage of observation. The uptake of K, as influenced by different treatments, by grain, straw and total uptake ranged from 8.4 to 19.68,40 to 67.5 and48.4 to 87.18 kg ha^{-1}, respectively and the data are presented in (Table 4.10 and Fig.4.7). The different Nitrogen levels and sources had also significantly influenced the K uptake in grain with maximum K uptake in treatment 100% RDN from NCU (T13) and in treatment 100% RDN from PCU (T14). All treatments were found significantly superior to control (T1) .The minimum K uptake in grain was observed in control (T1) . This may be due to higher grain yield of rice intreatments. Similarly, Nitrogen levels and sources significantly influenced the K uptake in straw with maximum K uptake in treatment 75% RDN from NCU (T8). All treatments were found significantly superior to control (T1). The significantly lower uptake K in straw was observed by control (T1). The Nitrogen levels and sources had also significantly influenced the total K uptake with maximum uptake in 100% RDN from NCU (T13). All treatments were significantly superior to control (T1) and significantly lower total uptake K was recorded under control (T1). Similar results were also reported by Kaneta *et al.* (1994).

Table 4.9 :Influence of different nitrogen levels and sources on potassium content at in irrigated rice

Treatment		Potassium content (%)	
		Grain	Straw
T1	Control	0.40	1.25
T2	50% RDN from prilled urea(PU)	0.42	1.27
T3	50% RDN from Neem coated urea(NCU)	0.34	1.20
T4	50% RDN from Polymer coated urea(PCU)	0.33	1.18
T5	50% RDN from Vermi compost	0.41	1.27
T6	50% RDN from Rice Straw(RS)	0.41	1.26
T7	75% RDN from PU	0.45	1.34
T8	75% RDN from NCU	0.46	1.26
T9	75% RDN from PCU	0.46	1.25
T10	75% RDN from VC	0.43	1.30
T11	75% RDN from RS	0.44	1.29
T12	100% RDN from PU	0.46	1.36
T13	100%RDN from NCU	0.48	1.25
T14	100% RDN from PCU	0.48	1.23
T15	100% RDN from VC	0.45	1.33
T16	100% RDN from RS	0.44	1.32
SEm±		0.01	0.01
CD(0.05)		0.03	0.03

Table 4.10 :Influence of different nitrogen levels and sources on potassium uptake (kg ha^{-1}) by plant

Treatment		Potassium uptake (kg ha^{-1})		
		Grain	Straw	Total
T1	Control	8.40	40.00	48.40
T2	50% RDN from prilled urea(PU)	11.76	52.07	63.83
T3	50% RDN from Neem coated urea(NCU)	11.00	54.00	65.00
T4	50% RDN from Polymer coated urea(PCU)	11.22	55.46	66.68
T5	50% RDN from Vermi compost (VC)	9.84	44.45	54.29
T6	50% RDN from Rice Straw(RS)	9.43	45.36	54.79
T7	75% RDN from PU	13.95	58.96	72.91
T8	75% RDN from NCU	16.56	59.22	75.78
T9	75% RDN from PCU	16.56	58.75	75.31
T10	75% RDN from VC	11.18	48.10	59.28
T11	75% RDN from RS	11.88	49.02	60.90
T12	100% RDN from PU	15.64	63.92	79.56
T13	100%RDN from NCU	19.68	67.50	87.18
T14	100% RDN from PCU	19.68	66.42	86.10
T15	100% RDN from VC	13.50	54.53	68.03
T16	100% RDN from RS	12.76	52.80	65.56
SEm±		0.86	1.97	2.79
CD (P= 0.05)		2.59	5.95	8.42

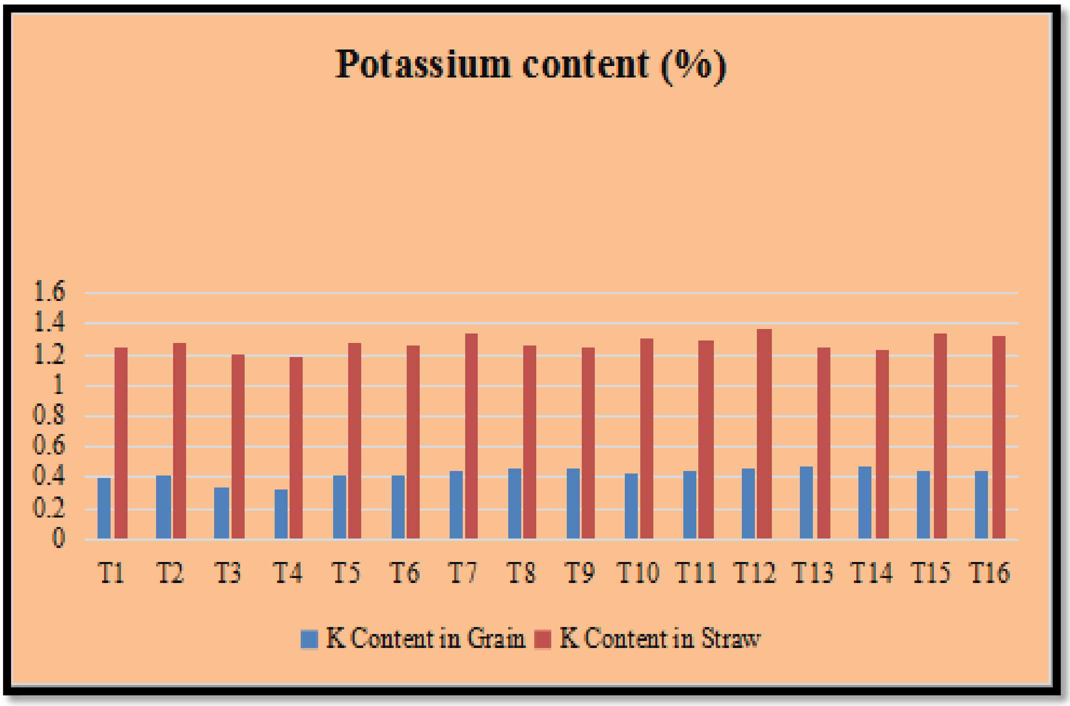


Fig 4.6 :Influence of different nitrogen levels and sources on potassium content in irrigated rice

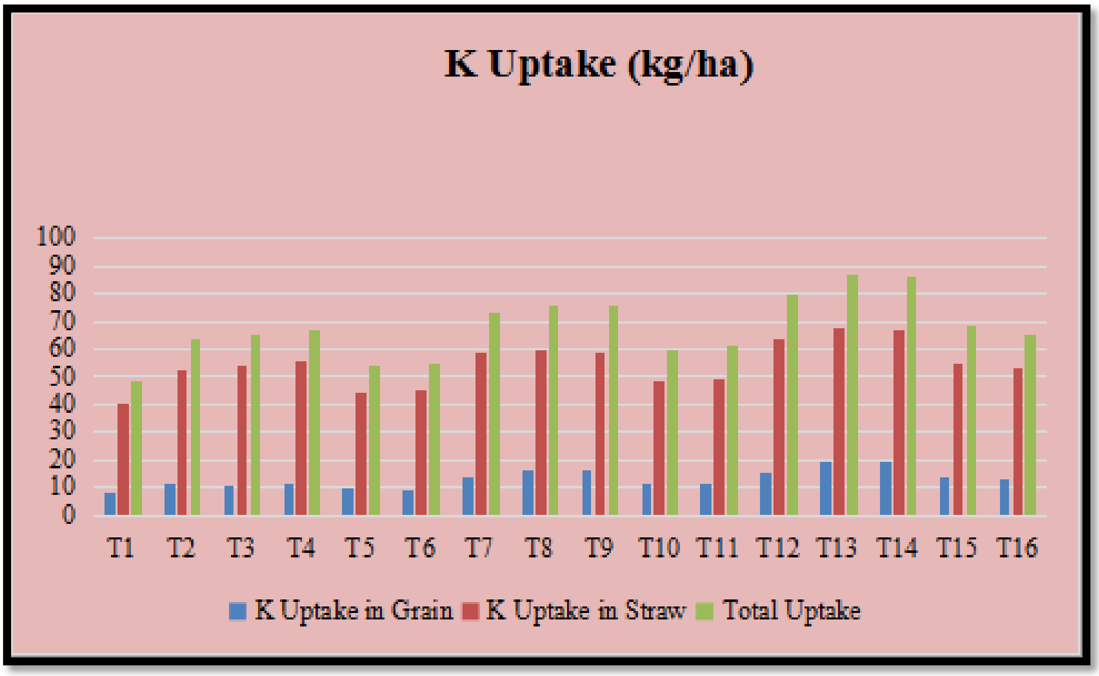


Fig 4.7 :Influence of different nitrogen levels and sources on potassium uptake by irrigated rice

4.4 Influence of different nitrogen levels and sources on NPK use efficiency in irrigated rice

4.4.1 Nitrogen use efficiency (NUE)

The different Nitrogen levels and sources influenced the N use efficiency by Rice crop. The experimental data analysed for nitrogen use efficiency ranged from 18.4 to 46.3(%)(Table 4.11 and Fig. 4.8). The maximum N use efficiency was recorded in 100% RDN from NCU (T13)followed by treatment 100% RDN from PCU (T14) treatment and minimum N use efficiency was observed in 50% RDN from Rice straw (T6). This could be due to higher uptake of nitrogen with higher availability andless losses in these applied fertilizer nitrogen treatments in soil, there by resulting in higher N use efficiency. These results are in confirmity with the findings ofMangat and Narang (2004), Suganya *et al*. (2007), Tachibana (2007) and Kumar *et al.* (2010).

4.4.2 Phosphorus use efficiency (PUE)

P use efficiency influenced by the applied nitrogen levels and sources by rice crop. Data recorded on phosphorus use efficiency ranged from 9 to 24% (Table 4.11 and Fig. 4.9). The maximum P use efficiency was recorded in 100% RDN from NCU (T13) which followed by treatment 100%RDN from PCU (T14) and minimum P use efficiency was observed in 50% RDN applied through Rice straw (T6).This may be due to the synergistic effect of applied different nitrogen sources with phosphorous uptake resulting in higher P use efficiency varied with applied different nitrogen levels. This finding was also supported by Kaneta *et al.* (1994).

4.4.3 Potassium use efficiency (KUE)

Data recorded on potassium use efficiency ranged from 77.2 to 97% (Table 4.11 and Fig. 4.10). The maximum K use efficiency was recorded in 100% RDN from NCU (T13) which followed by treatment 100% RDN from PCU (T14) and minimum K use efficiency was observed in 50% RDN from Rice straw (T6). This may be due to the synergistic effect of applied different nitrogen sources with potassium uptake resulting in higher K use efficiency varied with applied different nitrogen levels . This finding was also supported by Kaneta *et al.* (1994).

Table 4.11 :Influence of different nitrogen levels and sources on NPK use efficiency (%) in irrigated rice

Treatment		NUE	PUE	KUE
T1	Control	-	-	-
T2	50% RDN from prilled urea(PU)	18.4	9	77.2
T3	50% RDN from Neem coated urea(NCU)	37.6	18	83.0
T4	50% RDN from Polymer coated urea(PCU)	41.1	19	91.4
T5	50% RDN from Vermi compost	12.6	6	29.5
T6	50% RDN from Rice Straw(RS)	11.4	4	32.0
T7	75% RDN from PU	29.5	15	81.7
T8	75% RDN from NCU	43.1	20	91.3
T9	75% RDN from PCU	42.0	17	89.7
T10	75% RDN from VC	15.5	8	36.3
T11	75% RDN from RS	15.7	8	41.7
T12	100% RDN from PU	27.1	15	77.9
T13	100%RDN from NCU	46.3	24	97.0
T14	100% RDN from PCU	44.9	21	94.3
T15	100%RDN from VC	18.4	12	49.1
T16	100% RDN from RS	14.2	10	42.9

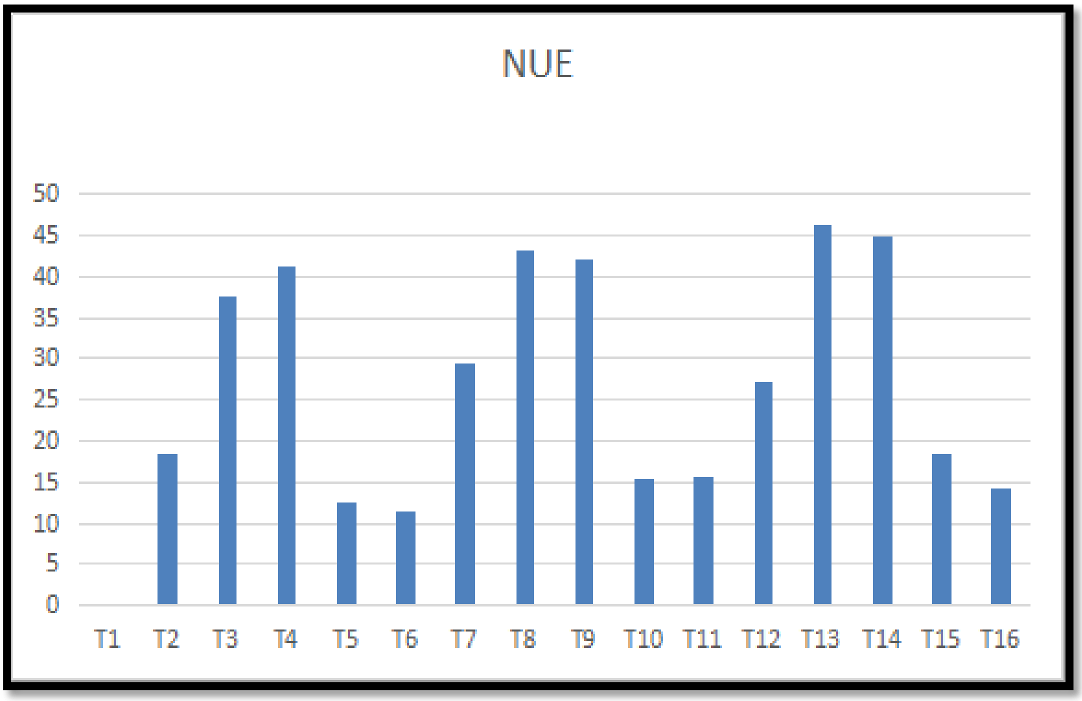


Fig 4.8. : Influence of different nitrogen levels and sources on N use efficiency in irrigated rice

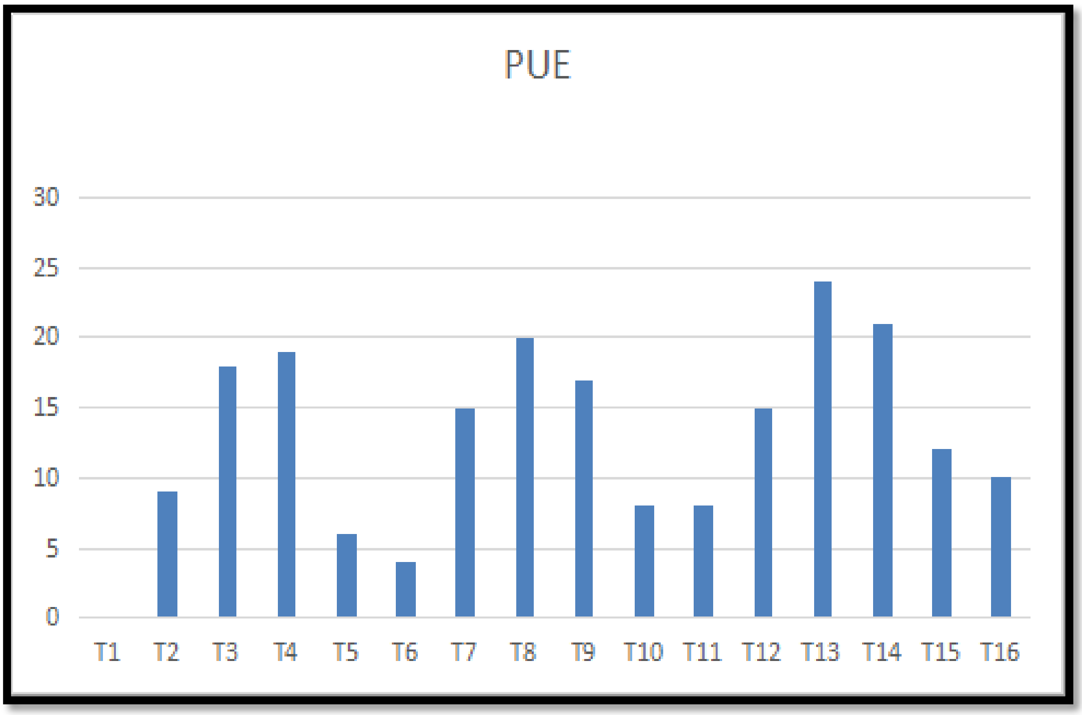


Fig 4.9 :Influence of different nitrogen levels and sources on P use efficiency in irrigated rice

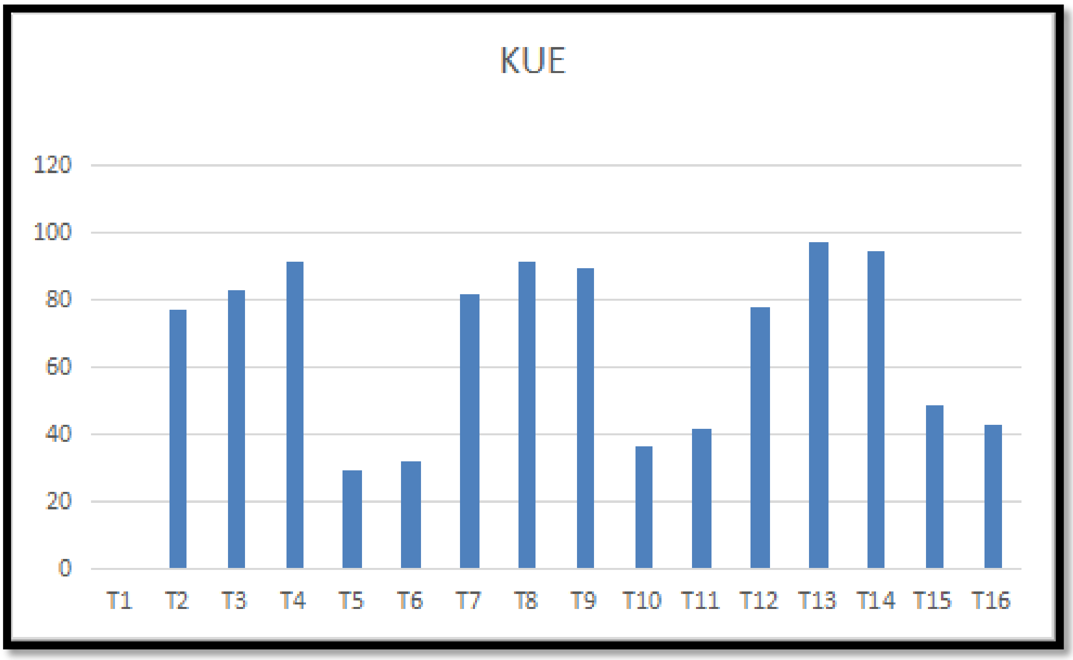


Fig 4.10 :Influence of different nitrogen levels and sources on K use efficiency in irrigated rice

4.5 Influence of different nitrogen levels and sources on enzyme activity of soil

4.5.1 Urease activity (µg TPF g^{-1} soil 2hr)

Soil urease plays a major role in catalysis of the hydrolysis of urea to ammonical form, which will be subsequently oxidized by nitrifiers to nitrate form, which increases the utilization rate of nitrogen fertilizer. The urease activities in soil as influenced by different Nitrogen levels and sources have been presented in (Table 4.12 and Fig. 4.11) The urease activities at tillering, panicle initiation and harvesting stages varied from 254 to 697, 328 to 736 and 149 to 571 µg of NH4+g^{-1} soil 2hr, respectively. The different Nitrogen levels and sources significantly influenced the urease activity at tillering. The maximum urease activity was recorded in treatment 100% RDN from NCU (T13)with compare to 100% RDN from VC (T15) and 100% RDN from RS (T16) and minimum urease activity was observed in Control (T1). In case of panicle initiation, the maximum value of urease activity was recorded with which was statistically superior over 100% RDN from NCU (T13) but statistically at par with rest of treatments except in control (T1) and lower urease activity was observed in Control (T1). At harvesting stage, the maximum urease activity was recorded in treatment which was at par with treatment 100% RDN from NCU (T13) and lower urease activity was observed in Control (T1). The urease activity showed an increasing trend with the age of the crop. It increased from MT stage to PI stage, exhibited highest activity at panicle initiation stage and there after the activity decreased at maturity. The urease activity showed an increasing trend with the age of the crop. It increased from MT stage to PI stage, exhibited highest activity at panicle initiation stage and there after the activity decreased at maturity. Similarly, Similar results were reported by Kumar *et al.* (2000) at different growth stages of rice. Ramalakshmi *et al.* (2012) also reported highest urease activities at panicle initiation stage in long term nutrient management practices on rice. .

Table 4.1 :Influence of different nitrogen levels and sources on urease activity (µg TPF g^{-1} soil 2hr) of soil in irrigated rice

Treatment		Urease activity (µg TPF g^{-1} soil 2hr)		
		Tillering	Panicle Initiation	Harvesting
T1	Control	254	328	149
T2	50% RDN from prilled urea(PU)	280	374	187
T3	50% RDN from Neem coated urea(NCU)	371	473	236
T4	50% RDN from Polymer coated urea(PCU)	345	448	221
T5	50% RDN from Vermi compost	278	365	177
T6	50% RDN from Rice Straw(RS)	261	358	167
T7	75% RDN from PU	400	523	304
T8	75% RDN from NCU	480	553	331
T9	75% RDN from PCU	445	550	310
T10	75% RDN from VC	320	418	215
T11	75% RDN from RS	315	400	215
T12	100% RDN from PU	573	462	384
T13	100%RDN from NCU	697	736	571
T14	100% RDN from PCU	608	554	468
T15	100% RDN from VC	385	490	285
T16	100% RDN from RS	379	483	264
SEm±		32.78	25.46	28.74
CD (P= 0.05)		98.81	76.74	41.02

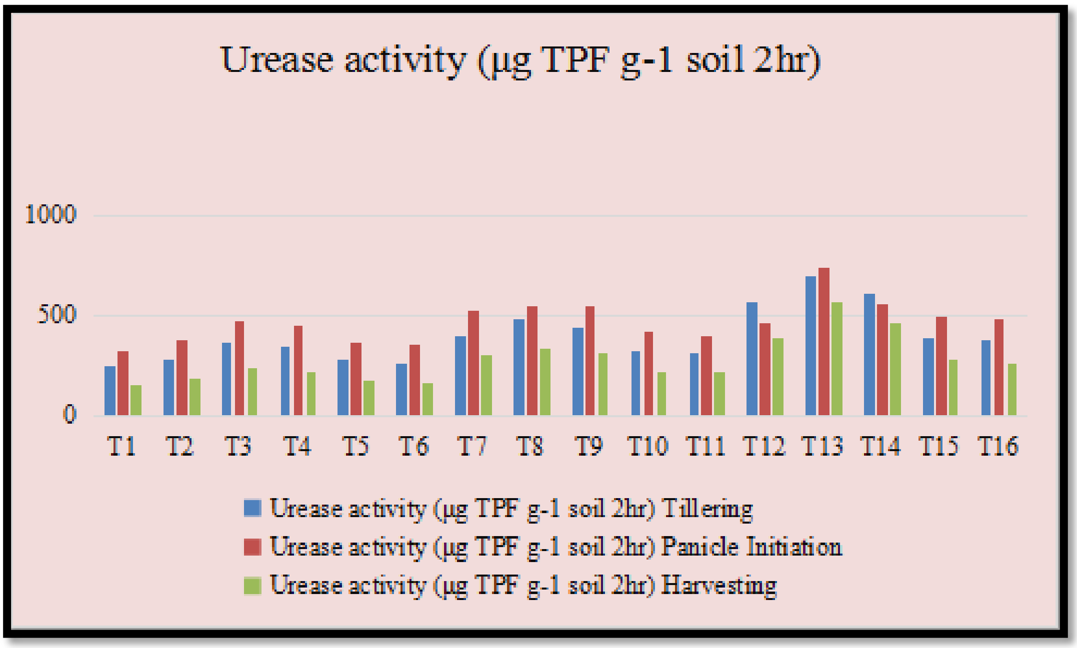


Fig 4.11 :Influence of different Nitrogen levels and sources on Urease activity (µg TPF g^{-1} soil 2hr) of soil

4.5.2 Dehydrogenase activity (µg TPF g^{-1} soil day^{-1})

The dehydrogenase activity in soil as influenced by different treatments have been presented in (Table 4.13 and Fig. 4.12) The dehydrogenase activities at tillering, panicle initiation and harvesting stages varied from 55.63 to 86.87, 71.63 to 99.45 and 44.52 to 66.78 µg TPF g^{-1} soil day^{-1}, respectively. Dehydrogenase is considered as an indicator of overall microbial activity because it occurs intracellularly in all living microbialcellsand it is linked with microbial respiratory processes. The dehydrogenase activity is commonly used as an indicator of biological activity in soils .The treatments significantly influenced the dehydrogenase activity with maximum recorded in treatment 100% RDN from NCU (T13) which showed significant difference compared to rest of all treatments. The minimum dehydrogenase activity was observed in control (T1).This may be due to application of combination of inorganic fertilizers with organic manures, moisture availability and microbial activities responsible for their activity in soil. In case of panicle initiation, the maximum value of dehydrogenase activity was recorded with 100% RDN from NCU (T13) which was statistically superior over control (T1) but at par with 100% RDN from PCU (T12) and lower dehydrogenase activity was observed in control (T1). This high activity may be due to application of combination of inorganic fertilizers with organic manures as well as maximum moisture availability and higher microbial activities responsible for their higher activity in soil. At harvesting stage, the maximum dehydrogenase activity was recorded in treatment 100% RDN from VC (T15) which was statistically superior over all other treatments but at par with 100% RDN from NCU (T13) and lower dehydrogenase activity was observed in control (T1). This lower activity at harvest stage compared to other stages could be due to decrease in moisture availability and microbial activities at harvest. The dehydrogenase activity showed an increasing trend with the age of the crop. It increased from MT stage to PI stage, exhibited highest activity at panicle initiation stage and there after the activity decreased at maturity. The activities of dehydrogenase enzyme in the soil system is very important as it may give indications of the potential of the soil to support biochemical processes which are essential for maintaining soil fertility Manna *et al.* (2005). Similar observations were noted by Shingha *et al.* (2014). The dehydrogenase activity showed an increasing trend with the age of the crop. It increased from MT stage to PI stage, exhibited highest activity at panicle initiation stage and there after the activity decreased at maturity. The activities of dehydrogenase enzyme in the soil system is very important as it may give indications of the potential of the soil to support biochemical processes which are essential for maintaining soil fertility (Joychim *et al.*, 2008). Significantly highest dehydrogenase activity in nutrient management practices treatments might be due to addition of organic matter which in turn increased microbial activity and microbial biomass and consequently increased activity of dehydrogenase (Tejada and Gonalez, 2009). The applied organic sources were able to get mineralized rapidly in early days of incubation hence, there was more mineralization than immobilization which consequently provided sufficient nutrition for the proliferation of microbes and their activities in terms of soil dehydrogenase. Similar observations were noted by Joychim *et al.* (2008) and Lakshmi *et al.* (2014).

Table 4.13 :Influence of different Nitrogen levels and sources on Dehydrogenase activity (µg TPF g^{-1} soil day^{-1}) of soil

Treatment		Dehydrogenase activity (µg TPF g^{-1} soil day^{-1})		
		Tillering	Panicle Initiation	Harvesting
T1	Control	55.63	71.63	44.52
T2	50% RDN from prilled urea(PU)	68.56	77.48	52.16
T3	50% RDN from Neem coated urea(NCU)	74.21	84.56	56.82
T4	50% RDN from Polymer coated urea(PCU)	75.86	86.59	58.94
T5	50% RDN from Vermi compost	81.41	92.53	61.25
T6	50% RDN from Rice Straw(RS)	74.21	84.56	56.82
T7	75% RDN from PU	81.41	92.53	61.25
T8	75% RDN from NCU	74.21	85.21	58.14
T9	75% RDN from PCU	83.54	95.87	62.74
T10	75% RDN from VC	83.54	94.12	61.34
T11	75% RDN from RS	75.86	86.95	58.94
T12	100% RDN from PU	70.15	80.13	55.42
T13	100%RDN from NCU	74.21	84.56	56.82
T14	100% RDN from PCU	75.86	86.59	58.94
T15	100% RDN from VC	86.87	99.45	66.78
T16	100% RDN from RS	85.14	97.58	65.23
SEm±		2.05	2.08	1.43
CD (P= 0.05)		6.19	6.29	4.31

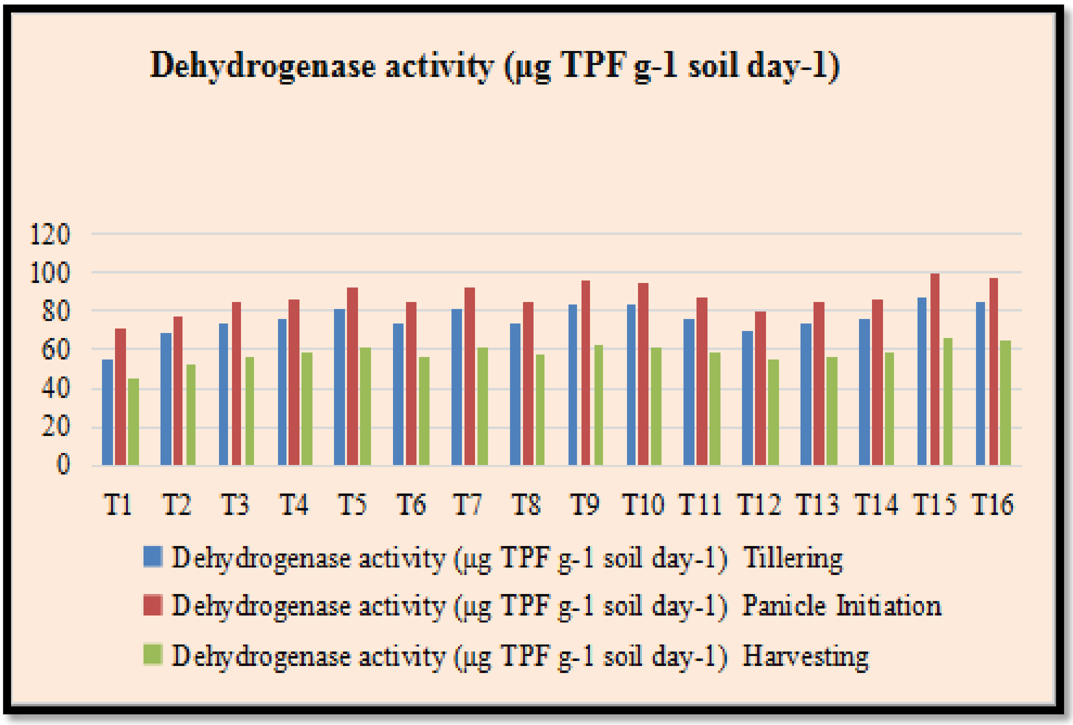


Fig 4.12 :Influence of different nitrogen levels and sources on dehydrogenase activity (µg TPF g-1 soil day-1) of soil

4.6 Influence of different nitrogen levels and sources on pH, EC and Organic carbon in soil after harvest

4.6.1 pH

The data pertaining to pH after rice harvest as influenced by different nitrogen levels and sources have been presented in (Table 4.14and Fig.4.13). The pH ranged from 7.96 to 8.22 after rice harvesting. Different Nitrogen levels and souces could not produce any significant difference in pH just after one season of experimentation.

4.6.2 Electrical Conductivity (dS m^{-1})

The electrical conductivity of soil after rice harvest as influenced by different Nitrogen levels and sources have been presented in (Table 4.14 and Fig 4.14). The EC ranged from 0.28to 0.66 dSm-1 after rice harvesting. Similar findings were observed by Ketkar (1974).

4.6.3 Organic Carbon (%)

The Organic carbon of soil after rice harvest as influenced by different Nitrogen levels and sources have been presented in (Table 4.14 and Fig 4.15). The OC ranged from 0.64 to 0.85 after rice harvesting. All the treatments were statistically similar as different Nitrogen levels and sources could not produce any significant difference in OC. Similar findings were observed by Chesti et al. 2013.The maximum organic carbon recorded in 100% RDN from VC (T15). This may be due to addition of vermicompost have created environment conducive for formation of humic acid, which ultimately resulted in an increase in the organic carbon content of the soil. Also, this treatment, being the best treatment, might have resulted in higher root growth that could have contributed to higher organic carbon content. These finding were also supported by Patta (2011).

Table 4.14 :Influence of different nitrogen levels and sources on pH, EC and Organic carbon in soil after harvest.

Treatment		pH	EC	OC
T1	Control	8.11	0.44	0.64
T2	50% RDN from prilled urea(PU)	8.01	0.45	0.65
T3	50% RDN from Neem coated urea(NCU)	7.99	0.52	0.68
T4	50% RDN from Polymer coated urea(PCU)	7.96	0.54	0.7
T5	50% RDN from Vermi compost	8.13	0.52	0.78
T6	50% RDN from Rice Straw(RS)	8.22	0.40	0.65
T7	75% RDN from PU	8.05	0.61	0.7
T8	75% RDN from NCU	8.13	0.57	0.72
T9	75% RDN from PCU	7.99	0.35	0.74
T10	75% RDN from VC	8.14	0.53	0.82
T11	75% RDN from RS	8.13	0.46	0.68
T12	100% RDN from PU	8.14	0.44	0.75
T13	100%RDN from NCU	8.04	0.44	0.85
T14	100% RDN from PCU	8.09	0.66	0.83
T15	100% RDN from VC	8.14	0.28	0.65
T16	100% RDN from RS	8.06	0.55	0.72
SEm±		0.01	0.02	0.01
CD(P= 0.05)		0.05	0.07	0.04

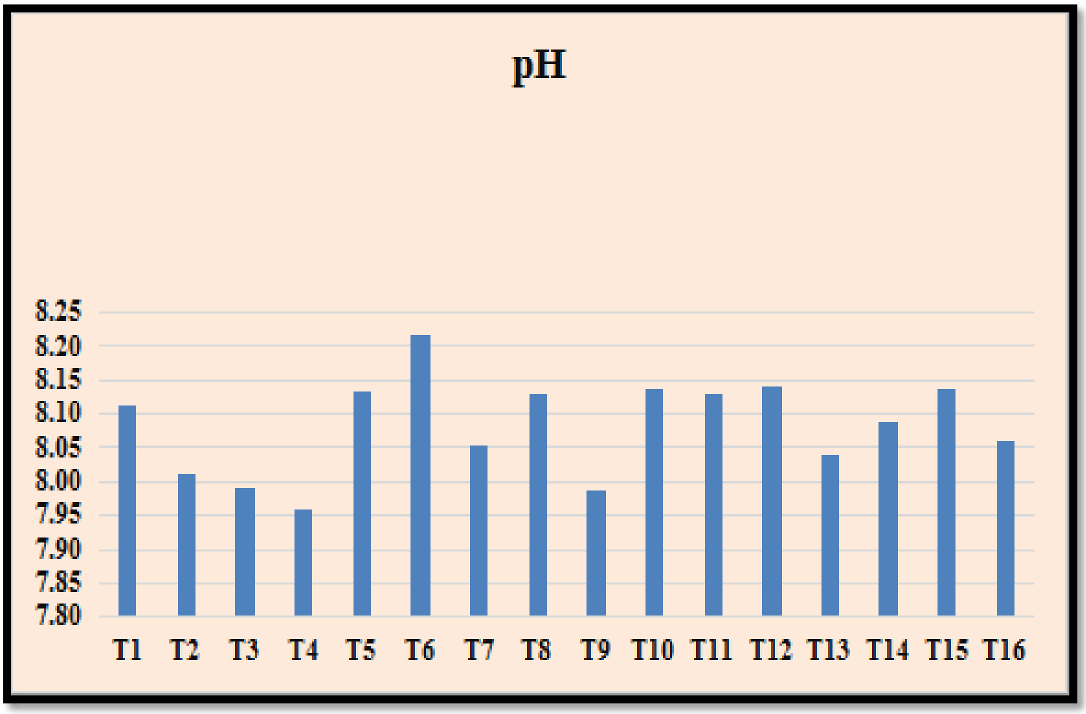


Fig 4.13 Influence of different nitrogen levels and sources on pHin soil after harvest

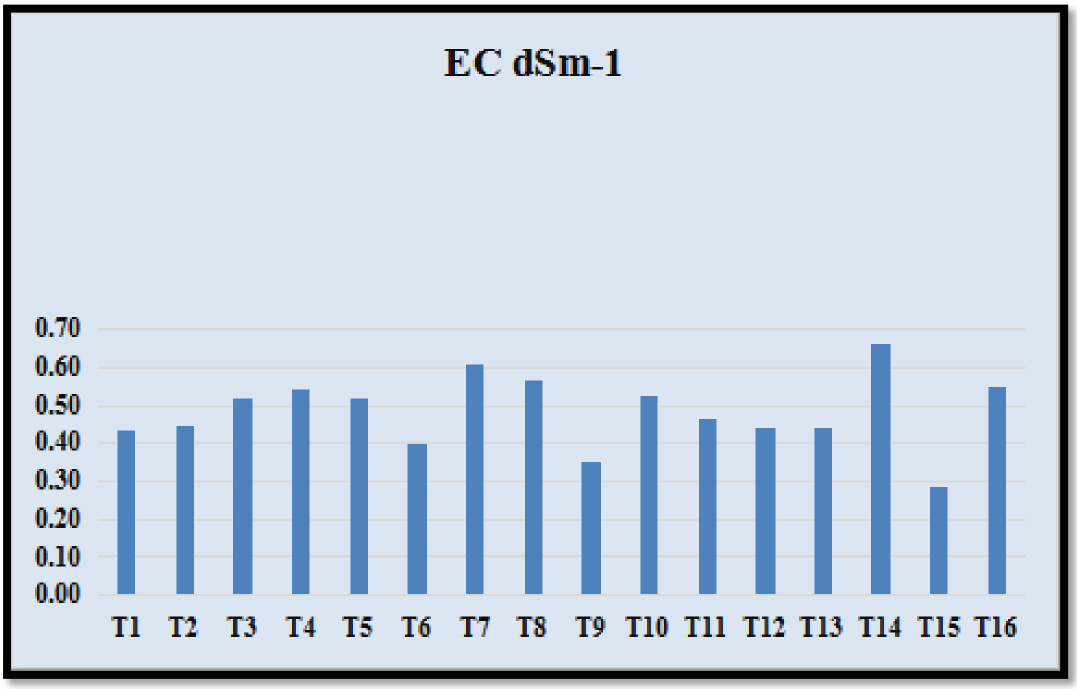


Fig 4.14 Influence of different nitrogen levels and sources on EC in soil after harvest

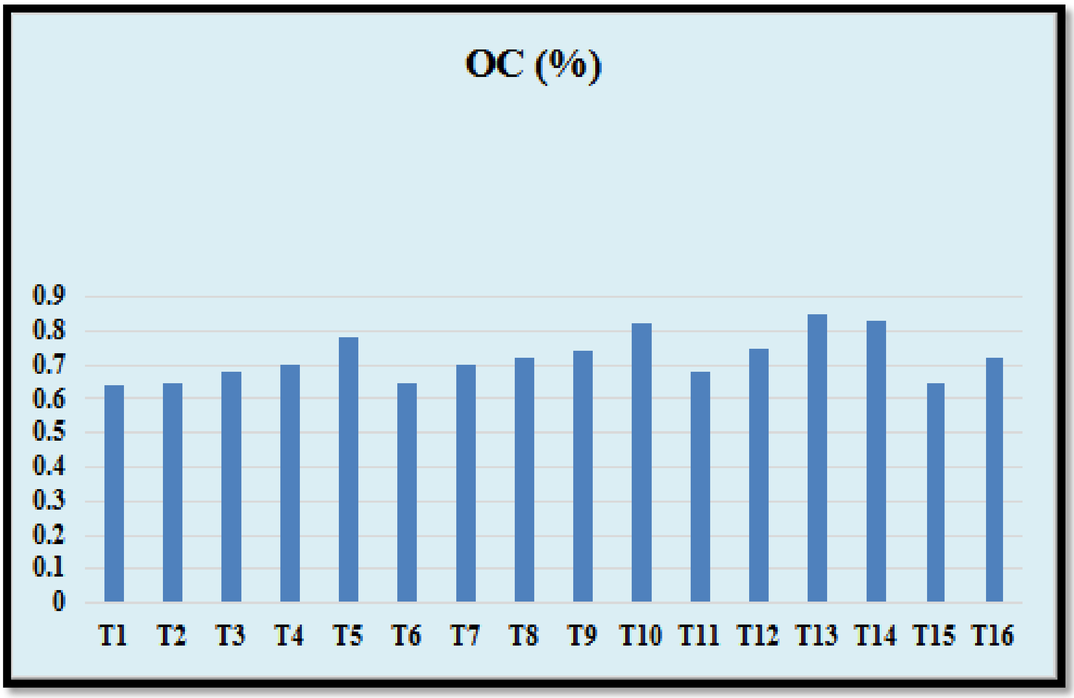


Fig 4.15 Influence of nitrogen levels and sources use on Organic carbon in soil after harvest

4.7 Influence of different nitrogen levels and sources on available NPK in soil after harvest

4.7.1 Available nitrogen (kg ha^{-1}) in soil after harvest

The fertility status of soil in terms of available nitrogen as affected by different Nitrogen levels and sources after harvesting of rice crop have been shown in Table 4.15 and Fig. 4.16. Available N in soil after harvest of rice crop ranged from 190 to 246 kg ha^{-1}. Based on the overall means, treatment 100% RDN from NCU (T13) recorded maximum value of available N; it was statistically superior to control (T1) and Control (T1) recorded minimum available N. Addition of fertilizers alone or along with different nitrogen levels and sources. The status of soil considerably due to mineralization of nutrients and change of unavailable forms of nutrients into available forms in addition to applied nutrients (Yadav and Chhipa, 2007). This slight increase in available nitrogen content can be attributed to the mineralization of soil nitrogen leading to build up of available nitrogen (Swarup and Yaduvanshi, 2000 and Kumar *et al.*, 2012).

4.7.2 Available phosphorus (kg ha^{-1}) in soil after harvest

The fertility status of soil in terms of available phosphorus as affected by nutrient management treatments after harvesting of rice crop have been shown in Table 4.16 and Fig. 4.16. Available P in soil after harvest of rice crop ranged from 75 to 93kg ha^{-1}.The different Nitrogen levels and sources, indicated significant change in available soil P, and maximum soil P was recorded after harvesting in treatment 100% NCU (T13) which was at par with rest of treatments. Increase in available phosphorus with the application of NPK fertilizers alone or in conjunction with different nitrogen levels and sources which in turn helped in releasing phosphorus through solubilizing action of native phosphorus in the soil Wang *et al.* (2011).

4.7.3 Available potassium (kg ha^{-1}) in soil after harvest

The fertility status of soil in terms of available potassium as affected by different Nitrogen levels and sources after harvesting of rice crop have been shown in Table 4.16 and Fig. 4.16. Available K in soil after harvest of rice crop ranged from 414 to 484 kg ha^{-1}. Maximum and higher value of available K was observed in treatment 100% RDN from NCU (T13). Increase in available potassium due to addition of NCU may be ascribed to the reduction of potassium fixation and release of potassium due to interaction of different nitrogen levels and sources reported by Wang et al.(2011).

Table 4.15: Influence of different nitrogen levels and source on available NPK in soil after harvest

Treatment		N	P	K
T1	Control	190	33	414
T2	50% RDN from prilled urea(PU)	209	34	419
T3	50% RDN from Neem coated urea(NCU)	215	36	442
T4	50% RDN from Polymer coated urea(PCU)	213	34	440
T5	50% RDN from Vermi compost	207	34	418
T6	50% RDN from Rice Straw(RS)	198	33	417
T7	75% RDN from PU	230	38	450
T8	75% RDN from NCU	234	33	463
T9	75% RDN from PCU	232	33	456
T10	75% RDN from VC	212	34	437
T11	75% RDN from RS	209	34	432
T12	100% RDN from PU	235	38	475
T13	100%RDN from NCU	246	41	484
T14	100% RDN from PCU	246	39	476
T15	100% RDN from VC	224	37	449
T16	100% RDN from RS	220	36	448
SEm±		4.05	1.3	5.5
CD (P= 0.05)		12.2	3.93	16.59

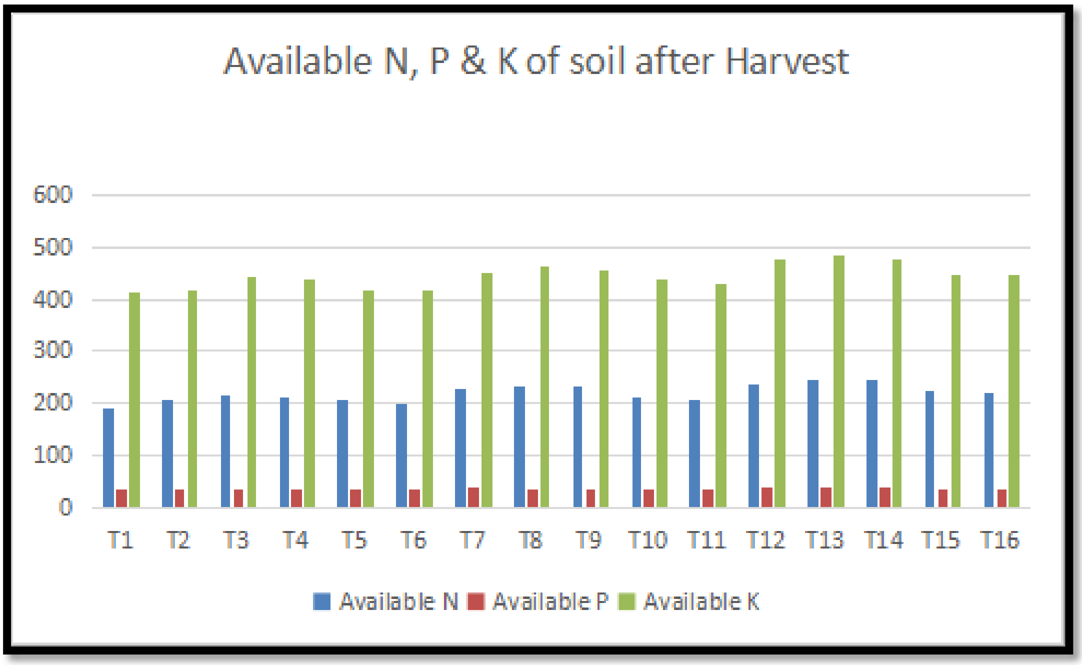


Fig 4.16 Influence of different nitrogen levels and sources on available NPK in soil after harvest.

CHAPTER-V

SUMMARY AND CONCLUSION

Present study has been taken up to evaluate the effect of different nitrogen levels and sources on rice productivity and soil property at the Indian Institute of Rice Research (formerly DRR), Rajendranagar, Hyderabad, during *kharif 2016.*

Salient findings of thestudy conducted:

The experimental findings are summarized as follows:

1. All the growth parameters (viz. plant height and number of tillers m-2) were influenced by various levels of nitrogen and sources.

2. At different growth stages, the treatment 100% RDN from NCU (T13) was found to be significantly superior not only over control (T1) but also over rest of the treatments in increasing the plant height and number of tillers m^{-2} in irrigated rice.

3. The treatments significantly influenced the yield and yield attributing characters viz., grain yield, straw yield, panicle length, filled grains percentage and higher number of grain per panicle were found higher under treatment 100% RDN from NCU (T13).

4. The treatments also significantly influenced the nitrogen, phosphorus and potassiumuptake. The N, P and K uptake in grain, straw and total uptake were significantly higher in treatment 100% RDN from NCU (T13). The N, P and K uptake in grain, straw and total uptake were lowest in control (T1) over rest of the treatments.

5. N, P and K use efficiency were influenced significantly and the highest N, P and K use efficiency were recorded in 100% RDN from NCU (T13).

6.The enzyme activity showed an increasing trend with the age of the crop. It increased from MT stage to PI stage, exhibited highest activity at panicle initiation stage and there after the activity decreased at maturity. Urease activity at different stages was found significantly higher in treatment 100% RDN from NCU (T13).Dehydrogenase activity at tillering stage and Panicle initiation stage were found significantly higher in treatment 100% RDN from vermi compost (T15).

7.Differentnitogen levels and sources could not produce any significant difference in soil pH and EC in irrigated rice at harvest and these properties will not be changed in a single season.

8. The significantly higher value of available N, P and K were observed in treatment 100% RDN from NCU (T13) over control.

Conclusion

Application of 100% RDN from NCU increased crop growth and yield as evidenced by increased plant height, number of tillers and panicles per m^2 and grains per panicle. Under irrigated rice, application of 100% RDN from NCU upgraded soil fertility as evidenced by increased soil OC status, available P and K; improved the soil biological health as evidenced by good enzymes activity and use efficiency of applied nutrients as evidenced better NUE, PUE and KUE.

Future line of work

- ✓ Multi-location trials with adaptable and beneficial Nitrogen use efficiency management practices can be studied with special emphasis on crop production improvement and sustaining soil fertility and health.
- ✓ Studies highlighting the effect of combined use of organic and inorganic sources of nutrients on crop yield and soil health, a major concern all over the world to be carried out.
- ✓ Use efficiency of applied nutrients mainly N is very low in rice. Hence, effective strategies to overcome this through possible nutrient sources combinations can be framed out.

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APPENDICES

Appendix – A

Preparation of TTC (Triphynyl Tetrazolium Chloride) 3% solution

1. Take 100 ml volumetric flask.
2. 2. Weight 3 g. TTC powder in 100 ml volumetric flask.
3. 3. Add 80 ml distil water in volumetric flask and mixed properly.
4. 4. Made the volume 100 ml with distil water.

Appendix - B

Preparation of TPF (Triphynyl Farmzone) solution

1. Take 100 ml volumetric flask.
2. Weight 0.1 g. TPF powder in 100 ml volumetric flask.
3. Add 80 ml methanol in volumetric flask and mixed properly. 4. Made the volume 100 ml with methanol.

Appendix – C

Preparation of THAM buffer 0.05M pH- 9 (Tris-hydroxymethyl aminemethan) solutions

1. Take 1000 ml volumetric flask.
2. Dissolve 6.1 g. THAM in about 700 ml of distill water
3. Titrate the pH of the solution to 9 by the addition of approximately 0.2M H_2SO_4.
4. Made the volume 1000 ml with distill water.

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Membership of Professional Societies : No

Awards / Recognitions : No

Publications : No

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