COMPARISON OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLIED ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA

Thesis

Submitted to the

G.B. Pant University of Agriculture and Technology
Pantnagar-263145, (U.S. Nagar), Uttarakhand, India

By

Gurpreet Singh

IDNo.:58090

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF

Master of Science in Agriculture

Soil Science

September, 2023

ACKNOWLEDGEMENT

Words are an inadequate medium for conveying the depth of emotions and gratitude one feels in moments like these. It is on this occasion, as I reflect upon the debts of gratitude I owe, that I am reminded of the limits of human expression. I am deeply humbled and profoundly grateful for the divine presence in my life, which has illuminated my path during times of adversity. To the Almighty, the Creator, the Supreme Power, the Light—whatever name we choose to use—I extend my eternal gratitude, for it is from Him that all blessings flow, and "He is the cause of every cause."

My first and foremost gratitude goes to my beloved parents, whose boundless love, selfless sacrifices, and heartfelt blessings have been my guiding lights throughout my life. To them, I owe not just my success but the very essence of who I am. They have been unwavering in their support, and for that, I am eternally indebted.

I am filled with joy as I express my deepest reverence and appreciation to ***Dr. Swayam Prakash Gangwar,*** *Senior Research Officer and Chairman of my Advisory Committee in the Department of Soil Science. His guidance, constructive criticism, and unending encouragement have been instrumental in shaping my thesis. His dedication ensured that I completed my work well within the allotted time, and I am forever grateful for his invaluable mentorship.*

I am equally privileged to acknowledge the esteemed members of my advisory committee, ***Dr. Ajaya Srivastava, Dr. Veer Singh,*** *and* ***Dr. Staya Pratap Pachauri,*** *Professors in the Department of Soil Science, College of Agriculture. Their technical guidance, keen interest, and valuable critiques during my research journey have been instrumental in preparing this manuscript.*

My heartfelt thanks extend to our Head of Department, ***Dr. Navneet Pareek,*** *for his guidance, moral support, and timely suggestions throughout my studies.*

I must express my sincere appreciation to all my professors, the librarian, the Director, University Experiment Station, the Deans of the College of Agriculture and the College of Post Graduate Studies, and the Registrar for providing the essential facilities for my research. I am also thankful for the dedicated lab assistants and field workers who supported my work tirelessly.

My respect and personal obligation extend to my parents, ***Shri Lakhvinder Singh*** *and* ***Smt. Jaswant Kaur,*** *for their remarkable patience, boundless love, unwavering affection, moral support, and lifelong inspiration. Without their unwavering encouragement since my childhood, this arduous task could not have been accomplished.*

I am deeply grateful for the love, moral support, guidance, and cooperation from my siblings and extended family. To my brothers—Prince, Sunny, Aman, Jaspreet, Karam, Goldy, Gurjeet, and to my sisters—Simran, Raman, Nanu, and Jaspreet—I extend my heartfelt thanks for your unwavering encouragement and assistance throughout my journey.

I would like to extend my gratitude to Dean PGS, Dr. Kiran P. Raverkarr, for her support and guidance.

I cannot forget the love, moral support, guidance, and cooperation I received from my dear friends—Manisha, Rohit, Arjun, Ritik, Malo, Khaba, Ayan, Deepak, Amritanshu, Jitendra, Karan, Sarthak, Zeeshan, Rajat, Mohit—for their love, guidance, help, and moral support in every step of my master's thesis.

To my juniors—Krishna, Ravi, Neelesh, Anukul, Parth, Shubhyam, Mayank, Deepak, Akansha, Rakhi, Divya, Pooja, Barsha, Rekha—I extend my gratitude for your camaraderie and support.

I feel the limitation of my diction to truly reflect my feelings of gratitude. Hence, I have chosen this simple way of acknowledging the help received. To all those whose blessings and support have propelled me forward, even if not mentioned individually due to space constraints, I owe a debt of gratitude that words can only begin to convey.

Pantnagar
September, 2023

(**Gurpreet Singh**)
Author

CERTIFICATE- I

This is to certify that the thesis entitled **"COMPARISON OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLEID ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** with major in **Soil Science**, of the College of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of bonafide research carried out by **Mr. Gurpreet Singh, Id. No. 58090** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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

Pantnagar
September, 2023

(Swayam Prakash Gangwar)
Chairman
Advisory Committee

<u>CERTIFICATE-II</u>

We, the undersigned, members of the Advisory Committee of **Mr. Gurpreet Singh, Id. No. 58090,** a candidate for the degree of **Master of Science in Agriculture** with major in **Soil Science**, agree that the thesis entitled **"COMPARISON OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLEID ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA"** may be submitted in partial fulfillment of the requirements for the degree.

(Swayam Prakash Gangwar)
Chairman
Advisory Committee

(Ajaya Srivastava)
Member

(Veer Singh)
Member

(Satya Pratap Pachauri)
Member

LIST OF ABBREVIATIONS

DAT	:	Date of transplanting
DAS	:	Date of sowing
@	:	At the rate
%	:	Percent
Et al.	:	Et alia(and others)
etc.	:	Etcetera
R.B.D.	:	Randomized block design
DAP	:	Di-ammonium phosphate
SSP	:	Single super phosphate
NUE	:	Nutrient use efficiency
EC	:	Electrical Conductivity
FYM	:	Farmyard manure
RDF	:	Recommended dose of fertilizer
H_3PO_4	:	Ortho-phosphoric acid
$KMnO_4$	:	Potassium per-magnet
HNO_3	:	Nitric acid
N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
Zn	:	Zinc
Ha	:	Hectare
CRC	:	Crop research centre
Fig.	:	Figure
OC	:	Organic carbon
Kg	:	Kilogram
$kgha^{-1}$	:	Kilogram per hectare
$HClO_4$	:	Per chloric acid
M	:	Million
M	:	Metres
Mm	:	Millimeter
Mg	:	Milligram
mL	:	Milliliter
Sem	:	Standard error of mean

Mt	:	Million tonnes
N	:	Nitrogen
N	:	Normality
$NaHCO_3$	:	Sodium bicarbonate
TPF	:	Triphenylformazan
NaOH	:	Sodium hydroxide
P	:	Phosphorus
PNP	:	Para-nitro phenyl
qha^{-1}	:	Quintal per hectare
T	:	Tonne
Q	:	Quintal
C.D.	:	Critical difference
C.V.	:	Coefficient of variation
%	:	Percent
WUE	:	Water use efficiency
RDF	:	Recommended dose of fertilizer

Introduction

Chapter-1 INTRODUCTION

The daily food consumption rises in India due to the country's expanding population, while agricultural output does not. In India, extensive cropping with hybrid cultivars to increase food production has led to nutrient depletion in the soil. Deficits in macro and micronutrient have been discovered in Indian soils as a result. **(Bhalla *et al.* 1999).** On the other side, agricultural productivity has increased, but people's access to and availability of food (i.e., food security) continues to be a major concern. Furthermore, not only is nutritional security important, but also food security. Nutritional security is necessary for food security. Human needs can only be addressed by consuming a wide range of macro- and micronutrients in order to maintain optimum health. One of the most crucial factors in raising agricultural productivity is nutrition.

The growing demand for food grains, which is expected to reach 300 million tonnes by 2030 to meet the needs of a growing population, represents a significant challenge for the current agricultural environment **(Fischer et al., 2009).**The 1960s green revolution, which lasted for more than three decades, is now in jeopardy, and future increases in food production must instead come mostly from crop intensification and increased productivity. On many platforms, agricultural scientists have emphasized the importance of increasing soil productivity through a variety of practices, such as organic farming, integrated nutrient management, and biodiversity. In order to maintain the same level of production, nitrogen dosage was increased by three to four times from the 1960s, when it was applied to paddy at a rate of 80 to 100 kg ha^{-1}.

Paddy production in India is an important part of the national economy. Paddy (*Oryza sativa* L.) belongs to the family Poaceae. Paddy, *(Oryza sativa)*is one of the most important cereal crops of *kharif* season (**Chaturvedi *et al*. 2023)**Paddy is an excellent source of carbohydrates and protein, which has nutritious and possesses lesser crude fibers and fat (1 to 2 percent). About 20per cent of the world's dietary energy supplier is paddy alone and higher than wheat or maize **(Chaudhari *et al.*, 2018)** . Therefore, paddy production needs to be increased to satisfy consumer demand; concerns about increasing paddy productivity are more prevalent in scenarios of rising food demand as a result of consistent population growth and agricultural land shrinkage. In the 2020-2021, paddy is farmed all over the world and is one of the most significant cereal crops. Paddy dominates overall crop output and food consumption in China more than anywhere else on the planet. China produced over 148 million metric tons of milled paddy, a higher volume than any other country India came in second place with 122 million metric tonnes of milled paddy in a year. Paddy occupies nearly 43.8 m ha area in India, which has a total production of 177.6 million tons and productivity of 4,057 kg ha^{-1}**(FAOSTAT, 2021)**. Paddy production in India is contributed by four states namely West Bengal, Uttar Pradesh, Punjab and Andhra Pradesh. The other major producers are Odisha, Bihar, Chhattisgarh, Assam, Tamil Nadu, Haryana, Karnataka, Jharkhand, Madhya Pradesh, Maharashtra, Gujarat and Kerala. West Bengal is the largest producer of paddy in India contributing about 14.33 percent of the total paddy production from 12.8 percent of the paddy producing area of the country. In Uttarakhand paddy is cultivated in an area of 2.56 lakh hectare with the production of 6.17 lakh tones, and productivity of 2412 kg ha^{-1}**(DES, 2018)**. Crops require nitrogen, an essential ingredient that is frequently added as fertilizer to boost production In fact, according to **Erisman *et al*. (2008)**, half of the world's population depends on N fertilizers for food in the twenty-first century. The usage of N fertilizer will keep rising as a result of the expanding world population **(Good and Beatty, 2011).**

The structures of proteins, enzymes, co-enzymes, nucleic acids, and other cytochromes are affected by nitrogen, a nutrient that is commonly ingested **(Hasegawa *et al.*, 2008).** Chlorophyll molecules, which are essential to photosynthesis, must include nitrogen. Increased chlorophyll synthesis can result in greater photosynthetic efficiency and better crop performance when nitrogen is more readily available **(Evans *et al.*, 2019)**.

A contentious topic is the loss of 30–50 percent of nitrogen fertilizers. In order to meet the needs of plants, significantly more fertilizer is needed; nevertheless, over use of chemical N fertilizers has a negative impact on global water resources and causes lagoon processes in aquatic ecosystems **(Chinnamuthu and Boopathi, 2009).** Using slow-release fertilizers to gradually supply nitrogen to the plant at each stage of its development is one straightforward solution to this issue **(Akhlaghi, 2008).** Release nutrients gradually throughout the crop growing season, allowing the plant to receive the maximum amount of nourishment while reducing leaching-related fertilizer loss.

According to **Peng *et al.* (2016)**, paddy plants can take a sizable amount of nitrogen from the soil and have a high demand for nitrogen. The researchers found that during the vegetative and reproductive growth stages, paddy crops absorbed roughly 70–80 percent of their entire nitrogen requirement. If not properly managed, this significant nitrogen intake may deplete soil nitrogen stores and cause nutrient shortages.

For paddy production to be at its best, nitrogen control must be effective. Nitrogenous fertilizers are essential for increasing crop yield since they are made specifically to deliver nitrogen to paddy plants. Agricultural practices have a significant impact on the quality of the global environment in addition to crop productivity **(Tilman *et al.,* 2002)**. Therefore, we should aim for high crop yields with high nutrient usage efficiency and also minimizing the influence on the quality of the world's ecosystem.

Fertilizers are essential in the agricultural production system. Fertilizer application began in the country in the 1960s, coinciding with the introduction of the green revolution, when fertilizer-responsive varieties were introduced into Indian agriculture. Despite the fact that fertilizer application significantly increased grain growth, yields of several crops have plateaued across the country due to low fertilizer response ratios, imbalanced fertilization, low organic matter, and increased intensities of multi-micronutrient deficiencies. Balanced fertilization is one of the most critical factors for N management among the challenges confronting soil scientists. Farmers began using nitrogenous fertilizers heavily, particularly urea, because of the universal response in crops and the low paddy due to decontrol (subsidized rate), resulting in the current NPK ratio of 8.2:3.2:1. In contrast, the optimal ratio is stipulated as 4:2:1. This is a significant problem that causes nitrate pollution in ground water and eutrophication in aquatic systems. This necessitates the development of slow-release fertilizers to regulate the nitrification processes and thus maintain N availability throughout the crop period **(Trenkel *et al.,* 2021).**

Nitrogen is a vital nutrient required for the healthy growth and development of plants. In agricultural practices, nitrogenous fertilizers play a crucial role in providing an accessible and sufficient nitrogen supply to crops. Traditionally, nitrogenous fertilizers were available in solid form, but with advancements in technology, liquid and nano fertilizers have emerged as alternative formulations.

Fertilizers are one of the most important inputs required for increasing the production on various crops. Balanced use of chemical fertilizer has become our necessity to meet the increasing demand of food grains as well as vegetables crops. Efficient and economic use of fertilizers would help in increasing the production and input cost for obtaining maximum returns. Supplementing the nutrient requirement of crops through organic manures plays a key role in sustaining soil fertility, crop productivity and restoring overall soil quality. Intensive land use with continuous use of higher doses of inorganic fertilizers significantly influences soil health and crop growth. This has raised concerns about the potential long term adverse effects on soil health and environmental quality. Organic materials hold great promise as source of multiple nutrients because of their ability to improve soil characteristics. Therefore, integration of inorganic with organics may go long way in maintaining sustainable crop production and enhancing soil health through their complementary effects. By supplying plant nutrients through- nanotechnology, nano fertilizer or nano composites could possibly boost the plant growth**.** NMs are defined as materials with a single unit between 1 and 100 nm in size in at least one dimension **(Liu and Lal, 2015)**. Hence, nano fertilizers are either NMs which can supply one or more nutrients to the plants resulting in enhanced growth and yield, or those which facilitate for better performance of conventional fertilizers, without directly providing crops with nutrients **(Liu and Lal, 2015)**.

The Indian government has allowed the use of Nanotechnology in the production of plant nutrients. IFFCO has created a form of fertilizer known as Nano N. It was created in-house at IFFCO's Nano Biotechnology Research Centre (NBRC) in Kalol using proprietary technologies. The new Nano N liquid, according to IFFCO, will increase crop productivity while improving nutritional quality. The new product is projected to reduce environmental pollution produced by granular urea by eliminating its excessive use, which intance soil, water, and air pollution, as well as climate change problems.

The Central Fertilizer Committee, which oversees fertilizer products in India, anticipated that adopting Nano N will increase production by 15per cent and reduce urea needs (and import dependence) by half.

Lower usage and costs, higher productivity

Every crop season, an Indian farmer will normally spread two bags of urea per acre, with the quantity fluctuating slightly depending on the crop. According to IFFCO, field tests have demonstrated that a 500 mL bottle of Nano N may substitute for one bag of traditional urea which has 40,000 ppm of nitrogen, because it has the same amount of nitrogen that one bag of conventional urea provides.

Liquid fertilizers

Modern agricultural practices rely heavily on liquid fertilizers because they provide ease of use, effectiveness, and diversity in nutrient delivery. Liquid fertilizers, as opposed to conventional granular fertilizers, are created as solutions or suspensions of vital nutrients, making them easily absorbable by plants. This introduction examines the advantages, methods of application, and potential difficulties related to liquid fertilizers, utilizing pertinent citations and references to support the topic.

Benefits of Liquid Fertilizers: Compared to traditional solid fertilizers, liquid fertilizers provide a number of advantages. First off, their liquid nature makes application simple and consistent, especially when used with irrigation systems, foliar sprays, or fertigation techniques **(Havlin *et al.*, 2014)**. This makes accurate nutrient targeting easier, ensures that crops absorb nutrients optimally, and lowers the chance of nutrient imbalances or loss. Liquid fertilizers can also be combined with other inputs like insecticides or micronutrients with ease, allowing farmers to apply numerous items at once and save time and effort **(Saeed *et al.*, 2017)**. Because of their adaptability in composition and use of liquid fertilizers are a favorite among many farmers. Foliar sprays apply nutritional solutions directly to plants, facilitating quick absorption and resolving nutrient deficits

Due to its low cost when compared to other nitrogen sources, urea is the most significant inorganic nitrogen fertilizer for crop production worldwide. In addition to urea, another source of nitrogen is urea ammonium nitrate (UAN) solution (28–32 percent). A complex fertilizer called urea ammonium nitrate contains nitrogen in three different forms: urea, ammonium, and nitrate. Urea ammonium nitrate solution is a source of nitrogen for plant nourishment 25 percent of the nitrate is immediately available for plant absorption. Although

25 percent of it can be taken up directly by plants, ammonium oxidizing bacteria quickly convert it to nitrate. The remaining 50 percent of the urea is digested by soil enzymes to create ammonium, which is then converted to nitrate in the majority of the soils. For many crops, UAN solutions serve as a source of plant nourishment.

Solid fertilizers

Solid nitrogenous fertilizers are essential for increasing the yield and productivity of paddy crops. These fertilizers supply critical nutrients, especially nitrogen (N), which is necessary for the rapid growth and development of paddy plants.

Importance of Solid Nitrogenous Fertilizers in Paddy Cultivation:

To meet the nitrogen needs of the crop, solid nitrogenous fertilizers including urea, ammonium sulphate, and ammonium nitrate are frequently employed in paddy production **(Khan *et al.,* 2020).** The synthesis of chlorophyll, the creation of proteins, and enzymatic activity are just a few of the physiological processes that nitrogen is essential for in paddy **(Kumar *et al.,* 2020).** To maintain the balance of nutrients and support the healthy development of paddy crops, solid nitrogenous fertilizers must be applied.

There are several ways to apply solid nitrogenous fertilizers to paddy, including broadcasting, banding, and top-dressing. Before planting or during the first phases of crop growth, fertilizer is broadcast evenly over the entire field **(Dobermann *et al.,* 2002)**. When seeds are sown, fertilizer is positioned in little bands either below the seed or alongside it **(Fageria, 2007)**. During the crop's active growth stage, top-dressing entails applying fertilizer to the soil's surface **(Khan *et al.,* 2020)**. The efficiency of nutrient uptake by paddy plants can be greatly impacted by choosing the right delivery method, which is dependent on variables, such soil quality, crop stage, and nutrient availability. The development, productivity, and quality of paddy crops are directly influenced by the use of solid nitrogenous fertilizers. Increased grain yield is the outcome of improved tillering, leaf area development, and panicle formation brought about by an adequate nitrogen supply **(Kumar *et al.,* 2020)**.

One of the most crucial inputs needed to boost the production of diverse crops is fertilizer. To address the rising demand for food grains and vegetable crops, judicious use of artificial fertilizer has become essential. Utilizing fertilizers effectively and economically would help to raise output and input costs in order to get the best returns. Maintaining soil fertility, increasing agricultural output, and improving soil quality all depend on supplementing crops' nutrient needs with organic manures. Crop growth is severely impacted by intensive land usage combined with ongoing use of increased doses of inorganic fertilizers. Concerns have been expressed regarding the potential long-term negative consequences on the environment's quality and soil health. Because they can enhance soil properties, organic materials have a lot of potential as sources of various nutrients. Because of their complementing effects, combining inorganic and organic materials can help maintain sustainable crop production and improve soil health. Nano fertilizer or nano composites that deliver plant nutrients through nanotechnology may accelerate plant growth.

The best fertilizer management strategies involve applying tiny amounts of nitrogen frequently using various fertilizers, such as liquid fertilizers like urea ammonium nitrate (UAN), and better fertilizer application techniques. The nitrogen content of urea ammonium nitrate ranges from 28 percent to 32 percent with a100 percent solubility. because nitrogenous liquid fertilizers commonly mix with solutions containing P and K and other crucial plant nutrients, improved fertilizer delivery procedures should result in greater application uniformity, decreased fertilizer waste, and reduced environmental effects. It is possible to carefully mix liquid fertilizers to fulfill the needs of the soil and crop. Through improved fertilizer application methods and improved fertilizer supply, it is necessary to manage the amount of fertilizer applied and its distribution over the cultivated area. All In the field, the plants get a same amount of fertilizer without going overboard.

Owing to all above points, the present investigation **'COMPARISON OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLIED ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA'** will be carried out with following specific objectives:

1. Comparison of soil fertility status viz. pH, EC, OC, available N, P and K under fertilization of Nano urea, urea ammonium nitrate (UAN) and solid fertilizers.
2. Impact of different form of nitrogenous fertilizers on nutrient uptake viz. N, P and K.
3. Comparison of different fertilizers on yield and yield attributes of paddy crop.

Review of Literature

Chapter-2 REVIEW OF LITERATURE

In this chapter an attempt has been made to review the research work done in India and abroad on the respective on the respective objective mentioned as follows:

2.1 Comparison of soil fertility status *viz.* pH, EC, and O.C. available N, P, K, under the fertilization of Nano urea, urea ammonium nitrate (UAN) and solid fertililizers.

Yogananda *et al.* (2004) conducted field trials on farmers field revealed that although KRH-2 hybrid paddy out yielded over IR-64. The soil EC, organic carbon, available NPK was found almost same between varieties. Soil pH and EC were significantly decreased by the application of 4.25 t urban compost + 100:50:50 kg NPK ha^{-1}, 8.5 t urban compost + 50:50 kg PK ha^{-1} and 4.25 urban compost + 50:50:50 kg NPK ha^{-1}.

Subehia *et al.* (2005) conducted field trials in maize and wheat and observed that the organic carbon content increased in all the treatments as compared to its initial value with the application of P, FYM and lime. There was a significant increase in the organic carbon content of the soil which might be due to addition of organic matter through FYM, incorporation of biomass through root and leaf fall from the plants in varying degrees and creation of favorable conditions for the growth and development of soil microorganisms.

Laxminarayana *et al.* (2006) conducted an experiment during *kharif* 2002 on paddy. Treatment 100per cent NPK + poultry manure and 100 NPK + FYM application of different organic manures showed a significant increase in soil pH from 5.9 to 6.1 over the initial value of 5.6 after three years of continuous cropping. This finding suggests that the incorporation of organic manures in combination with conventional NPK fertilizers had a positive influence on the soil pH, leading to a slight increase in alkalinity over the cropping period.

Hati *et al.* (2008) conducted an experiment on soybean–wheat crop rotation. NPK + FYM treatment maintained the pH of surface soil as compared to the initial level, a slight decrease in soil pH was observed under control, NP and NPK treatments, whereas a considerable decrease in soil pH was recorded in N alone treatment. Similar trend was observed in sub-surface layer of the soil.

Raj *et* al. (2014) studied nitrogen availability nitrogen from different N sources i.e. prilled urea, urea gypsum, rock phosphate coated urea, coal tar coated urea and neem cake blended urea in semi dry paddy on sandy loam soil during two consecutive *rabi* seasons of 2009 &2010 and found that maximum amount of soil available N (285, 274, 256 and 235 kg ha $^{-1}$) was observed with application of neem cake blended urea in four equal splits at the rate of 100 kg N ha^{-1} followed by rock phosphate coated urea in four equal splits at the rate of 100 kg N ha^{-1} (282, 269, 248 and 230 kg ha^{-1}) than prilled urea at the rate of 100 kg N ha^{-1} (266, 253, 232 and 214 kg ha^{-1}) at all phenological stage.

Aula *et al.* (2016)evaluated the nitrogen application on winter wheat during 1993 to 2014.Considerable increase in TN (total nitrogen) was reported and it was mentioned that TN was maximum at high N rates. soil organic carbon was greatly raised by fertilizer N, especially when N rates were greater than 90 kg ha^{-1}. The annual application of 134 kg N ha^{-1} resulted in the greatest SOC (13.1 g kg1) was recorded. High rates of long-term N application led to an increase in TN and SOC in the topsoil.

Shawer *et al*. (2019) conducted an experiment on wheat-maize crop to investigate the effect of organic and nano N fertilization. Following the harvest, they observed that all the treatments led to a reduction in soil pH as compared to the control treatment. This finding suggests that both organic and nano N fertilization had an acidic impact on the soil after crop cultivation.

Sahar *et al.* (2020) conducted an experiment on paddy crops and observed the effects of different fertilization methods. Specifically, they found that after the harvest of soybeans, the electrical conductivity (EC) values of the soils tended to decrease with increasing rates of mineral fertilizers combined with compost or NPK nano-fertilizers. The result indicates that the application of these fertilizers had a beneficial impact on reducing soil salinity after the cultivation of soybean crops.

Ajithkumar *et al. (*2021) conducted an experiment on maize crop and concluded a slight increase in the soil chemical properties after the harvest of the crop. Treatments Control + 2 sprays of nano nitrogen (4mL L^{-1}) + 2 sprays of IFFCO nano N 2X (8mL L^{-1}) + 2 sprays of IFFCO nano Zn (2mL L^{-1}) + 2 sprays of IFFCO nano N (4mL L^{-1}) mixed with IFFCO nano Zn (2 mL L^{-1}) RDF (100per cent NPK) + 100per cent zinc 50per cent N, 100per cent PK + 2 sprays of IFFCO nano N (4mL L^{-1}) RDF (100per cent NPK) + 2 sprays of IFFCO nano Zn (2mL L^{-1}) 50per cent

N, 100per cent PK, 0per cent Zinc + 2 sprays of IFFCO nano N (4mL L^{-1}) mixed with IFFCO nano Zn(2 mL L^{-1}) 50per cent N, 100per cent PK, 0per cent Zinc + 2 sprays of IFFCO nano N (4mL L^{-1}) mixed with IFFCO nano Zn (2 mL L^{-1}) and IFFCO nano Cu (2mL L^{-1}) 50per cent N, 100per cent PK, 0per cent Zinc + 2 sprays of IFFCO nano N (4mL L^{-1}) mixed with IFFCO Sagarika (2 mL L^{-1}). The soil pH was slightly decreased from 8.12 to 8.05 and slight increase in EC and slight increase in OC, available N, P, K, were slightly increased.

Sarwar *et al*. (2021) studied the different level of nano fertilizer on sweet corn at different time interval sand they found that the significant effect was found on pH, EC and organic carbon content of soil.

Sha *et al.* (2022) conducted an experiment in flooded paddy crop applied urea and ammonium bicarbonate recorded high pH because unstable nitrogen sources, While urea treated with Limus reduced NH3 loss under simulated flooded conditions by 36.6per cent compared to urea alone, the pH of the floodwater had a substantial impact on the inhibitor's efficiency.

AL Aasmi, *et al.* (2022) conducted an experiment on paddy investigate and the impact of different nitrogen fertilizer treatments on soil pH and soil-available nitrogen in the root zone. They applied varying levels of nitrogen fertilizers, ranging from no added nitrogen (control treatment) to light, moderate, and heavy nitrogen application. As a result, under each fertilizer treatment, the soil pH exhibited a significant decrease. Specifically, the soil pH values were measured at 7, 6.5, and 5.6 for the control treatment, and as the soil water content increased, these pH values declined. In contrast, the concentration of soil-available nitrogen in the root zone demonstrated a significant increase, with values measured at 22, 24, and 26 mg for the same control treatment, light, and moderate nitrogen applications, respectively. This indicates a relationship between soil pH, nitrogen fertilizer application, and soil-available nitrogen in the root zone of paddy crop soil.

Choudhary *et al.* (2022) conducted an experiment on Indian mustard nutrient management practices increased organic carbon in soil significantly over control. Highest organic carbon content (0.445 per cent) was found with the application of 75 percent NPK and S + Zn 5 kg ha^{-1} + Bio-stimulants + Nano N + Nano Zn spray at 40 DAS. The available N, K, and Zn in soil were significantly altered due to the foliar application of nano fertilizers after harvest of maize crop over control. It was observed that the combined application of conventional fertilizers and nano fertilizers increased the available amount of N, K and Zn in soil when tested at the harvest of the crop.

Singh *et al.* (2023) conducted an experiment during *Kharif* 2022 in maize and paddy. TNU (Urea nanoparticles) 100per cent RDN (in three equal splits) + TNU: 75per cent RDN (in three equal splits) + TNU: 50per cent RDN (in three equal splits) + TNU :100per cent RDN: 50per cent RDN (only basal dose) + TNU through two foliar applications: 33per cent RDN (only basal dose) + TNU through two foliar applications: 75per cent RDN + 2per cent bulk urea spray T9: 50per cent RDN + 2per cent bulk urea spray: Negative control. pH of 7.1, organic carbon of 0.41per cent, available N of 112.0 kg per hectare, available P of 29.0 kg per hectare and available K of 115 kg per hectare, while paddy experiment had a pH of 6.98, organic carbon of 0.34per cent, available N of 84.7 kg per hectare, available P of 27.0 kg per hectare, and available K of 113 kg per hectare.

Yadav *et al.* (2023) laid an experiment on lentil in split plot arrangement had four nitrogen management treatments in main plot *viz.,* control (only P and K), RDF (150-60-60 kg ha^{-1} N-P2O5-K2O), 75per cent RDN (Inorganic) + 25per cent through FYM, 75per cent RDN (Inorganic) + 25per cent through Vermicompost. Maximum value of soil electrical conductivity (EC) was recorded in treatmentN2 (75per cent RDN (inorganic) +25per cent through FYM) being on par withN3 (75per cent RDN (inorganic) +25per cent through VC) and N1 (100per cent nitrogen through inorganic). Lowest value of EC was observed in N0 (only P and K).

Dawood *et al.* (2023) conducted an experiment in pearl millet .FYM application resulted the highest soil organic carbon, whereas the control treatment recorded the lowest soil organic carbon. The FYM application increased soil organic carbon by 39.13per cent and 40.00 percent as compared to the control treatment and also available N in soil was significantly altered and overall urea + FYM application and seed inoculation with RB resulted in the highest values of soil-available N during the study. Urea + FYM application increased soil-available N by 250.00per cent and 233.33per cent.

2.2 Impact of different form of nitrogenous fertilizers on nutrient uptake viz. N, P, and K by paddy crop

Meena *et al.* (2008) investigated the application of neem-coated urea compared to prilled urea at a rate of 120 kg N ha^{-1}, applied in three splits. They found that neem-coated urea resulted in significantly higher uptake of nitrogen (93.4 kg ha^{-1}), phosphorus (26.0 kg ha^{-1}), and potassium (132 kg ha^{-1}) compared to prilled urea at the same dose and splits. This improved nutrient uptake was attributed to the slow and steady release of nitrogen from neem-coated urea, which enhanced the use efficiency of the applied nutrients. The study suggests that the utilization of neem-coated urea can be a more effective approach in enhancing nutrient uptake and improving crop productivity.

Bazaya *et al.* (2009) investigated the effect of different nitrogen levels on total nutrient uptake in paddy. They observed that as the nitrogen level increased from 0 to 120 kg N ha^{-1}, there was a significant rise in total NPK uptake. The highest value of total nutrient uptake was recorded when 150 kg N ha^{-1} was applied. Specifically, the application of 150 kg N ha^{-1} in recommended splits resulted in the highest total N (74.64 kg ha^{-1}), P (23.20 kg ha^{-1}), and K (96.81 kg ha^{-1}) uptake, surpassing the uptake observed with lower nitrogen doses. This finding suggests that proper nitrogen management, particularly at the 150 kg N ha^{-1} level, can lead to increased overall nutrient uptake and potentially enhance crop productivity.

Yadav *et al.*(2023) evaluated the efficiency of substituting different proportions of fertilizer nitrogen (25%, 50%, and 75% of total N) with various organic nitrogen sources, including farm yard manure (FYM), green leaf manure (GLM), poultry manure, and blue-green algae (BGA) on nutrient uptake (NPK) and yield of paddy variety Sarju-52. They observed that the highest uptake of nutrients and grain yield were achieved when 25% of nitrogen was applied through green manure, and the remaining 75% was applied through urea fertilizer. Among all the organic sources tested, green leaf manure (GLM) demonstrated the highest efficiency at all the different proportions of nitrogen substitution. At also indicates that utilizing a combination of green manure and urea, with GLM as the organic source, could be an effective approach in promoting nutrient uptake and maximizing the yield of paddy crops, particularly for the Sarju-52 variety.

Sunitha *et al.*(2010) conducted an experiment on paddy*(Oryza sativa)* during *Kharif* 2007 to determine the effect of INM approach on soil properties, available nutrient status, concentration and uptake of major nutrients. The treatments were: control; 50per cent N; - 100per cent N; - 50per cent N + 50per cent N GLM; - 50per cent N+ 50per cent N FYM and farmers practices. The treatment had received organic manures viz., glyricidia or FYM in combination with 50per cent N recorded maximum uptake of N, P and K as compared to farmer's practice and 100per cent N applied through urea. It was mentioned that the adoption of integrated nutrient management approaches comprising 50per cent N through urea + 50per cent through GLM.

Kumar *et al.* 2018) assessed the relative efficiency of prilled urea coated with major neem oil components in lowland irrigated paddy of the Indo-gangetic plains. The results showed that the concentration and uptake of nitrogen in paddy grain and straw, as well as total nitrogen uptake, were significantly influenced by the neem oil components and their varying doses. Among the different coated urea treatments, meliacins-coated urea demonstrated the highest nitrogen content in grain (1.12%) and straw (0.60%), as well as the highest total nitrogen uptake in grain (71.5 kg ha^{-1}) and straw (127.5 kg ha^{-1}). These findings suggest that the use of meliacins-coated urea could be a promising approach to enhance nitrogen content and uptake in paddy crops, contributing to improved yield and productivity in the lowland irrigated paddy of the Indo-gangetic plains.

Singh *et al.* (2011) revealed that the application of N, P and K fertilizers (100per cent RDF or 50per cent RDF), lime and sulphur in combination with FYM, significantly increased the total uptake of N, P, K and S by upland paddy in paddy-pea cropping system. The highest total N, P and K uptake by paddy obtained with application of 100 per cent RDF was at par with integrated use of 50per cent RD F along with application of 5t FYM + 250 kg lime + 20kg S ha^{-1}. Integration of sulphur in INM resultedthe higher uptake of S by paddy over rest of the treatments. Total K uptake by paddy crop was quite higher in comparison to the uptake of N, P and S with the application of INM treatments.

Rahman *et al.* (2011) conducted an experiment on maize to evaluate the impact of elemental sulfur and nitrogen fertilizer on nutrient uptake in sandy calcareous soil. The researchers found that the application of sulfur at a rate of 5 t ha^{-1} along with nitrogen at 0.34 t ha^{-1} resulted in significantly higher nutrient uptake by the plants. Specifically, the plants exhibited higher nitrogen uptake (34.19 mg g^{-1}) and phosphorus uptake (14.67 mg g^{-1}) compared to the control group where no sulfur and lower nitrogen (5.65 and 5.70 mg g^{-1} for N and P, respectively) were applied. This suggests that the combined application of sulfur and nitrogen had a positive effect on nutrient uptake by maize plants in sandy calcareous soil, potentially leading to improved crop growth and yield.

Bhatt *et al.* (2012) reported that application of lower dose of nitrogen (80per cent of RDN) in three equal splits to paddy crop recorded higher nitrogen use efficiency. N applied than the higher doses 120 kg N ha^{-1} (100per cent) with same source and splits. Among the sources, neem coated urea was resulted in higher NUE compared to prilled urea at both 80 and 100per cent nitrogen doses. The beneficial effect of NCU over prilled urea was due to its nitrification inhibiting action of neem coating in neem coated urea.

Gopakkali *et al.* (2012)found that the application of the recommended dose of fertilizer along with farmyard manure (FYM) at a rate of 10 t ha^{-1} resulted in significantly higher nutrient uptake by the paddy plants. Specifically, this treatment recorded a higher nitrogen uptake of 122.9 kg ha^{-1}, phosphorus uptake of 31.3 kg ha^{-1}, and potassium uptake of 94.0 kg ha^{-1} compared to the other treatments tested on sandy clay loam soils. These findings suggest that the combination of the recommended dose of fertilizer with FYM at a suitable rate can enhance nutrient uptake in paddy crops and potentially lead to improved growth and yield on sandy clay loam soils.

Sannagoudra *et al.* (2012) found that the application of the recommended dose of fertilizer along with farmyard manure (FYM) at a rate of 10 t ha^{-1} resulted in significantly higher nutrient uptake by the paddy plants. Specifically, this treatment recorded a higher nitrogen uptake of 122.9 kg ha^{-1}, phosphorus uptake of 31.3 kg ha^{-1}, and potassium uptake of 94.0 kg ha^{-1} compared to the other treatments tested on sandy clay loam soils. These findings suggest that the combination of the recommended dose of fertilizer with FYM at a suitable rate can enhance nutrient uptake in paddy crops and potentially lead to improved growth and yield on sandy clay loam soils.

Bandaogo *et al.* (2015) conducted an experiment on irrigated paddy and reported that the highest nutrient uptake i.e. N, P and K by using urea super granules-USG were 73.67, 2.71 and 41.01 kg ha^{-1}, respectively. and also it was observed that the application of USG increase the grain N uptake by 3 per cent, P uptake by 6 per cent and K uptake by 8 per cent over PU And highest P (3.36 kg ha^{-1}) and K (50.16 kg ha^{-1}) grain uptakes were observed with the combination of USG and FKR 19 treatment. The combination of paddy varieties and urea fertilizer type significantly ($P < 0.05$) affected straw N and P uptakes, and highest N (41.53 kg ha^{-1}) and P (1.21 kg ha^{-1}) uptakes were obtained from the combination of FKR 19 and PU treatment.

Khatun., *et al.* (2015) conducted experiment on lowland paddy (BRRI dhan-28) to investigated the nitrogen use efficiency of paddy affected by different organic and chemical nitrogen sources. The compared the effects of urea combined with poultry manure and urea combined with cow dung on nitrogen uptake in paddy grain and straw. The results showed that the treatment with urea + poultry manure resulted in the highest nitrogen uptake in paddy grain (66 kg ha−1) and straw (38 kg ha−1). The urea + cow dung treatment also led to a significant nitrogen uptake in paddy grain (36 kg ha^{-1}) and straw. This suggests that the combination of urea with poultry manure proved to be more effective in enhancing nitrogen uptake in the paddy crop compared to the urea with cow dung treatment, indicating its potential for improving nitrogen use efficiency in lowland paddy cultivation.

Selvarajh *et al.* (2020) resulted in an increase of nutrient uptake. The paddy plant N uptake in treatment amended with RSRH biochar at 5 t ha^{-1} (T_2),10 t ha^{-1}(T_3)100 g soil + 0.97 g urea + 0.14 g paddy straw biochar + 0.14 g paddy husk biochar and 100 g soil + 0.97 g urea + 0.28 g paddy straw biochar + 0.28 g paddy husk biochar) was significantly higher than other treatments. The plant P and K uptake showed a significant increase in T2 and T3 as compared to toT0, T1, T4, and T5.100g soil alone and 100g soil + 0.97g urea, 100g soil + 0.97g urea + 0.42g paddy straw biochar + 0.42g paddy husk biochar, 100g soil + 0.97g urea + 0.56g paddy straw biochar + 0.56g paddy husk biochar. The increase in plant dry weight, height, tiller number, panicle number, and greenness was observed.

Chandana *et al.* (2021) revealed that the effects of different fertilization treatments on paddy grain yield and nitrogen uptake. They compared the application of 100% NPK with Nano N at active tillering and 75% N with 100% PK along with Nano N at active tillering stage, They found that both treatments resulted in increased grain yield, with the first treatment recording a yield of 5112 kg ha^{-1} and the second treatment at par with it. Additionally, the application of 100% NPK with Nano N at active tillering showed significantly higher total nitrogen uptake at harvest (106.48 kg ha^{-1}). This indicates that using Nano N in combination with NPK fertilizer can enhance grain yield and nitrogen uptake in paddy crops, potentially improving overall productivity and nutrient utilization.

Singh *et al.* (2023) observed that the fertilizing treatment had the combination of 75per cent dose of the conventional fertilizer in addition with urea nanoparticles (TNU) applications as the supplementary nitrogen source outperformed the other treatments in terms of growth, yield in paddy crop. Application of TNU along with conventional urea in paddy via 75per cent RDN + TNU leads to the significantly higher amount of N uptake in grain and straw as compared to other N treatments except 100per cent RDN and 100per cent RDN + TNU. The improved N content of grain and straw in 75per cent RDN + TNU was significantly higher than total N uptake of 115.4 kg per hectare as compared to 93.0 kg per hectare in 75per cent RDN + 2per cent conventional urea spray.

Paramesh *et al.*(2023) observed that farmyard manure and chemical fertilizer had significantly higher crop yield and nutrient (N P and K) uptake by paddy crop. The N and K uptake was 75 per cent N-NCU + 25per cent N-FYM followed by 100per cent N-FYM, while the P uptake was found to be higher in 100per cent N-FYM for both seasons. The application of 75per cent N-NCU + 25per cent N-FYM ensued in 231per cent, 308per cent, and 134per cent higher N, P, and K uptake.

2.3 Comparison of different fertilizers on yield and yield attributes of paddy crop

Cahill *et al.* (2007) compared Urea Formaldehyde Polymer (UFP) aqueous Urea Ammonium Nitrate (UAN) in wheat and maize. The UFP and UAN at the rate 0,50,75,106,134,168 and190 kg N ha^{-1}in wheat and 0,39,78,118,157,196 and235 kg N ha^{-1} for maize were taken. UAN was applied less than one-third at planting, and remaining was applied before tillering stage of wheat and corn. UAN gave satisfactory or better grain yield and nitrogen use efficiency than UFP in both crops. Under laboratory conditions, UFP release of urea and urea hydrolysis were completed in less than 2 weeks. It was concluded that UFP release was limited to time and insignificant for summer crop.

Maragatham *et al.* (2010) conducted an experiment on paddy to studied the impact of different nitrogen fertilizer treatments on various growth parameters, yield attributes, and grain yield. They compared the effects of applying 50% of nitrogen as Urea and 50% as poultry manure, and 100% of nitrogen as urea. The results showed that the treatment with 50% of N as Urea + 50% of N as poultry manure resulted in higher growth characteristics, yield attributes, and grain yield compared to the application of 100% of N as urea. This suggests that the combination of Urea and poultry manure as nitrogen sources can lead to improved crop growth and higher grain yield in paddy crops, making it a potentially beneficial nitrogen management practice for paddy cultivation.

Siddaram*et al.* (2010) conducted an experiment on paddy at different levels of nitrogen which increases the yield attributes like number of productive tillers per hill, number of filled grains per panicle and 1000 grain weight. Similarly, **Ashouri and Amiri (2011)** showed that weight of 1000 grain in paddy, 150 kg ha^{-1} N fertilizer was 22.2 g in 2008 and 23.3 g in 2009. The highest paddy yield at 200 kg N per hectare was due to the higher number of grains per panicle.

Gagnon *et al.* (2012) conducted an experiment during 2008-2010 and found that fertilizer treatments increased the corn yield in all 3 years of the study, but the magnitude of the response varied with years. In the wet years i.e.2008 and 2009 polymer coated urea (PCU), urea ammonium nitrate 32per cent (UAN) and nitrification inhibitor urea (NIU) significantly increased yields by 1.6, 1.4 and 0.6 Mg ha^{-1} over urea; respectively. Grain N concentration showed linear response with increased rates of urea and PCU in 2010 and quadratic in 2008 and 2009.In 2008, only polymer coated urea and urea ammonium nitrate treatments (UAN) at the rate of 150 kg N ha^{-1} gave higher grain N than the control.

Pramanik *et al.* (2013)conducted an experiment on hybrid paddy and observed that the five levels of nitrogen viz., N0, N50, N100, N150 and N200 kgha^{-1}, among the different nitrogen levels N200 kg ha^{-1} gave significant higher plant height, panicle initiation, number of tillers hill^{-1}, total chlorophyll content, panicle length and straw yield followed by nitrogen levels N150 kg ha^{-1} gave significant higher number of effective tillers per hill, effective tiller index, panicle weight, filled grain panicle^{-1}, 1000 grain weight, grain yield, and harvest index as compared to N0, N50, N100 during both years. N150 kg ha^{-1} recorded significantly higher grain yield (6286 and 6652 kg ha^{-1}, respectively) in 2010 and 2011.

Saleem *et al.*, (2013)conducted trials on wheat for three consecutive years and found that the soil application of urea was compared with 1per cent spray of urea (6 sprays from 2 leaves to booting stage), 2per cent spray of urea (at two leaves, tillering and booting stage), 3per cent spray of urea (at tillering and booting stage) and ½ urea as soil application + 2per cent spray of urea (at tillering and booting stage) in order to assess their impact on Yield components, grain yield data, nitrogen concentration in grain and uptake and cost benefit ratio were calculated. Based on three years observation reported that ½ soil + 2 sprays of 2per cent urea significantly increased the grain yield (4.97 t ha^{-1}) and was at par with soil application of urea alone. Concentration and uptake of nitrogen increased in grain by foliar application of urea as compared to soil application at sowing due to efficient mobilization of nitrogen to grain after foliar application.

Son *et al.* (2013) conducted the experiment on paddy to study the effect of different treatments on paddy yield and yield attributes. They found that the combined application of composted paddy straw with 100% NPK fertilizer resulted in the highest plant height, measuring 78.6 cm. On the other hand, the lowest plant height of 63.5 cm was recorded when raw paddy straw was applied alone. These results suggest that the use of composted paddy straw, in combination with NPK fertilizer, led to better plant growth and taller paddy plants compared to using raw paddy straw alone. The incorporation of composted paddy straw may have contributed to improved soil fertility and nutrient availability, thereby promoting healthier and taller paddy plants.

Akhand *et al.* (2013) studied the suitability of urea spraying for nitrogen management on paddy cultivation. Urea at 266 kg/h was applied in Boro and 175 kg $ha^{-1}$was applied in aman which was top dressed at 20, 30 DAT (date after transplanting) and at panicle initiation stage, 2/3rd of recommended N, top dressed at 20, 30 DAT along with 3.5per cent urea spraying at PI stage, 2/3rd of recommended N, top dressed at 20, 30 DAT along with 3.5per cent urea solution spraying at PI and booting stage, 2/3rd of recommended N along with 3.5per cent urea spraying at maximum tillering, PI and booting stage. It was found that urea could be saved by 4per cent in Aman and 17per cent in Boro seasons without scarifying grain yield when 2/3rd of recommended N, top dressed at 20 and 30 DAT along with urea solution spraying with 3.5per cent concentration at tillering, panicle initiation and booting stages.

Moro *et al.* (2015) reported the impact of different nitrogen (N) levels on paddy crop performance. They observed that the total number of tillers per square meter (m^2) increased significantly as the N level was increased to 90 kg N ha^{-1}. However, the total number of panicles did not show the same relationship and did not increase proportionally with N levels. The total biomass yield of the paddy crop display a significant and linear increase with increasing N levels. This indicates that higher N application resulted in greater biomass production in the paddy plants. Moreover, the paddy yield, showed a significant increase with increasing N levels. The control treatment (no added N) yielded 1.7 t ha^{-1}, while the maximum yield of 9.4 t ha^{-1} was achieved with the application of 90 kg N ha^{-1}. This demonstrates that proper N fertilization played a crucial role in significantly enhancing paddy yield and overall paddy productivity.

Farnia and Omidi, *et al.*, (2015) investigated the effects of zinc Nano fertilizer and Nano bio-fertilizer on maize biomass yield. The researchers found that the application of zinc Nano fertilizer and Nano bio-fertilizer resulted in a significantly higher biomass yield of 17,000 kg ha^{-1}, compared to the control treatment with a biomass yield of 11,000 kg ha^{-1}. Additionally, the study examined the interaction between irrigation frequency and zinc Nano fertilizer application on maize grain yield. The results showed that when irrigation was done once every 7 days in combination with zinc Nano fertilizer, the maize crop achieved the highest grain yield of 10.5 t ha^{-1}.

Benzon *et al*. (2015) reported that the recommended rate of conventional and Nano fertilizer (FRR-CF+FRR-NF) enhanced the plant height, chlorophyll content, number of reproductive tillers, panicles, and spikelets in paddy significantly increase over the full recommended rate of conventional fertilizers were 3.6per cent, 2.72per cent, 9.10per cent, 9.10per cent, and 15.42per cent, respectively. Similar results were seen in panicle weight (17.4per cent), total grain weight ($unpolished^{-1}$7.5per cent, polished-20.7per cent), total shoot dry weight (15.3per cent), and harvest index (2.9per cent) of paddy.

Amrutha *et al.*, (2016) conducted field experiment on paddy to study the impact of different levels and timing of nitrogen application during the *kharif* season in red sandy loamy soil. The study focused on the growth parameters of the paddy crop. This showed that the number of productive tillers per hill was significantly higher, with a value of 22.77, when nitrogen was applied at a rate of 120 kg ha^{-1}. On the other hand, lower yield parameters were observed when nitrogen was applied at a lower rate of 80 kg ha^{-1}. So this suggests that the application of nitrogen at a higher level (120 kg ha^{-1}) positively influenced the development of productive tillers in aerobic paddy, contributing to improved yield parameters. Conversely, a lower rate of nitrogen application (80 kg ha^{-1}) led to reduced yield parameters in the red sandy loamy soil conditions during the *kharif* season.

Chen *et al.* (2016) conducted an experiment to determine the effects of placement methods (broadcast and band) and N rates (60, 150 and 240 kg ha^{-1}) on the fate of $urea^{-}$ $^{1}5N$ in the wheat. the fertilizer N banding, the 15N labeled urea as basal fertilizer was side-banded by shovel 5 cm from wheat and 10 cm under the soil surface. N fertilizer applied in bands increased grain yield by 15per cent compared with broadcast application. The N fertilizer application rate had a significant effect on grain yield, straw yield and aboveground biomass, as well as on N uptake and N concentration of wheat.

Jamil *et al.* (2016) conducted experiment on paddy to studied the effect of different treatments on plant height in the crops. They observed that the application of 4 t ha^{-1} of vermicompost resulted in the highest plant height, measuring 93.89 cm. On the other hand, the control treatment, where no vermicompost was applied, showed the lowest plant height of 90.05 cm. This indicates that the use of vermicompost at the rate of 4 t ha^{-1} had a positive impact on the growth and development of the crops, leading to taller plants compared to the control treatment. Vermicompost is a rich source of nutrients and organic matter, which likely contributed to improved soil fertility and plant growth, resulting in taller plants in the field. The findings highlight the potential benefits of using vermicompost as a soil amendment to enhance plant height and overall crop performance in clay loamy soils.

Kumar *et al.(*2018) conducted a study in silt loam soil on transplanted paddy and revealed that plant height was significantly influenced by different nitrogen management practices at 30, 60, 90 DAT and at harvest. The plant height increased continuously with the advancement of crop age up to 90 DAT and thereafter, it was reduced gradually. At all the growth stages, application of 150 kg N ha^{-1} through NCU as 50per cent basal, 25per cent at active tillering and 25per cent at panicle initiation recorded the highest plant height.

Abdel-Aziz *et al*., (2018) studied that the effects of foliar application of nano chitosan nitrogen, phosphorus, and potassium (NPK) fertilizer on wheat plants. and found that the application of nano chitosan NPK resulted in a decreased life cycle of wheat plants by 23.5% (130 days for yield production from the date of sowing). This also indicates that the foliar application of nano chitosan NPK had a significant impact on accelerating the growth and development of wheat plants. Moreover, the study observed that treating wheat plants with nano chitosan NPK at 10% induced notable improvements in various growth and yield parameters. Specifically, this treatment led to increased plant height (86.33 cm), a higher number of spikelets per main spike (17.33), greater 100-kernel weight (6.02 g), and higher grain yield per plant (6.12 g). These findings suggest that the use of nano chitosan NPK at an appropriate concentration had positive effects on enhancing wheat plant growth, spikelet formation, and grain yield, indicating its potential as a promising fertilizer option for improving wheat crop productivity.

Al-Saray and Al-Rubaee (2019) showed the significant differences between different fertilization treatments in wheat. The Nano fertilizer treatment (2 ml nano nitrogen l^{-1} water) achieved the maximum number of row in ears (16.867, 16.011 row ear^{-1}), number of grain in row (39.31 and 41.91 grain row^{-1}), number of grains in ear (651.88 and 693.77 grain ear^{-1}), 500 grain weight (157.600 and 159.478 g) and a total grain yield of 9.28 and 9.35 t ha^{-1} at both spring and autumn seasons, respectively.

Pradhan *et al.* (2019) conducted an experiment on low land paddy and revealed that application of 80 kg N ha $^{-1}$ as NCU was effective over application of 100 kg N ha^{-1} as prilled urea (PU). The highest plant height was 109.8 cm with panicle length of 24 cm and effective tiller (11.5) was observed with (100 kg N ha^{-1} as PU) whereas lowest value of 84.5 cm, 20.6 cm and 9.1 cm for plant height, panicle length and effective tillers per hill respectively. The highest grain yield of 47.3 q ha $^{-1}$ was observed in T8 (80 kg N ha^{-1} as NCU) and lowest value - of 32.7 q ha^{-1} in control. The grain yield of paddy under (100 kg N ha^{-1} as PU) was 47.0 q ha^{-1} which was statistically at par with (80 kg N ha^{-1} as NCU) indicating the higher efficiency of NCU than that of PU. With the doses at 80 kg N ha^{-1} the yield advantages were due to application of NCU which had a 5.1per cent more yield advantages than that of PU.

Singh *et al.* (2020) conducted an experiment on paddy with six treatments *viz.*, control, Azolla incorporation at the rate of 1.6 tonnes ha^1, 30 kg N ha through urea, 60 kg N ha^{-1} through urea, 30 kg N ha^1 through urea + Azolla incorporation at the rate of1.6 tonnes ha and 60 kg N ha^{-1} through urea with Azolla incorporation at the rate of 1.6 tonnes ha^1. The application of 60 kg N ha^1 through urea along with Azolla incorporation at the rate of 1.6 tonnes ha^1 recorded highest dry matter i.e. 58.15 g $hill^1$ at maturity of paddy. 60 kg N ha^1 through urea with Azolla incorporation at the rate of1.6 tonnesha produced highest grain and straw yield i.e. 4.2 tha and 7.68 t ha followed by T, and T_1. The increase in N, P and K concentration and uptake in grain was 28.57, 97.02; 26.09, 84.21 and 15.69, 76.47 percent in T, over T_1.

Yogendra *et al.* (2020) reported the effect of different fertilizer treatments on the grain yield of maize and barley. The researchers found that the treatment with FFP, which represents the farmer's traditional fertilizer practice, resulted in the lowest grain yield for both maize (4100 kg/ha) and barley (3200 kg/ha). the treatment with FFP combined with 50% of the recommended nitrogen (N) application, along with one spray of nano N, one spray of nano Zn, and one spray of nano Cu, showed significantly higher grain yields for both maize (6000 kg/ha) and barley (5900 kg/ha). This indicates that the combination of reduced conventional nitrogen application and foliar sprays of nano N, nano Zn, and nano Cu had a positive impact on enhancing grain yield in both crops.

Ajithkumar *et al.* (2021) observed that a specific treatment with 50% N, 100% PK, and no zinc, along with two sprays of IFFCO nano N mixed with IFFCO Sagarika, resulted in the highest growth and yield parameters for maize. The treatment led to maximum plant height (226 cm), leaf area (801.16 cm2), stem girth (6.97 cm), 100-kernel weight (40.71 g), cob weight (182.68 g), and grain yield (58.90 q ha^{-1}). These findings suggest that this particular combination of fertilizers and foliar sprays positively impacted maize crop productivity during the study.

Lahari *et al.* (2021) conducted an experiment in Sandy loam soils during rabi, 2020 to study the effect of nano nitrogen and nano zinc on the yield of paddy with the application of 50per cent conventional nitrogen fertilizer + foliar spray of 4 mL $^{-1}$ nano nitrogen at tillering and before panicle initiation stage + foliar spray of 2 ml L^{-1} nano zinc. At tillering and before panicle initiation stage the grain yield significantly increased with 6810 kg ha^{-1} and uptake of nitrogen by 147.7 kg ha^{-1} , phosphorous by 30.0 kg ha^{-1} and potassium by 137.9 kg ha^{-1} .

Tezera *et al.* (2021)demonstrated that the treatment combination of 2 g ha^{-1} of nano urea and nano DAP seed dressing, along with 39 g DAP and 10.8 g urea, resulted in the highest plant height (132.4 cm), highest grain yield (38 q ha^{-1}), and the earliest maturity date (119 days) in the experimental maize crop. On the other hand, the control treatment, without any nano fertilizers or specific nutrient application, recorded the least grain yield of 2.5 q ha^{-1}. These results indicate that the application of nano urea and nano

DAP seed dressing, along with DAP and urea, significantly improved maize crop performance, leading to taller plants, higher grain yield, and an earlier maturity date. The findings suggest the potential of utilizing nano fertilizers in combination with conventional fertilizers to enhance maize productivity and expedite crop maturity.

Midde *et al.* (2021)conducted experiment on paddy with the treatment *viz*., Control, 100per cent Nano N, 90per cent RDN + 10per cent Nano N, 80per cent RDN + 20per cent Nano N, 70per cent RDN + 30per cent Nano N, 60per cent RDN + 40per cent RDN, 50per cent RDN + 50per cent Nano N, 40per cent RDN + 60per cent Nano N. The results of the study revealed that the maximum highest plant height (104.7 cm), Number of Tillers (348) and Grain yield (7056 kg ha^{-1}), Straw yield (8342 kg ha^{-1}) found in the treatment 50per cent RDN + 50per cent Nano N (T7).

Sharma *et al.* (2022) conducted experiment on pearl millet during *Kharif* season of 2021. (50per cent RDN, 75per cent RDN and 100per cent RDN) and three treatment of Nano-Urea (control, one spray of nano urea at 4 mL^{-1} water at 30 DAS and two spray of nano urea at 4 mL^{-1} water at 30 and 45 DAS).showed that highest plant height, dry matter accumulation, chlorophyll content, nitrogen content, phosphorus content and potassium content in grain and straw of pearl millet was obtained with the application of 100per cent RDN which was significantly superior to 50per cent RDN. Results further showed that foliar spray of Nano-Urea (4 mL^{-1} water) at 30 and 45 DAS significantly increased the plant height, dry matter accumulation, chlorophyll content, nitrogen content, phosphorus content and potassium content in grain and straw of pearl millet over control and foliar spray of Nano-Urea (4 mL^{-1} water) at 30 DAS.

Kothari *et al.* (2023) investigated the effect of different treatments on various growth and yield parameters of paddy. They found that the treatment with 50% recommended dose of nitrogen (RDN) in combination with 50% Nano N resulted in the highest values for plant height (104.7 cm), number of tillers (348), grain yield (7056 kg ha^{-1}), and straw yield (8342 kg ha^{-1}). However, the exact differences in yield among the treatments labeled as T2, T3, T4, and T5 were not specified in the provided text. Further information would be required to determine the specific variations in yield among these treatments. and the study suggests that the combined application of 50% RDN and 50% Nano N had a significant positive impact on various growth and yield parameters of paddy, potentially making it a promising approach to improve paddy productivity and sustainability.

Ranjan *et al.*(2023)conducted an experiment on paddy and found the highest number of tillers meter-2 , number of panicles meter-2 , number of filled grains panicle^{-1}, 1000-grain weight (g), grain yield (4899 kg ha^{-1}) and straw yield 6094 kg ha^{-1}) was observed in treatment 100per cent RDN through urea along with 2 foliar sprays of Nano-urea (4mL L^{-1}) at AT and PI which was at par with 100per cent RDN through urea [50per cent basal + 25per cent active tillering (AT) + 25per cent panicle initiation (PI)]. The lowest grain and straw yield (3287 and 4051 kg ha^{-1}) was recorded under control.

Reddy *et al.* (2023) conducted an experiment to study the impact of nano Nitrogen in combination with zinc (soil application or foliar spray) on yield of paddy. The recommended dose of nitrogen was applied through NCU granules along with RDPK and soil application of 25 kg zinc sulphate ha^{-1}which resulted in an increase in grain and straw yields by 23 and 24per cent. The highest dry matter was recorded at panicle initiation, grain and straw yield in the treatment applied with 100 percent recommended dose of nitrogen through neem coated urea(NCU) granules along with RDPK and soil application of 25 kg zinc sulphate ha^{-1}resulted in an increase in grain and straw yields by 23 and 24 per cent over basal application of 1/3rd of 100 per cent RDN through NCU granules along with RDPK coupled with Nano nitrogen sprays (each at MT and PI stages in paddy).

Krishna *et al.* (2023) showed that the recommended dose of fertilizers along with nano urea applied with 100per cent N+Nano N applied twice at 30 and 60 days after sowing an it was the best treatment in terms of growth and yield (7.2 t/ha) of maize. The highest test weight (35.7 g) and number of grains per row (25.3) was recorded in (Recommended NPK +2 foliar spray nano urea at knee height stage) and silking stage, followed by (Recommended NPK +1 foliar spray nano urea at knee height stage) while the lowest test weight (22.7 g) and number of grains (17.3) was observed in control.

Aher *et al.* (2023) experiment the three levels of nano urea i.e.N1- 1 mL^{-1} foliar spray nano urea, N2 -2 mL^{-1} foliar spray nano urea and N3 - 3 mL^{-1} foliar spray nano urea on paddy. The result showed the nano urea on plant height at harvest and the data indicated the significant impact on plant height during the crop growth period. Application of Nano urea 3mL L^{-1} t. had significantly influenced the plant height in baby corn at 60 DAS. The maximum plant height (175.25 cm) was recorded in Nano urea 3 mL L^{-1} t.

Ravi *et al.* (2023) conducted an experiment on paddy and reported that application of 125 per cent RDN along with foliar spray of nitrogen at the rate of 4000 ppm and nano Zn at the rate of 2000 ppm had significantly higher grain yield, straw yield, soil available N, P_2O_5, K_2O, S and Zn during *kharif* season and which was at par with and 100 per cent RDN along with spray of nano nitrogen at the rate of 4000 ppm and nano Zn at the rate of 2000 ppm.Soil available N (246.90 and 227.65 and 274.78 and 244.24 kg ha^{-1}), P_2O_5 (55.41 and 40.20 and 58.31 and 46.56 kg ha^{-1}), K_2O (344.22, and304.57 and 348.80 and 309.80 kg ha^{-1}), S (18.85 and 15.46 and 19.70 and 15.37 mg kg^{-1}) and Zn (1.25 and 1.16 and 1.31 and 1.22 mg kg^{-1}) was recorded with the combination of 125 per cent RDN along with FS of nano N at the rate of 4000 ppm and nano Zn at the rate of 2000 ppm.

Ramesh and chhabra (2023) conducted an experiment on maize with ten treatment combinations i.e. 100per cent Recommended dose fertilizers (RDF) + Farmyard manure(FYM)15 t ha^{-1}, 100per cent RDF + Vermicompost7.5 t ha^{-1};100per cent RDF + seed priming with Biofertilizers (Azotobacter), 75per cent RDF + FYM 11 t ha^{-1},75per cent RDF + Vermicompost 5.6 t ha^{-1}, T6-75per cent RDF +seed priming with Biofertilizers (Azotobacter);, 50per cent RDF basal dose + Nano urea spray 0.15per cent (25 and 50 Days After Sowing);, 50per cent RDF basal dose + Nano urea spray 0.30per cent (25 and 50 DAS), Vermicompost 3.5 t ha^{-1} + seed priming with Biofertilizers (Azotobacter), control. The results showed that application of 100per cent RDF + Vermicompost 7.5 t ha^{-1} had significant effect on growth and yield of maize. The plant height, number of leaves per plant and dry matter accumulation were also significantly higher in T_2followed by 100per cent RDF + FYM 15 t ha^{-1}. The highest grain yield (64.36 q ha^{-1}) was obtained in T_2 followed by T_1 (63.6 q ha^{-1}), T_3 (57.92 q ha^{-1}) andT8 (56.16 q ha^{-1}).

Bhargavi *et al.* (2023) the impact of nano urea on paddy production and growth in the context of paddy intensification. Five replications of the experiment were used in its randomized block design layout. Four different approaches were used: Farmer's practice with RDF 120:40:40 (NPK kg/ha), 100per cent RDN + nanourea (2 foliar sprays) + P + K, 75per cent RDN+ nanourea (2 foliar sprays) + P + K, and 50per cent RDN + nanourea (2 foliar sprays) + P + K. According to the experimental results, 75per cent RDN + nanourea (2 foliar sprays) + P + K was most effective in increasing plant height (32.1, 65.7, and 83.6 cm), leaf area index (5.10), dry matter production (3.2, 7.2, and 13.2 t/ha), and the number of productive tillers/m2 (17.6), which in turn increased grain yield (5485.2 kg/ha) and straw yield (7525.2 kg/ha).

Materials and Methods

Chapter-3 MATERIALS AND METHODS

The present study, entitled **"COMPARISON OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLIED ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA "** was carried out at Norman E. Borlaug Crop Research Centre Pantnagar. During the course of the investigation, the following materials were used, experimental procedures were followed, and statistical techniques were used to analyze the data.

3.1 The Experimental Site

The experiment was carried out during *kharif*, 2022 at C-1 block of the Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology Pantnagar, District Udham Singh Nagar, (Uttarakhand).Pantnagar is located at the foothills of the *Siwalik* range of the Himalayas, also known as *Tarai*. It has a latitude of 29^{o}N, alongitude of 79^{o} 29'E, and an elevation of 243.84 m. above mean sea level.

3.2 Climate and Weather Conditions

Climate of Pantnagar is sub-humid and sub-tropical, with hot and dry summers and cold winters. It is in the *Tarai* region, and the dry season lasts from early October to mid-June, and the wet season lasts from mid-June to early October. The maximum temperature ranges between 40 and 45^{o} C in May and June, and minimum 2 to 5^{o} C in December and January. The average relative humidity is highest in July and lowest in April and May. The average annual rainfall is 1400 mm, with the majority coming from the south-west monsoon, with 85-90 percent falling between June and September. The mean weekly data of weather for the cropping season (08/06/2022 to 28/10/2022) obtained from the Crop Research Centre Meteorological Observatory during the experimental period for various important meteorological parameters which was tabulated in appendix and shown in **Fig 3.1.**

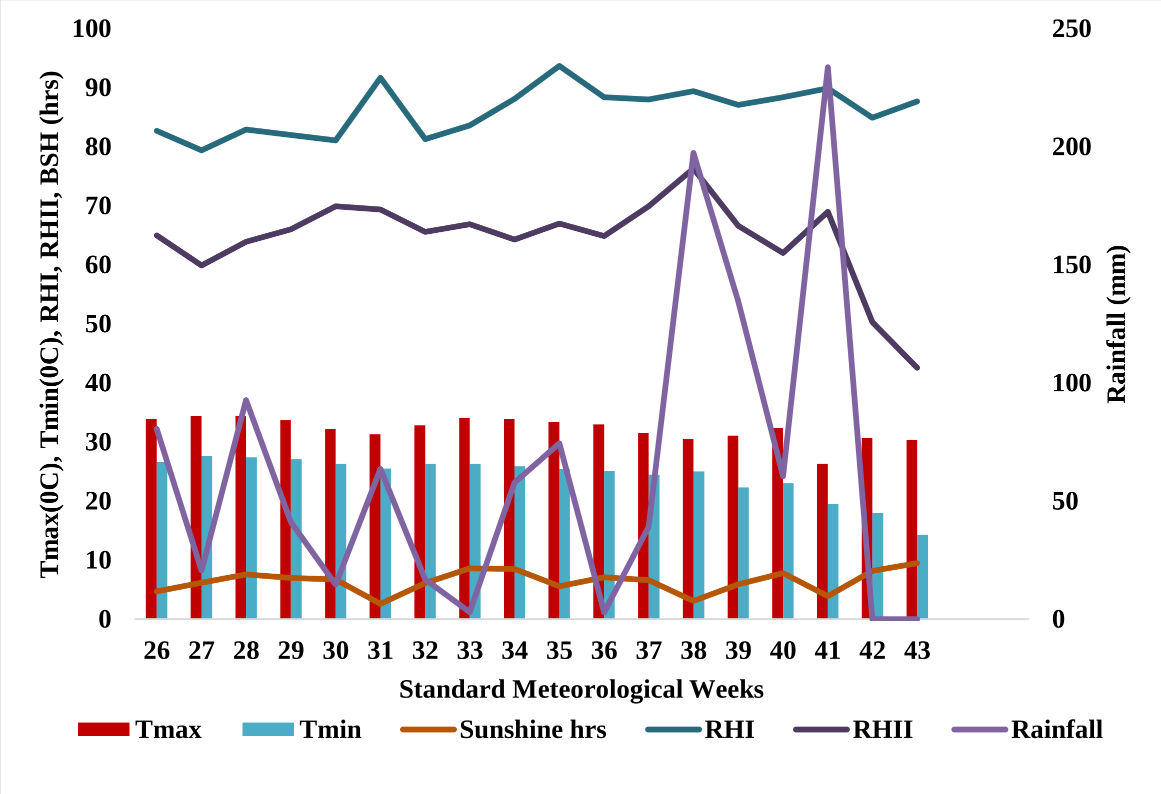

Fig 3.1Meterological observations during paddy growing season 2022 on weekly basis

3.3 Vegetation

The *Tarai* region is a fertile zone with clay-rich marshes and mixed vegetation. Semal (*Bombaxceiba*), sal (*Shorearobusta*), and khair are the most frequent tree species (*Acaciacatechu*). Perennial grasses found in the *Tarai* region include rhod grass (*Phragmitesspontannum*), soru grass (*Thimidearundinacea*), tiger grass (*Saccharumspontannum*), and khush grass (*Vetiveriazizamodies*).

3.4 Soil of the Area

The soil at the experimental location **(Table 3.1 and 3.2)** is alluvial in origin and characterized as Mollisol **(Deshpande *et al.*, 1971)**. The soils are well-drained to poorly-drained, dark in colour, and formed beneath calcareous alluvium out wash of the *Shivalik* range of mountains.

Table 3.1: The soil of experimental site was classified as

Order:	**Mollisol**
Suborder:	Udoll
Greatgroup:	Hapludoll
Subgroup:	Aquichapludoll
Family:	Fine-silty mixed hyperthermic
Series:	Benisilty clay loam

Table 3.2:Initial soil properties of experimental site

Particulars	**Initial status**
	0-15cm
(A)Physical properties	
1.Textural analysis	
Sand%	9.24%
Silt%	38.31 %
Clay%	52.45 %
Textural class	Silty clay
(B)Chemical properties	
1. pH (1:2)	6.5
2. Electrical conductivity (dS m^{-1})	0.16
3. Organic carbon (%)	0.69
4. Mineralizable N (kg ha^{-1})	149.8
5. Extractable P (kg ha^{-1})	18.8
6. Exchangeable K (kg ha^{-1})	130.8

3.5 Experimental Details

The details of experiment **(Table 3.3, 3.4 and 3.5) and (Fig 3.2)** conducted in *kharif* 2022-23 are given below:

Table3.3: The details of the experiment

Sr. No.	Particular	Details
1.	Location	NEB Crop Research Centre, Pantnagar
2.	Year of study	2022 (*Kharif*)
3.	Crop	Paddy
4.	Design of experiment	Randomized Block Design (RBD)
5.	Variety	Paddy: HKR-47
6.	No. of replications	3
7.	No. of treatments	10
8.	Total number of plots	30
9.	Gross plot size	6m X 5m = 30m^2
10.	Total plot area	53m X 22m = 1166m^2
11.	Date of paddy transplanting	29.06.2022

Table 3.4: Treatment details

Treatments	Paddy
T1	Control
T2	General Recommended Dose (GRD) (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.
T3	Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2mL L^{-1} it of water at recommended time of top dressing for N application.
T4	UAN@ 4mL L^{-1} it of water
T5	Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2mL L^{-1} it of water at recommendation time of top dressing for N application.
T6	Nano urea @4mL L^{-1} it
T7	Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5mL L^{-1} it of water at recommendation time of top dressing for N application.
T8	Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5mL L^{-1} it of water at recommendation time of top dressing for N application.
T9	Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0mL L^{-1} it of water at recommendation time of top dressing for N application.
T10	Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0mL L^{-1} it of water at recommendation time of top dressing for N application.

Layout

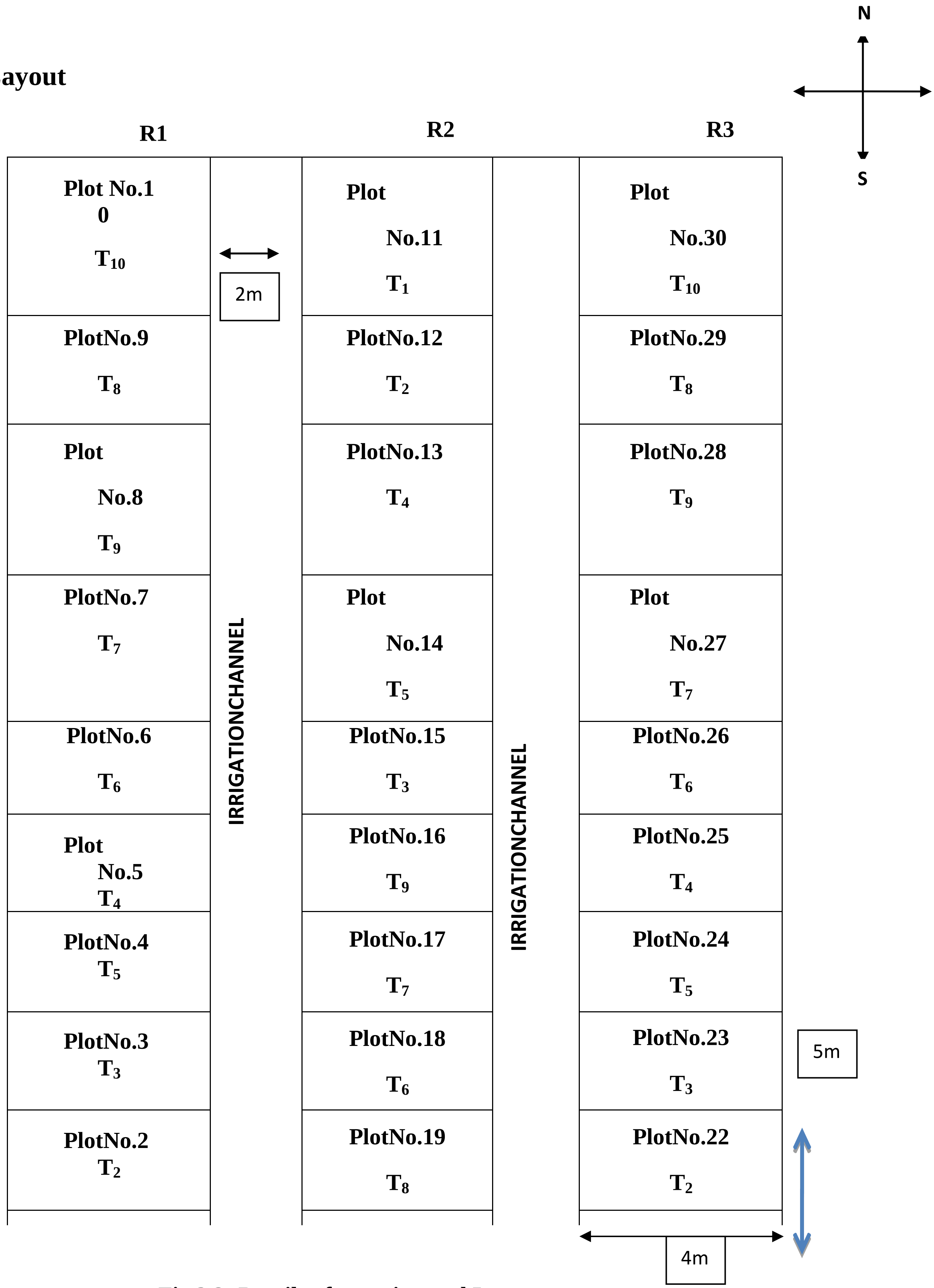

Fig 3.2: Details of experimental Layout

Table3.5: Details of Field Operations during *Kharif* 2022

S. No.	Operations	(*Kharif*)
	Paddy Crop	**2022**
1.	**Pre sowing irrigation**	07/06/2022
2.	**Nursery sowing**	09/06/2022
3.	**Field preparation**	22/06/2022
5.	**Transplanting**	29/06/2022
6.	**Basal application of fertilizers**	29/06/2022
7.	**Foliar application**	30,60, 90 DAT
8.	**First irrigation**	15DAT
9.	**Second irrigation**	25DAT
10.	**Weeding**	Manually at 30, 60 and 90 DAT
11.	**Harvest**	27/10/2022
12.	**Date of plant sample collection**	27/10/2022
13.	**Date of post-harvest soil sample collection**	27/10/2022

3.6 Collection and Processing of Soil Samples

Soil samples were collected using an auger at 0-15 cm. depths. Both before sowing and harvesting of paddy. The samples were air dried in the shade and crushed with a hardwood roller, sieved with a 2 mm sieve and stored in a labeled polythene bag for further analysis work.

3.7 Soil Analysis

The processed soil samples were subjected to chemical analysis **(Table 3.6).** The following standard methods used to ware analyze the soil samples.

Table 3.6: The methods used in soil analysis

S.NO.	Properties	Method
1.	Soil texture	Bouyoucos hydrometer method **(Bouyoucos, 1936)**
2.	pH (1:2soil:waterratio)	Glass electrode on a digital pH meter **(Jackson, 1971)**
3.	Electrical conductivity (EC)	Conductivity meter method **(Bower and Wilcox, 1965)**
4.	Organic carbon	**Walkley and Black (1934)** as described by **Jackson (1967)**
5.	Mineralization nitrogen	Alkaline $KMnO_4$ method **(Subbiah and Asija, 1956)**
6.	Extractable phosphorus	Olsen's method **(Olsen *et al.*, 1954)**
7.	Exchangeable potassium	1 N neutral ammonium acetate method **(Black, 1965)**

3.8 Plant analysis

The processed plant samples were subjected to chemical analysis **(Table 3.7).**

Table 3.7: Analysis of paddy grain and straw

S.NO	Properties	Method
1.	Nitrogen(N)	Kjeldahl method **(Jackson, 1973)**
2.	Phosphorus(P)	Yellow colour method **(Jackson,1973)**
3.	Potassium(K)	Flame-photometer method **(Jackson,1973)**

3.9 Fertilizer application

N, P, K and fertilizers were applied as a basal at the sowing time. Foliar application of UAN and Nano N was 30 DAS (1^{st}spray), 60 DAS (2^{nd} spray).

3.10 Irrigation

Irrigation was provided following the agronomic practices package and it is given based on paddy crop requirements.

3.11 Harvesting

Paddy was ready to harvest when moisture content remained 20%. The crop was harvested by hand. The grain and straw yield were both measured.

3.12 Observation made during the research

3.12.1 Collection and processing of soil

Representative soil sample were collected at 0-15 cm depth from ten treatment of all three replication before paddy sowing. These soil samples were air-dried in the shade and stored in polythene bags for further analysis. The air-dried soil samples were ground gently with a wooden pestle and mortar and sieved. The polythene bags were correctly labeled and were preserved for study. For the biological properties of the soil, samples were collected at 40 DAS, 75 DAS and harvesting stages.

3.13 The processed samples were used for the following observations

3.13.1 Soil physical properties

3.13.1.1 Soil texture

The soil texture was determined using the Bouyoucos hydrometer method

(Bouyoucos, (1936).

3.13.2 Soil chemical properties

3.13.2.1 Soil reaction (pH)

The pH of soil was determined in a 1:2 soil and water suspension using a glass electrode on a microprocessor-based pH meter, as described by **Jackson (1967).**

3.13.2.2 Soil electrical conductivity (EC)

The soil electrical conductivity was determined with the help of conductivity meter in 1:2 Soils: water suspension (**Bover and Wilcox, 1965)**.

3.13.2.3 Soil organic carbon

Organic carbon of soil was determined by modified **Walkley and Black method (1934)** as described by **Jackson (1967)**.

The % age of organic carbon in the soil was then computed using the following given equation.

$$\text{Soil Organic carbon (\%)} = \frac{(\text{meq. of } k_2cr_2o_7 - \text{meq. of FAS})0.0003 \times 1.3 \times 100}{\text{weight of dry soil (g)}}$$

3.13.2.4 Mineralisable Nitrogen (N)

The procedure described by **Subbiah and Asija (1956)** was used to determine available soil nitrogen using 0.32 % alkaline $KMnO_4$. 5 g of soil sample was placed in the kjeldahl's flask and treated with 25 mL of 0.32 % KMnO4 in this procedure. The kjeldahl's flask was then connected to the distillation apparatus, and the distillation was carried out with 2.5 % NaOH. The liberated ammonia was collected in a conical flask containing a 4% boric acid solution with a mixed indicator (pH 4.5). The color of boric acid changes to green when ammonia is absorbed. It was then titrated with 0.02 NH_2SO_4 until the color changed to pink at the end point.

Formula used for calculating available nitrogen in the soil is given below:

$$\text{Available N (Kg/ha)} = (S - \text{B})\frac{0.02\ X\ 14\ X\ 1000\ X\ 2.24}{Weight\ of\ soil\ ing}$$

Where,

S=A volume of 0.02 NH_2SO_4 in mL is required for sample titration.

B=A volume of 0.02 NH_2SO_4 in mL is required for blank titration.

3.13.2.5 Extractable Phosphorus (P)

The procedure described by **Olsen *et al*. (1954)** was used to extract available P from soil using sodium bicarbonate extractant (0.5M $NaHCO_3$) at pH 8.5. 1 g of soil was taken and treated with 20mL of 0.5M $NaHCO_3$ in this procedure (pH8.5).The suspension was filtered after 30 minutes of shaking the flask, and colour development was done in the filtrate using the ascorbic acid method described by Murphy and Riley (1962). Using a pnitrophenol indicator, the extracted solution was treated with ammonium molybdate, potassium antimony tartarate, and ascorbic acid. The intensity of the blue colour was then measured at 882 nm with a spectrophotometer. KH_2PO_4 was used to create a standard curve.

Available P (kg ha^{-1}) was calculated using the following formula:

Available P (kg ha^{-1})=P×dilution factor×2.24

Where,

P=Phosphorus concentration (ppm) In samples determined using a standard curve.

3.13.2.6 Exchangeable Potassium (K)

The available K in soil was determined using 1 N NH_4OAc (pH 7) according to the **Black (1965)** procedure. According to the procedure, 5 g of soil sample was treated with 25 mL of neutral ammonium acetate (pH 7) and shaken for 5 minutes. The K concentration in the filtrate was then determined using a flame photometer.

The potassium concentration was then calculated using the following formula: Available K (kgha^{-1}) =flame photometer reading × dilution factor×2.24

3.14 Crop Yield and Nutrient Uptake

3.14.1 Grain yield

The total produce of paddy and wheat crop from the net plot area was harvested, threshed, cleaned, and the weight of the grains was recorded in kg. The final grain yield was expressed in quintals per hectare.

3.14.2 Straw yield

The paddy straw yield was worked out after separation of grains and expressed in quintal per hectare.

3.14.3 Nutrient uptake

Nutrient uptake in paddy grain and straw was calculated by using the following formula:

Uptake of major nutrient (kg ha^{-1}) =Nutrient concentration in grain/straw (%) ×grain/straw yield (qha^{-1})

$$\text{N uptake by grain (kg/ha)} = \frac{\text{N conc. in grains} \times \text{grain yield (kg/ha)}}{100}$$

$$N\ uptake\ by\ straw\ (kg/ha) = \frac{N\ conc.\ in\ straw \times straw\ yield\ (kg/ha)}{100}$$

Total N uptake by paddy (kg/ha) = Nitrogen uptake by grain (kg/ha) + Nitrogen uptake by straw (kg/ha)

$$Phosphorus\ uptake\ by\ grain\ (\frac{kg}{ha}) = \frac{P\ conc.in\ grain\ (\%)\ x\ grain\ yield\ (\frac{kg}{ha})}{100}$$

Phosphorus uptake by straw (kg/ha) $= \frac{P\ conc.in\ straw\ (\%)\ x\ straw\ yield\ kg/ha}{100}$

Total P uptake by paddy (kg/ha) =P uptake by grain(kg/ha)+P uptake by straw(kg/ha)

$$K\ uptake\ by\ grain\ (kg/ha) = \frac{K\ conc.\ In\ grains\ (\%)\ grain\ yield\ kg/ha}{100}$$

$$K\ uptake\ by\ straw\ (kg/ha) = \frac{K\ conc.\ In\ straw\ (\%)\ \ straw\ yield\ kg/ha}{100}$$

Total K uptake by paddy (kg/ha) = K uptake by grain (kg/ha) + K uptake by straw (kg/ha)

3.15 Field Observation

Field observations for the crop were recorded at 30, 60, 90 120days interval.

3.15.1 Plant height

Five plants in each plot were selected at random and tagged for recording plant height. The height of the main shoot was measured in centimeter from ground level up to the tip of the growing point of the crop in *kharif* seasons.

3.15.2 Number of tillers per square meter

At all stages of the recording, the 11 hills within an area of (1 x 1 m) located in the third and fourth rows of the plot on both sides were marked for counting the number of tillers.

1000-Grainweight

To calculate the 1000-grain weight, weight of one hundred dried filled grains from each plot were measured in gram, then the weight were multiplied by ten to find out the1000-grainweight the crop.

3.16 Statistical analysis

The data sets were analyzed using analysis of variance in compliance with the randomized block design, using the least significant difference as described by **Gomez and Gomez (1984).** Correlation studies were performed in accordance with conventional techniques to explain the relationship between two or more series of data **(Panse and Sukhatme, 1962 and Snedecor and Cochran, 1967).**

Results and Discussion

Chapter-4 RESULTS AND DISCUSSION

The research, entitled **'COMPARISION OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLIED ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA'** was carried out during the *Kharif* seasons (2022-23). This chapter presents and discusses the results obtained for various parameters during the investigation.

4.1 Growth and Yield Attributes

4.1.1 Plant height

The data pertaining to plant height are presented in table 4.1 and Fig 4.1, the highest plant height was observed in treatment T_3 (basal dose of nitrogen through prilled urea as per recommendation and foliar application of UAN @ 2.0 mL L^{-1} of water at recommended time of top dressing for N application and the lowest plant height was observed in (control) T_1 treatment at 30, 60, 90 and 120 DAT of rice crop, which was significantly higher than all other treatments at 30, 60 and 90 DAT. At 120 DAT is significantly higher among all the treatments except the treatment T_{10} where recommended dose of nitrogen as prilled urea was applied as basal and foliar application of Nano urea @ 6.0 mL L^{-1} of water at the recommended time of nitrogen top dressing. The foliar application of UAN @ 4.0 mL L^{-1} of water showed the significant more plant height than the treatment T2 (GRD of nitrogen i.e. 150 kg N ha^{-1}) at 30, 60, 90 while at 120 DAT statistically at par.

The plant height was recorded 30.1cm and 46.2cm under the treatment when recommended dose of nitrogen is applied through prilled urea in combination with Nano urea application @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing, which was significantly higher than the treatments T8 (basal dose of nitrogen through prilled urea as per recommendation and foliar application of Nano urea @ 1.5 mL L^{-1} of water at recommended time of top dressing for N application) and T5 (basal dose of nitrogen through prilled urea as per recommendation and foliar application of Nano urea @ 2.0 mL L^{-1} of water at recommended time of top dressing for N application) i.e. 28.6 cm, 25.5 cm and 42.6 cm and 43.8 cm at 30 and 60 DAT respectively and non significant difference at 90DAT , while non significant with the treatment T_8 and significantly higher than the treatment T_5.

The application of recommended dose of nitrogen through urea prilled in combination with foliar application of UAN @ 1.5 mL L^{-1} of water at recommended time of top dressing for nitrogen showed the significantly more plant height with the treatment T_8 where we apply recommended dose of nitrogen through prilled urea and foliar application of Nano urea @ 1.5 mL L^{-1} of water at recommended time of top dressing for nitrogen at 60 and 90 DAT while statistically at par at 30 and 120 DAT.

Among all the treatments that involved the application of nitrogenous fertilizers, treatment T_3 emerged as the clear frontrunner, exhibiting the highest rice plant height. This remarkable outcome can be attributed to the incorporation of foliar application of nitrogenous fertilizer, which facilitated faster and more efficient nutrient uptake and provided balanced crop nutrition during the critical crop growth period. By directly supplying nitrogen through foliar application, the plants could rapidly access this essential nutrient, bypassing the conventional soil and root pathway. This method of nutrient delivery allowed for an immediate and targeted supply of nitrogen, which likely played a pivotal role in promoting enhanced plant growth and development. **Benzon *et al.* (2015)** corroborated the beneficial effects of nitrogenous fertilizers, both conventional and Nano-based, on plant height. In their study, the application of the full recommended rate of conventional and Nano fertilizers resulted in increased plant height, yielding taller plants. These findings align with the research conducted by **Abdel-Aziz *et al*. (2018)**, who reported that the application of nano chitosan NPK at a rate of 10% induced a significant increase in plant height, reaching 96.33 cm. Furthermore, **Ajithkumar *et al.* (2021)** observed similar promising results, where the treatment involving 50% N, 100% PK, and 0% zinc, along with two sprays of IFFCO Nano N (4 mL L^{-1}) mixed with IFFCO Nano Zn (2 mL L^{-1}), led to the highest plant height recorded at 214.33 cm. These findings recommend tailored nutrient management and targeted foliar application in promoting remarkable plant height in rice crops. The study conducted by **Amanullah *et al.* (2014)** also reported increased nitrogen availability positively impacts plant growth attributes. They reported that higher nitrogen and zinc application rates led to maximum vegetative growth of plants, indicating the critical role of nitrogen availability in promoting robust growth and development.

Table 4.1: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy plant height.

Treatments	Plant height(cm)			
	30DAT	60DAT	90DAT	120DAT
Control	25	41.1	80.0	95.3
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	26.6	43.1	84.3	112.6
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL Lit^{-1} of water at recommended time of top dressing for N application.	31.5	48.5	99.3	123.2
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4.0 mL L^{-1} of water	30.1	46.8	92.0	112
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2.0 mL L^{-1} of water at recommendation time of top dressing for N application.	25.5	43.8	92.1	114.3
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4ml Lit^{-1} of water	26.4	41.5	88.5	111
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5 mL L^{-1} of water at recommendation time of top dressing for N application.	29.3	45.5	92.1	120.1
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5 mL L^{-1} of water at recommendation time of top dressing for N application.	28.6	42.6	88.2	118.3
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0 mL L^{-1} of water at recommendation time of top dressing for N application.	31.1	46.1	93.3	121.3
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0 mL L^{-1} of water at recommendation time of top dressing for N application.	30.1	46.2	89.2	120.1
SEm±	0.2	0.5	1.0	1.2
C.D.at5%	0.6	1.7	3.1	3.8

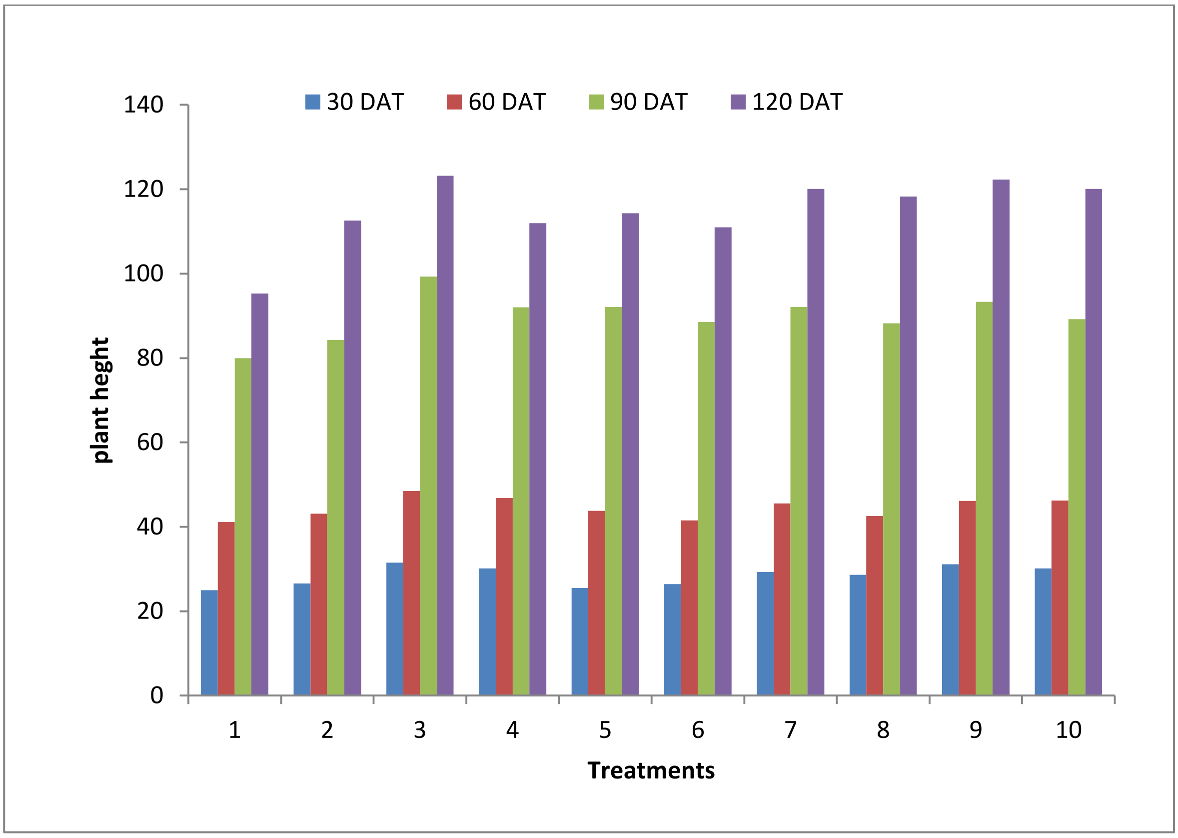

Fig 4.2: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy plant height.

4.1.2 Total number of tillers per meter square

The data pertaining to number of tillers are presented in table 4.2 and Fig 4.2, the maximum number of tillers i.e. 232, 270,259 and 254 respectively was observed with the treatment T_3 where we applied recommended dose of nitrogen as basal and foliar application of UAN @ 2 mL $^{-1}$ of water at the recommended time of nitrogen top dressing and the minimum under the treatment (Control) at all the stages (30, 60, 90, 120 DAT) of crop growth. The application of recommended dose of nitrogen through urea prilled as per recommendation for basal and top dressing treatment (T_2) showed significantly more number of tillers (than the treatment T_4 (foliar application UAN @4.0 mL L^{-1}) and the treatment T_6 (Nano urea @4.0 mL L^{-1}) at 60, 90 and 120 DAT of crop growth while statistically at par with the treatment T_4 at 30 DAT of crop growth. The foliar application of Nano urea at recommended time of top dressing of nitrogen along with the recommended basal dose of nitrogen(T_{10}) gave significantly more number of tillers than the treatment where we apply Nano urea @4.0 mL L^{-1} of water along with recommended basal dose of nitrogen (T_6) at all the stages of crop growth.

The nitrogen application in the treatment T_2 (GRD) as well as basal and top dressing showed more number of tillers (228, 253, 244 and 242) than the treatment T_7 where we apply UAN @ 1.5 mL L^{-1} of water through foliar spray at the recommended time of nitrogen top dressing which was significantly higher at all the stages of crop growth.

The treatment where basal dose of N through urea prilled and foliar application of UAN @ 4.0mL $^{-1}$ of water at the recommended time of top dressing (T_4) applied, significantly more number of tillers 226 was recorded at 120 DAT of crop growth than the treatment where we apply UAN @1.5 mL L^{-1} of water along with recommended basal dose of nitrogen(T_7).

The finding recommends foliar application in optimizing plant growth and overall crop performance in rice cultivation. It is crucial to consider these results in the context of sustainable agricultural practices to achieve higher yields and enhance the productivity of rice crops.

Among all the treatments involve in foliar application, the maximum number of tillers were observed in treatment T_3. This notable outcome might be attributed to the combination of RDN with 10% Nano N, as revealed by previous studies. For instance, **Midde *et al.* (2021)** reported that the treatment involving 50% RDN combined with 50% Nano N resulted in the highest number of tillers (348). This finding is consistent with other research studies that support the positive impact of Nano N on tiller development.

The higher number of tillers in treatment T_3 can likely be attributed to the enhancement of soil fertility achieved through the management of foliar application with nitrogenous fertilizers. By efficiently supplying nitrogen through a foliar application, the treatment positively influenced crop height and vigor, thereby encouraging the development of more tillers. The targeted and immediate nutrient supply facilitated by foliar application likely played a crucial role in stimulating the vegetative growth of the rice plants, leading to an increased number of tillers per plant.

Table 4.2: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy number of tillers of paddy per square meter

Treatments	Number of tillers per square meter			
	30DAT	**60DAT**	**90DAT**	**120DAT**
Control	**198**	**206**	**204**	**200**
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	228	253	244	242
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL L^{-1} of water at recommended time of top dressing for N application.	232	270	259	254
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4.0 mL L^{-1} of water	222	236	228	226
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2.0 mL L^{-1} of water at recommendation time of top dressing for N application.	224	240	230	228
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4.0 mL L^{-1}	219	232	227	225
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5 mL L^{-1} of water at recommendation time of top dressing for N application.	218	228	224	221
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5 mL L^{-1} of water at recommendation time of top dressing for N application.	224	245	232	230
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0 mL L^{-1} of water at recommendation time of top dressing for N application.	225	250	235	233
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0 mL L^{-1} of water at recommendation time of top dressing for N application.	230	264	255	249
SEm±	2.6	2.5	3.2	1.4
C.D.at5%	7.7	7.5	9.5	4.3

Notably, the study conducted by **Ranjan *et al.* (2023)** showcased similar results, where the application of 100% RDN through urea along with 2 foliar sprays of Nano-urea (4.0 mL L^{-1}) resulted in the highest number of tillers per square meter. This highlights the significant impact of combining conventional nitrogen fertilization with the foliar application of Nano N on tiller development. Additionally, **Moro *et al.* (2015)** revealed that the total number of tillers per square meter (440) increased significantly with increasing levels of nitrogen (90 kg N/ha). This finding is consistent with the understanding that nitrogen is a vital nutrient for tiller initiation and development in rice crops. Furthermore, **Pramanik *et al.* (2013)** and **Siddaram *et al.* (2010)** also reported similar results, further supporting the positive relationship between nitrogen application and tiller development.

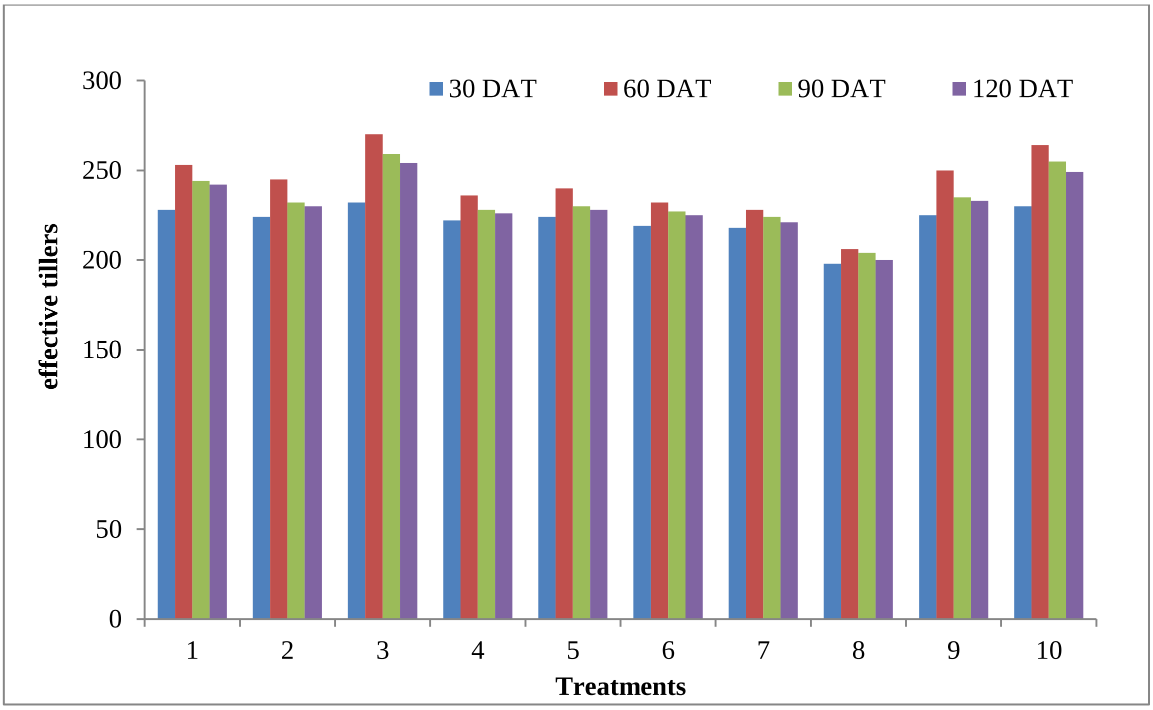

Fig 4.2: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy number of tillers of paddy per square meter

4.1.3 1000-Grainweight

The data presented in table 4.3 and Fig 4.3 reveals significant variations in the 1000-grain weight (g) among various treatments on rice crop. The application of nitrogenous fertilizers through foliar spray has been shown to have a profound impact on rice plants, stimulating photosynthetic efficiency and enhancing nutrient uptake. These effects ultimately lead to increased assimilate production and translocation to the developing grains, resulting in higher 1000-grain weight.

Among all the treatments, treatment T_3 exhibited the maximum 1000-grain weight, recording an impressive 32.86 grams, which was significantly higher among all the treatments except the treatment T_2 (GRD) and the minimum grain weight 22.02g was observed with the treatment T_1(control). This outcome can be attributed to the specific foliar application regimen utilized in T_3, which likely facilitated optimized nutrient availability and improved photosynthetic activity. The enhanced nutrient uptake and assimilation in treatment T_3 contributed to more efficient grain filling and nutrient accumulation, ultimately leading to the observed higher 1000-grain weight.

The significantly more grain weight 28.30g was recorded in the treatment T_4 (recommended basal dose of nitrogen with foliar application of UAN @4.0 mL L^{-1} at recommended time of nitrogen top dressing) than the treatment T_9 (recommended basal dose of nitrogen with foliar application of UAN @6.0 mL L^{-1} at recommended time of nitrogen top dressing).The grain weight 26.73 g was recorded in the treatment T_6 (recommended basal dose of nitrogen with foliar application of Nano urea @4.0 mL $^{-1}$ at recommended time of nitrogen top dressing) which was significantly higher than the treatment T9 (recommended basal dose of nitrogen with foliar application of Nano urea @6.0 mL L^{-1} at recommended time of nitrogen top dressing). Treatment T_2(GRD) showed the significantly more grain weight 29.76 g than the treatment T_8(recommended basal dose of nitrogen with foliar application of Nano urea @1.5 mL L^{-1} at recommended time of nitrogen top dressing), T_9(recommended basal dose of nitrogen with foliar application of UAN @6.0 mL L^{-1} at recommended time of nitrogen top dressing) and T10(recommended basal dose of nitrogen with foliar application of Nano urea @6.0 mL L^{-1} at recommended time of nitrogen top dressing) while at with the treatment T_6 (recommended basal dose of nitrogen with foliar application of Nano urea @4.0 mL L^{-1} at recommended time of nitrogen top dressing) and T_7 (recommended basal dose of nitrogen with foliar application of UAN @1.5 mL L^{-1} at recommended time of nitrogen top dressing).

The study by **Khospeyak *et al.* (2016)** likely investigated the effects of different fertilizer treatments, including conventional and Nano fertilizers, on rice crop parameters, with a specific focus on 1000-grain weight. The researchers observed a significant increase in 1000-grain weight in response to the Nano fertilizer treatment compared to the conventional fertilizer treatment. Nano fertilizers are designed to provide essential nutrients in a more targeted and efficient manner, owing to their nanoscale size and unique properties. This allows for improved nutrient uptake and utilization by plants, promoting better assimilate production and nutrient translocation to the developing grains. As a result, Nano fertilizer treatments can lead to higher grain weight, as reflected in the 1000-grain weight measurements.

Grain yield

The data presented in the table4.3 and fig 4.3 reveals that the rice grain yield (q ha^{-1}) from various treatments, showcasing notable variations in yield outcomes. The highest grain yield, reaching 64.10 q ha^{-1}, was obtained in the treatment T_3 (application of recommended basal dose of Nitrogen through Urea and foliar application of UAN @ 2.0 mL L^{-1} of water at the recommended time of nitrogen top dressing), which significantly surpassed all other treatments except the treatment T_2 (GRD) and the minimum grain yield was obtained in treatment T_1 (Control). This impressive yield enhancement in T_3 can be attributed to the application of nitrogenous fertilizers, which likely increased nutrient availability for a season or a short period, leading to a substantial boost in crop productivity. The treatment T_2 (GRD) showed significant increase in grain yield 59.73 q ha^{-1} of rice over the treatments T_6 (recommended basal dose of nitrogen with foliar application of Nano urea @4.0 mL L^{-1} at recommended time of nitrogen top dressing), T_7 (recommended basal dose of nitrogen with foliar application of UAN @1.5 mL $^{-1}$ at recommended time of nitrogen top dressing), T_8 (recommended basal dose of nitrogen with foliar application of Nano urea @1.5 mL L^{-1} at recommended time of nitrogen top dressing) and T_{10} (recommended basal dose of nitrogen with foliar application of Nano urea @6.0 mL L^{-1} at recommended time of nitrogen top dressing) while at par with the treatments T4(recommended basal dose of nitrogen with foliar application of UAN @4.0 mL $^{-1}$ at recommended time of nitrogen top dressing) and T_5(recommended basal dose of nitrogen with foliar application of Nano urea @2.0 mL L^{-1} at recommended time of nitrogen top dressing). The recommended basal dose of nitrogen through prilled urea and foliar application Nano urea @2.0 mL L^{-1} of water (T_5) showed the significantly increased in grain yield 55.73 q ha^{-1} of rice over the treatments T_8 (recommended basal dose of nitrogen through urea with foliar application of Nano urea @1.5 mL L^{-1} at recommended time of nitrogen top dressing) and T_{10}(recommended basal dose of nitrogen with foliar application of Nano urea @6.0 mL L^{-1} at recommended time of nitrogen top dressing). Treatment T_9 (recommended basal dose of nitrogen with foliar application of UAN @6.0 mL L^{-1} at recommended time of nitrogen top dressing) significantly increased the grain weight 60.73 q/ha than the treatment T_7 (recommended basal dose of nitrogen with foliar application of UAN @1.5. mL L^{-1} at recommended time of nitrogen top dressing). This supports the idea that the specific foliar application in T_3 played a significant role in achieving the highest grain yield among all the tested treatments.

This could be due to increased plant growth and metabolic processes like photosynthesis, resulting in increased photosynthates accumulation and translocation to the plant's economic parts. **Maragatham *et al.* (2010)** conducted an experiment in rice crops where 50% of the nitrogen was applied as Urea, while the remaining 50% was applied as poultry manure. The results showed a higher grain yield under this specific nutrient management approach. This could be due to the balanced supply of nitrogen through different sources, promoting optimal plant growth and ensuring sufficient nutrient availability during the crop's development stages. **Heba *et al.* (2018)** explored the effects of foliar application of Nano NPK formulation on rice crop performance. The study demonstrated increased yield attributing parameters and grain yield as a result of this application. The researchers justified the yield increase by attributing it to enhanced photosynthesis and the formulation acting as a "biological pump." This suggests that the Nano NPK formulation facilitated more efficient nutrient and water absorption by plants, leading to improved yield attributing parameters and ultimately higher grain yield.

Similarly, **Akhand *et al.* (2013)** found that when 2/3rd of the recommended nitrogen was applied, urea consumption could be reduced by 4% during the aman season and 17% during the boro season, without sacrificing grain yield. This indicates that strategic nutrient management practices, such as optimized nitrogen application, can lead to significant resource savings without compromising crop productivity. **Saleem *et al.* (2013)** also reported similar results, further supporting the notion that proper nutrient management can result in improved grain yield without excessive nitrogen use.

Straw yield

The data on straw yield of rice presented in the table 4.3 and fig 4.3 reveals that the highest rice straw yield (88.70 q/ha) was obtained with the treatment, when we apply recommended dose of nitrogen as basal and foliar application of UAN @2.0 mL L^{-1} of water at the recommended time of nitrogen top dressing (T_3), which was highly significant over all the treatment, except the treatment T_2 (GRD) and minimum straw yield of rice was obtained in the treatment T_1 (control). This impressive straw yield in T_3 can be attributed to the application of nitrogenous fertilizers, which likely temporarily or seasonally enhanced nutrient availability, promoting robust growth and biomass production.

The treatment T_2, where GRD were applied, rice straw yield was obtained 82.20 q/ha which was significantly more than the treatments T_7 (recommended basal dose of nitrogen with foliar application of UAN @1.5 mL L^{-1} at recommended time of nitrogen top dressing), T_8 (recommended basal dose of nitrogen with foliar application of Nano urea @1.5 mL L^{-1} at recommended time of nitrogen top dressing), T_9 (recommended basal dose of nitrogen with foliar application of UAN @6.0 mL $^{-1}$ at recommended time of nitrogen top dressing) and T_{10} (recommended basal dose of nitrogen with foliar application of Nano urea @6.0 mL L^{-1} at recommended time of nitrogen top dressing) while at par with the traement T_6 (recommended basal dose of nitrogen with foliar application of Nano urea @4.0 mL L^{-1} at recommended time of nitrogen top dressing).

When we applied recommended dose of nitrogen as basal and foliar application at the recommended time of nitrogen top dressing (T_5) gave significantly higher rice straw yield (78.66 q/ha) than the treatments T_8 (recommended basal dose of nitrogen with foliar application of Nano urea @1.5 mL L^{-1} at recommended time of nitrogen top dressing) and T_{10} (recommended basal dose of nitrogen with foliar application of Nano urea @6.0 mL $^{-1}$ at recommended time of nitrogen top dressing).

The findings presented above are further supported by the research conducted by **Midde *et al.* (2021)** Their study reported that when comparing the treatment involving 50% Recommended Dose of Nitrogen (RDN) combined with 50% Nano N to the treatment without any fertilizer application, there was a significant improvement in yield attributing characters of rice, ultimately leading to higher straw yield in rice crops.

Total biomass (grain + straw)

The data on total biomass of rice presented in the table 4.3 and fig 4.3 provides valuable insights into the across various treatments, highlighting significant variations in biomass production. Treatment T_3 (recommended dose of nitrogen as basal and foliar application of UAN @2.0 mL L^{-1} of water at the recommended time of nitrogen top dressing) emerges as the most productive, achieving the highest total biomass of 152.80 q/ha, which was significantly surpasses all other treatments while the minimum total biomass production was observed in T_1 (control). This notable increase in biomass in T_3 can be attributed to the application of nitrogenous fertilizers, which likely provided a temporary or seasonal enhancement in nutrient availability, fostering vigorous plant growth and leading to higher biomass accumulation. Conversely, treatment T_2(GRD), recorded the second highest total biomass of 141.93 q/ha. The treatment T_7 (recommended basal dose of nitrogen with foliar application of UAN @1.5 mL L^{-1} at recommended time of nitrogen top dressing) significantly increases the total biomass production (127.07 q/ha) than the treatment T_9 (recommended basal dose of nitrogen with foliar application of UAN @6.0 mL L^{-1} at recommended time of nitrogen top dressing). Whereas the application of recommended basal dose of nitrogen with foliar application of Nano urea @4.0 mL $^{-1}$ at recommended time of nitrogen top dressing treatment (T_6) significantly increases the total biomass production of rice than the treatment T_{10} where we apply recommended dose of nitrogen as basal along with the foliar application of Nano urea @ 6.0 mL L^{-1} of water at recommended time of nitrogen top dressing while statistically at par with the treatment T_8 (recommended basal dose of nitrogen with foliar application of Nano urea @1.5 mL L^{-1} at recommended time of nitrogen top dressing).

The application of nitrogenous fertilizers likely led to an increase in nutrient availability, stimulating various physiological processes in the plant. This, in turn, resulted in improved photosynthesis, enhanced assimilates production, and increased nutrient uptake, leading to overall enhanced plant growth and development. The increase in total biomass includes both above-ground biomass, such as leaves and stems, and below-ground biomass, such as roots. The optimized nutrient supply likely promoted extensive root growth, enabling efficient nutrient and water uptake, which ultimately contributed to the overall increase in biomass. The findings by **Tezera *et al.* (2021)** further support the role of nutrient management in influencing total biomass in rice crops. Their study demonstrated that the combination of nano urea and nano DAP seed dressing, along with a specific dosage of DAP (39 g), resulted in significantly higher biomass (132.4 q ha^{-1}). This emphasizes the importance of targeted nutrient application, such as using nano fertilizers and seed dressing, to enhance total biomass production in rice cultivation.

Table 4.3: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy1000-grain weight, grain yield, straw yield and total biomass of paddy

Treatments	1000 Grain wt.(g)	Grain yield q/ha	Straw yield q/ha	Total biomass
Control	22.02	45.27	59.43	104.70
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	29.76	59.73	82.2	141.93
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL L^{-1} of water at recommended time of top dressing for N application.	32.86	64.10	88.7	152.80
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4.0 mL L^{-1} of water	28.30	56.17	79.83	136.00
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2.0 mL L^{-1} of water at recommendation time of top dressing for N application.	27.82	55.73	78.66	134.40
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4.0 mL L^{-1}	26.73	53.40	74.63	128.03
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5 mL L^{-1} of water at recommendation time of top dressing for N application.	26.29	53.03	74.03	127.07
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5 mL L^{-1} of water at recommendation time of top dressing for N application.	24.40	49.07	68.46	117.53
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0 mL L^{-1} of water at recommendation time of top dressing for N application.	22.70	60.73	65.33	112.07
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0 mL L^{-1} of water at recommendation time of top dressing for N application.	23.33	46.33	64.8	111.43
SEm±	1.77	4.12	2.48	4.12
C.D.at5%	3.22	5.32	7.43	12.34

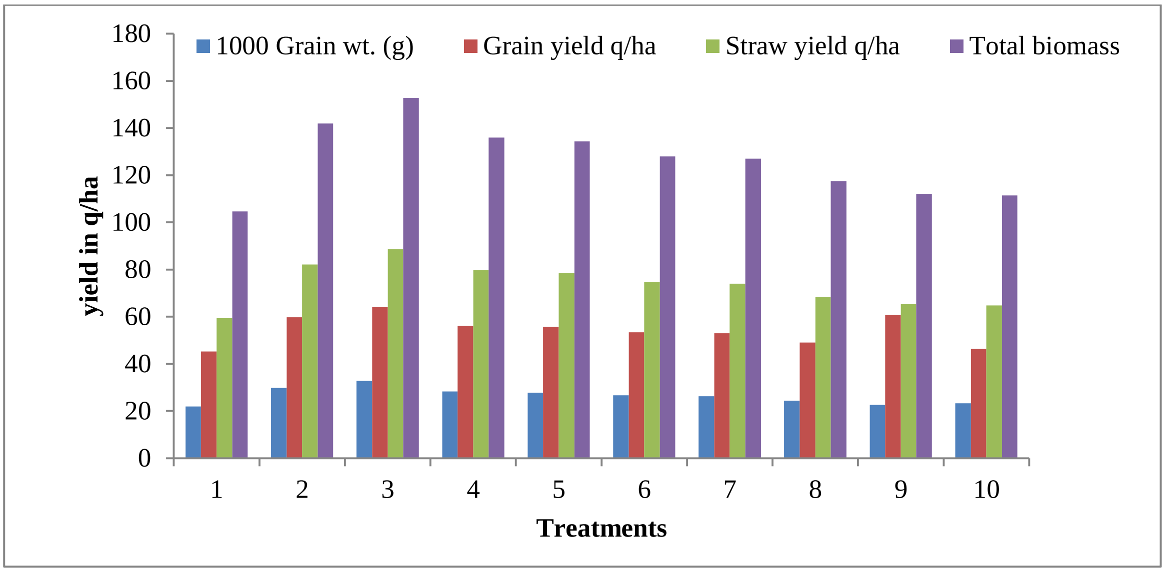

Fig 4.3: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy1000-grain weight, grain yield, straw yield and total biomass of paddy

4.2 Chemical Properties

4.2.1 Soil pH

The presented data in the table 4.4 and Fig. 4.4 clearly demonstrates the impact of foliar application on soil pH after rice crop harvesting. Soil pH is a crucial parameter that influences soil health, nutrient availability, and overall plant growth and development. The measurements of soil pH were performed using a glass electrode on a microprocessor-based pH meter **(Jackson, 1967)**, ensuring precise and reliable pH readings. The results indicate a non significant difference in soil pH among the various treatments due to the implementation of foliar application. The pH of the soil ranges from 6.3 to 6.8 after harvest of paddy crop. The lowest pH value was recorded 6.3 in the treatment, where we applied recommended dose of nitrogen as basal through urea along with the foliar application of Nano urea @ 6.0 mL L^{-1} of water at the recommended time of nitrogen top dressing (T_{10}), where as the highest pH value was observed in the treatment GRD (50 kg N ha^{-1}. As basal and top dressing) after harvest of the paddy crop. The treatment T_2(GRD) showed significantly higher soil pH (6.8) than the treatments T5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL L^{-1} of water at recommended time of nitrogen top dressing), T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL L^{-1} of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) i.e. 6.5,6.4 and 6.3 respectively, while at par with the treatments T_1 (control), T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL L^{-1} of water at recommended time of nitrogen top dressing), T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL L^{-1} of water at recommended time of nitrogen top dressing), T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL L^{-1} of water at recommended time of nitrogen top dressing) and T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL L^{-1} of water at recommended time of nitrogen top dressing) after harvest of paddy crop.

The data consistently shows that all treatments involving foliar application resulted in different soil pH values compared to the control treatment. This indicates that foliar application has a non-significant impact on soil pH and can alter the soil's chemical properties, potentially affecting nutrient availability and plant growth.

The observed decrease in soil pH with increasing nitrogen (N) rates and over time can be attributed to the nitrification process, a biological transformation of ammonium ($NH4^{+}$) to nitrate (NO^{3-}) by soil microorganisms. During nitrification, hydrogen ions (H^{+}) are released into the soil solution, leading to a decrease in pH. This process is consistent with previous research findings, where it has been observed that higher N fertilization levels can result in a reduction in soil pH **(Tuyen *et al.*, 2006 Rezig *et al.*, 2013)**. The study by **Elsayed *et al.* (2020)** also reported similar findings regarding soil pH changes with foliar applications of NPK nano fertilizers, either alone or in combination with NPK-mineral fertilizers. The researchers observed a minor decrease in soil pH due to these foliar applications, but the differences in pH were not statistically significant. These results suggest that the addition of nitrogen through both conventional and nano fertilizers, either through soil application or foliar application, can lead to changes in soil pH. The nitrification process, driven by microbial activity in response to increased nitrogen inputs, contributes to the release of hydrogen ions, thereby lowering soil pH levels. The impact of changes in soil pH due to nitrogen fertilization is essential to consider in agricultural practices. Soil pH directly affects nutrient availability to plants, microbial activity, and overall soil health. Maintaining optimal soil pH levels is crucial for promoting nutrient uptake by crops and ensuring proper nutrient cycling in the soil.

Soil EC

The data presented in the table 4.4 and Fig. 4.4 indicates the impact of different nitrogenous fertilizers on electrical conductivity (EC) of the soil after harvesting of paddy crop. Soil EC is a measure of the soil's ability to conduct electrical current, which is influenced by the concentration of dissolved salts in the soil solution. The measurements of soil EC were observed after harvest of paddy crop, providing valuable insights into the changes in soil salinity due to different treatments, including foliar application. The data indicate that the maximum soil EC 0.21 dS m^{-1} was observed in the treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL L^{-1} of water at recommended time of nitrogen top dressing) and the minimum soil EC 0.16 dS m^{-1} in the treatment T_1 (control). This indicates that foliar application has a non significant impact on soil salinity and can influence the soil's electrical conductivity.

This suggests that the specific foliar application used in the treatments did not lead to a significant buildup of salts in the soil, which could have affected the soil's EC. The findings of **Ajitkumar *et al.* (2021)** further support this idea. Their research on maize crop observed a slight increase in soil EC after harvest when some portion of conventional fertilizer was replaced by Nano fertilizer. This suggests that the use of Nano fertilizer did not cause a drastic increase in soil salinity, and the overall change in EC was relatively minor. The lack of significant changes in soil EC can be seen as a positive outcome, as excessive salt accumulation in the soil can be detrimental to plant growth and crop productivity. High soil salinity can negatively affect nutrient uptake by plants and disrupt their water balance, leading to reduced crop yields and overall plant health. It is important to note that maintaining proper nutrient management practices, including the judicious use of fertilizers (both conventional and Nano fertilizers), can help prevent undesirable increases in soil salinity. The careful selection of fertilizer types, application rates, and timing can all play a crucial role in optimizing soil health and crop performance.

Soil organic carbon

The data presented in the table 4.4 and Fig. 4.4 clearly indicates the significant impact of different nitrogenous fertilizers on soil organic carbon (O.C.) after harvesting of paddy crop. Soil organic carbon is a critical component of soil health, as it plays a vital role in nutrient cycling, water retention, and overall soil fertility. The measurements of soil organic carbon were observed after harvest of paddy crop, providing valuable insights into the changes in soil carbon content due to different treatments, including foliar application. The results indicate that the highest organic carbon content (0.78%) in soil was recorded in the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL L^{-1} of water at recommended time of nitrogen top dressing), which was significantly higher than T_2 (GRD), T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL L^{-1} of water at recommended time of nitrogen top dressing), T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL L^{-1} of water at recommended time of nitrogen top dressing), T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL L^{-1} of water at recommended time of nitrogen top dressing), T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL L^{-1} of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL L^{-1} of water at recommended time of nitrogen top dressing) while at par with the treatment T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL L^{-1} of water at recommended time of nitrogen top dressing) after harvesting of paddy crop.

The treatment T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL L^{-1} of water at recommended time of nitrogen top dressing) significantly increases the soil organic matter content (0.75%) over the treatment T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL L^{-1} of water at recommended time of nitrogen top dressing) while at par with the treatments T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL L^{-1} of water at recommended time of nitrogen top dressing) and T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL L^{-1} of water at recommended time of nitrogen top dressing) i.e. 0.72% and 0.72% respectively after harvest of paddy crop.

The treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL L^{-1} of water at recommended time of nitrogen top dressing) significantly increased the soil organic carbon content (0.78%) over the treatments T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL L^{-1} of water at recommended time of nitrogen top dressing), T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL L^{-1} of water at recommended time of nitrogen top dressing) and T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL L^{-1} of water at recommended time of nitrogen top dressing) i.e. 0.67, 0.66 and 0.67% respectively after harvest of paddy crop. This indicates that the specific application of UAN at the specified rate had a significant positive impact on soil organic carbon levels. In comparison to the control treatment (T_1), all other treatments displayed superior soil organic carbon levels, highlighting the positive influence of nutrient management practices, particularly foliar application, on enhancing soil organic matter content.

This increase in soil organic carbon can be attributed to the higher nitrogen (N) rates applied in this treatment. Increased N rates often lead to an increase in soil organic carbon, as it promotes the sequestration of carbon in the plant biomass during photosynthesis.

The higher levels of N likely stimulated plant growth and biomass production, resulting in more organic matter being incorporated into the soil as crop residue after harvest. The findings are consistent with previous research studies by **Aulakh *et al.* (2001) and Dolan *et al.* (2006),** which demonstrated that increased N rates can enhance soil organic carbon levels due to the increased carbon sequestration in plant tissues and subsequent return of organic matter to the soil through crop residues.

Similarly, **Raun *et al.* (1998)** and **Halvorson and Reule (1999)** reported similar results, showing that the application of N fertilizer had a significant impact on soil organic carbon. Their research indicated that the addition of N led to an increase in soil organic carbon content, likely due to the increased biomass production and organic matter input. Overall, the data provides evidence that the application of nitrogenous fertilizers, as seen in treatment T_3, can positively influence soil organic carbon levels. This is because the higher N rates encourage plant growth and carbon sequestration in the form of biomass, which, in turn, contributes to higher soil organic carbon content.

Table 4.4: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy pH, EC, and O.C.

Treatments	pH	EC	O. C.
Control	6.6	0.16	0.61
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	6.9	0.19	0.71
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL Lit^{-1} of water at recommended time of top dressing for N application.	6.7	0.20	0.78
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4ml Lit^{-1} of water	6.5	0.17	0.67
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2ml Lit^{-1} of water at recommendation time of top dressing for N application.	6.5	0.21	0.72
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4ml Lit^{-1} of water	6.5	0.19	0.75
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	6.5	0.20	0.66
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	6.6	0.18	0.72
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	6.4	0.19	0.67
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	6.3	0.17	0.68
SEm±	0.1	0.03	0.01
C.D.at5%	NS	0.08	0.03

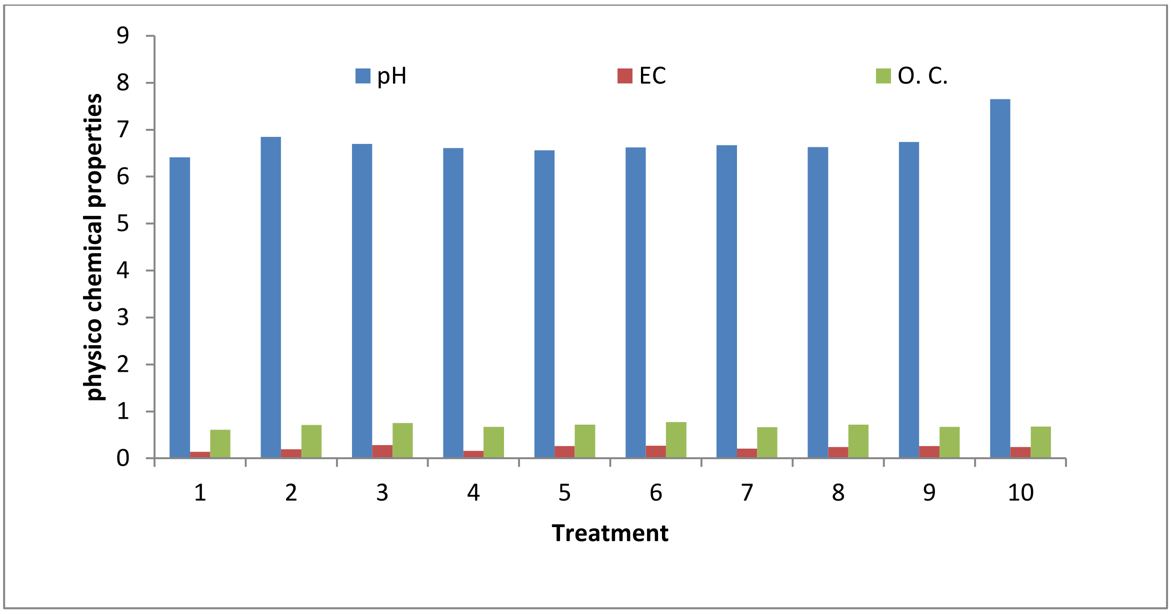

Fig 4.4: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy pH, EC, and O.C.

4.2.4 Mineralizable nitrogen

The data on mineralizable nitrogen in soil is presented in table 4.5 and Fig. 4.5 reveals that application of different nitrogenous fertilizers on paddy crop showed the highest mineralizable nitrogen content in soil (176.6 kg ha^{-1}) was observed in the treatment T_2 (GRD) which was significantly higher than all other treatments T_1 (control), T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while non- significantly with T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and the minimum (145.2 kg ha^{-1}) in the treatment T_1 (control) after harvest of paddy crop. The foliar application of UAN @ 2.0 mL^{-1} of water at recommended time of nitrogen top dressing along with recommended dose of nitrogen as basal (T_3) significantly increased mineralizable nitrogen in soil (173.8 kg ha^{-1}) than the treatment T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL^{-1} of water at recommended time of nitrogen top dressing), T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL^{-1} of water at recommended time of nitrogen top dressing), and T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) i.e. 168.4,158.4 and 143.8 kg ha^{-1} respectively after harvest of crop.

Indeed, the observed increase in soil organic carbon and nutrient availability in response to the application of nitrogenous fertilizers, particularly through foliar sprays, could be partially attributed to the role of root exudates in facilitating nutrient mobilization and solubilization in the soil. Root exudates are compounds released by plant roots into the rhizosphere, the region of soil surrounding the roots. These exudates consist of a diverse array of organic substances, such as organic acids, enzymes, sugars, and amino acids. They serve various functions, including improving nutrient availability, promoting beneficial microbial activity, and enhancing soil structure. One essential function of root exudates is their ability to enhance nutrient mobilization and solubilization in the soil. The exudates release organic acids and enzymes that contribute to the breakdown of organic matter and mineral weathering processes in the soil. This process leads to the release of bound nutrients, making them more available for plant uptake. In the context of nitrogenous fertilizers applied through foliar sprays, root exudates can play a significant role in the nutrient assimilation process. By applying nitrogenous fertilizers directly to the leaves, the plants can bypass the soil and root system to some extent. This reduces the dependence on soil-based nutrient absorption and allows for a more efficient and rapid uptake of nitrogen. As a result, the exudates can contribute to the mobilization of nitrogen and other essential nutrients from the soil, further enhancing nutrient availability and contributing to increased plant growth and soil organic carbon. The research conducted by **Ajithkumar *et al.* (2021)** aligns with these findings, indicating that inorganic nitrogen, particularly released by nitrogenous fertilizers, is prominently involved in nutrient cycling and assimilation processes. This highlights the importance of both soil and foliar nutrient management strategies in optimizing nutrient availability and promoting overall crop productivity.

Extractable phosphorus

The data on extractable phosphorus is presented in table 4.5 and Fig. 4.5 showed the range of extractable phosphorus from 16.5 to 26.2 kg ha^{-1} in soil after harvest of paddy crop. The treatment T_2 (GRD) significantly increased the extractable phosphorus 26.2 kg ha^{-1} among all other treatments. The treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL^{-1} of water at recommended time of nitrogen top dressing) significantly increased the extractable phosphorus (22.5 kg ha^{-1}) than the treatment T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL^{-1} of water at recommended time of nitrogen top dressing) while at par with the treatment T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) in soil after harvest of paddy crop. The treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) significantly increased extractable phosphorus in soil (23.4 kg ha^{-1}) than T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL^{-1} of water at recommended time of nitrogen top dressing) after harvest of crop.

Exchangeable potassium

The data on exchangeable potassium is presented in the table 4.5 and Fig. 4.5, clearly indicates that exchangeable potassium in the soil ranged from 122.09 to 154.3 kg ha^{-1}. The maximum exchangeable potassium (154.3 kg ha^{-1}) was found in the treatment T_2 (GRD) which was significantly higher than all other treatments except T9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) after harvest of paddy crop. The exchangeable potassium in soil significantly higher (150.6 kg ha^{-1}) was recorded in the treatment (T_{10}) where we applied recommended dose of nitrogen though urea as basal along with the foliar application of Nano urea @ 6.0 mL^{-1} of water at recommended time of nitrogen application as top dressing over the treatments T_4 (recommended dose of nitrogen as basal and foliar

Table 4.5: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy available N, P and K

Treatment	Mineralizable N	Extractable P	Exchangeable K
Control	145.2	16.5	122.5
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	176.6	26.2	154.3
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL Lit^{-1} of water at recommended time of top dressing for N application.	173.8	22.5	144.0
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4ml Lit^{-1} of water	160.6	19.3	143.5
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2ml Lit^{-1} of water at recommendation time of top dressing for N application.	168.4	21.8	125.7
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4ml Lit^{-1}	160.4	21.8	121.5
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	158.4	21.9	146.7
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	153.2	21.7	137.4
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	143.8	23.4	149.3
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	147.4	20.6	156.6
SEm ±	1.4	0.8	2.2
C.D.at 5%	4.2	2.3	6.6

application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while at par with the treatment T_5 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) after harvest of crop.

This suggests that the specific foliar application sources used in these treatments might have had a lesser impact on potassium availability in the soil compared to conventional fertilizer application. When compared to the control treatment (T_1), all treatments displayed superior exchangeable potassium in soil after harvest of paddy crop.

The data supports the idea that root exudates can indeed facilitate the mobilization and solubilization of nutrients in the soil, including potassium. Root exudates release organic compounds that promote nutrient cycling and mineral weathering processes, making nutrients more available for plant uptake. This likely contributed to the enhanced potassium availability observed in treatments involving foliar application.

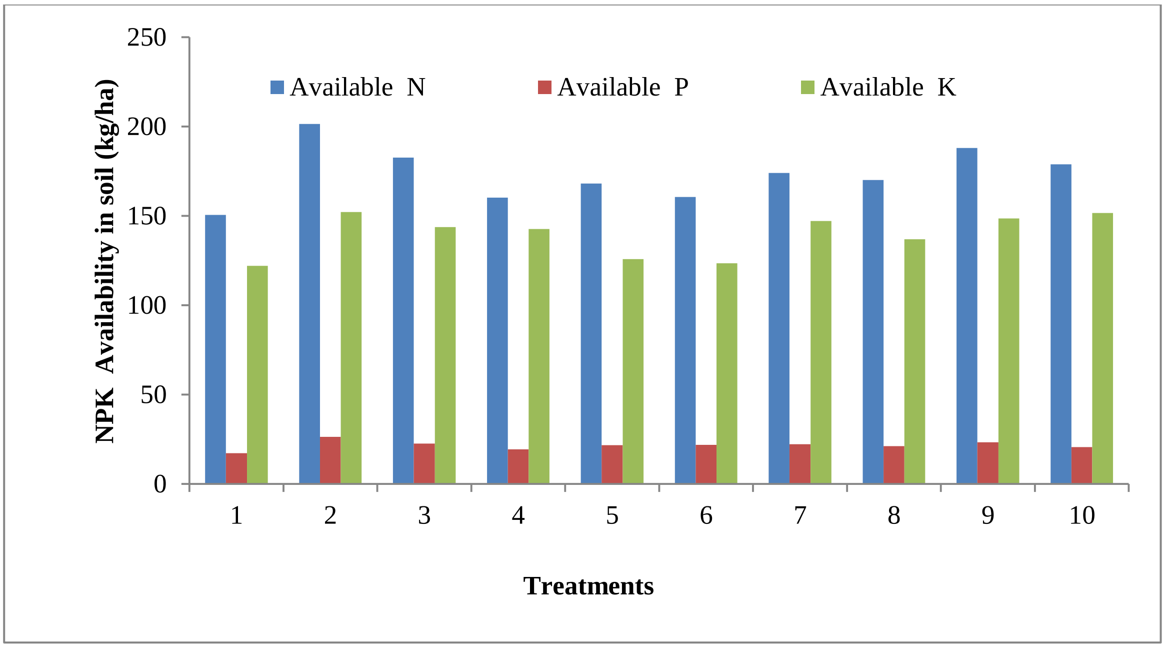

Fig 4.5: Effect of different nitrogenous fertilizers applied to soil and foliar application on paddy available N, P and K

4.3 Plant sample of paddy crop

4.3.1 Nitrogen content in grain and straw of paddy

4.3.1.1 N content in grain

The data pertaining to nitrogen content in paddy grain are presented in table 4.6 and Fig. 4.6 varied from 0.92 to 1.62%. The highest 1.62% N content in grain was observed under the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) which was significantly higher than all other treatments while at par with the treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The significantly higher nitrogen content in paddy grain 1.56% was recorded in the treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) than the treatments T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly increases the nitrogen content in grain (1.62%) over the treatments T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing)i.e. 1.36,1.42 and 1.22% respectively.

4.3.1.2 N uptake by grain

The data pertaining to nitrogen uptake by paddy grain is presented in table 4.6 and Fig. 4.6 revealed that the nitrogen uptake in grain varied from 41.65 to 101.42 kg ha^{-1}. The highest 101.42 kg ha^{-1} nitrogen uptake was observed under the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) which was significantly higher than all other treatments except the treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly increases the nitrogen uptake by grain (99.3 kg ha^{-1}) than the treatments T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing).

. Among all the treatments where UAN as foliar application were applied are found to be statistically superior than the treatments where nano urea is applied as foliar application.

4.3.1.3 N content in straw

The data pertaining on nitrogen content in paddy straw is presented in table 4.6 and Fig. 4.6 varied from 0.62% in the treatment T_1 (Control) to 0.90% with the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The highest N content in paddy straw (0.90%) was observed under the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) which was significantly higher among all other treatments. The treatment T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly increases the nitrogen content in paddy straw (0.84%) than the treatment T8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while statistically at par with the treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing).

This could be because foliar applications have very small particle sizes and are easily absorbed by rice plant parts surface like leaves when foliar spraying is used. Above finding were supported by **Kaviani *et al*. (2016),** discovered that, when compared to a control, foliar application of nitrogenous fertilizers had a significant positive effect on plant leaf N, P, and K contents.

4.3.1.4 N uptake in straw

The data on nitrogen uptake by paddy straw is presented in table4.6 and Fig. 4.6, revealed that the highest nitrogen uptake by paddy straw varied from 28.1 to 53.9 kg ha^{-1}. The highest nitrogen uptake 53.9 kg ha^{-1} was recorded in the treatment T3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL^{-1} of water at recommended time of nitrogen top dressing) which was significantly higher among all the treatments except the treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) while minimum with the treatment T1 (control) 28.1 kg ha^{-1}. The treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL^{-1} of water at recommended time of nitrogen top dressing) significantly increased the nitrogen uptake by paddy straw (45.7 kg ha^{-1}) than the treatment T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL^{-1} of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) i.e. 37.9 and 38.6 kg ha^{-1} respectively while at par with the treatment T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL^{-1} of water at recommended time of nitrogen top dressing). The treatment T_2 (GRD) significantly increased the nitrogen uptake by paddy straw (52.4 kg ha^{-1}) than the treatments T_4, T_5, T_6, T_7, T_8 and T_9.

4.3.1.5 Total nitrogen uptake by paddy

The data pertaining to total nitrogen uptake by paddy crop is presented in Table4.6 and Fig. 4.6 indicates that the total nitrogen uptake by paddy crop varied from 69.4kg ha^{-1} in treatment T_1 (control) to 154.3 kg ha^{-1} in treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL^{-1} of water at recommended time of nitrogen top dressing). The highest 154.3 kg ha^{-1} total nitrogen uptake by paddy crop was observed under the treatment T_3, which was significantly higher than all other treatments except the treatment T9(recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing), while the lowest 69.72 kg/ha uptake was under the treatment control (T_1). The treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing) significantly increased total nitrogen uptake by paddy crop (151.9 kg ha^{-1}) than the treatment T_2 (GRD), T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL^{-1} of water at recommended time of nitrogen top dressing) and T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL^{-1} of water at recommended time of nitrogen top dressing) i.e. 125.7, 139.9 and 124.1 kg ha^{-1} respectively. The treatment T5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL^{-1} of water at recommended time of nitrogen top dressing) significantly increased the total nitrogen uptake (129.5 kg ha^{-1}) by paddy crop over the treatment T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL^{-1} of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL^{-1} of water at recommended time of nitrogen top dressing). The foliar application of UAN @ 4.0 mL^{-1} of water at the recommended time of Nitrogen top dressing with recommended dose of nitrogen as basal (T_4) significantly increased the total nitrogen uptake by paddy crop than the treatment T_2 (GRD).

The enhanced nitrogen content and uptake in maize crops can be attributed to the slow-release pattern of Nano fertilizer, which ensures a sustained and steady supply of nitrogen to the plants. This unique slow-release mechanism allows for better nutrient availability to the crops over an extended period, leading to increased nitrogen uptake in both grains and straw. Among the various treatment combinations tested, the treatment with 50% nitrogen (N) combined with Nano N and Nano Zn demonstrated the highest crop yield and exhibited the most significant increase in nitrogen uptake by maize. This suggests that the synergistic effect of Nano N and Nano Zn played a crucial role in promoting nutrient uptake and overall crop performance. These findings align with previous research by **Bhuva and Sharma (2015)**, who observed significant improvements in pearl millet nutrient uptake with different nitrogen levels. Similarly, **Rajonee *et al.* (2016)** reported higher nitrogen content and uptake in Kalmi plants treated with both conventional fertilizer and Nano fertilizer, with the latter showing superior results. A noteworthy observation from earlier studies indicates that foliar NPK application can lead to increased nutrient uptake by maize roots **(Ling and Silberbush, 2002)**. The foliar

Table 4.6 Effect of different nitrogenous fertilizers applied to soil and foliar application on N content and uptake by grain and straw of paddy crop

Treatments	Content (%)		Uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Control	0.92	0.62	42.3	28.1	69.4
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	1.45	0.90	73.1	52.4	125.7
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL Lit^{-1} of water at recommended time of top dressing for N application.	1.62	0.85	101.6	53.9	154.3
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4ml Lit^{-1} of water	1.36	0.83	92.4	46.6	139.9
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2ml Lit^{-1} of water at recommendation time of top dressing for N application.	1.56	0.81	85.9	45.7	129.5
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4ml Lit^{-1} of water	1.27	0.82	86.1	43.3	128.9
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	1.42	0.80	82.3	44.4	124.1
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	1.42	0.76	74.8	37.9	112.1
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	1.22	0.82	99.3	51.3	151.9
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	1.24	0.84	74.8	38.6	112.9
SEm±	0.02	0.01	1.3	0.7	1.7
C.D.at5%	0.05	0.03	3.9	2.1	4.9

application of nutrients allows for direct absorption and utilization by the plant, bypassing potential losses through soil interactions. Consequently, this method optimizes nutrient delivery to the crops, positively impacting nutrient uptake and subsequent growth. The collective evidence from the aforementioned studies reinforces the significance of nitrogen fertilizer application in augmenting the nitrogen content of maize crops. The increase in nitrogen content percentage over the control, as discovered by **Das *et al.* (2000)**, further underscores the vital role of nitrogen fertilization in enhancing crop nutrition and productivity.

The slow-release pattern of Nano fertilizer emerges as a pivotal factor in driving increased nitrogen content and uptake in maize crops. The combination of Nano N and Nano Zn in specific treatments shows promising results in elevating crop yield and nutrient assimilation. These findings are in harmony with previous research, emphasizing the positive impact of nutrient management practices, such as foliar application, on nutrient uptake and overall crop performance. The insights gained from these studies can serve as valuable guidelines for optimizing fertilizer usage and improving nutrient use efficiency in maize cultivation, ultimately contributing to sustainable agriculture and meeting global food demands.

4.4 Phosphorus content in grain and straw

4.4.1 Phosphorus content in grain

The data on phosphorus content in paddy grain is presented in table4.7 and Fig. 4.7 indicates that the highest Phosphorus content in grain 0.56% to 0.29 %. The highest P content 0.56% was observed under treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) which was significantly higher than all other treatment while statistically at par with the treatment T_2 (GRD) and the minimum with the treatment T1(control) i.e. 0.29 %. The phosphorus content in paddy grain (0.51%) was observed with the treatment T2(GRD) which was significantly higher than the foliar application of UAN and Nano urea treatments (T_4,T_5, T_6, T_7, T_8, T_9 and T_{10}. The phosphorus content in paddy straw (0.45%) with the treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) was significantly higher than the treatment T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while statistically at par with the treatment T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing). and T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing).

4.4.2 P uptake in grain

The data on phosphorus uptake by paddy grain is presented in table 4.7 and Fig. 4.7 revealed that the highest phosphorus uptake by grain 35.9 kg ha^{-1} with the treatment (T_3) which was significantly higher than all other treatments except the treatment T_2(GRD). The treatment T_2 (GRD) significantly increased the phosphorus uptake by grain 34.7 kg ha^{-1} over the foliar application of UAN and Nano urea i.e. the treatments T_4, T_5, T_6, T_7, T_8, T_9 and T_{10}. The treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly increased the phosphorus uptake by grain 24.8 kg ha^{-1} than the treatment T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) treatment significantly increased the phosphorus uptake by grain 35.9 kg ha^{-1} than the treatmentsT4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing),T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The data presented in this table clearly indicated that the foliar application of UAN is better than the foliar application of Nano urea and GRD.

4.4.3 P content in straw

The data on phosphorus content in paddy straw is presented in table 4.7 and Fig. 4.7 varied from 0.14 % to 0.25 %. The highest P content 0.25 % was observed under the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) which was significantly higher than the treatments T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing)i.e. 0.19% and 0.16% respectively while Statistically at par with the treatment T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing).

4.4.4 P uptake in straw

The data on phosphorus content in paddy straw is presented in table4.7 fig. 4.7 varied from 15.9 kg ha^{-1} to 51.2 kg ha^{-1}. The highest P uptake 51.2 kg ha^{-1} was observed under the treatment T3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) which was significantly higher among all the treatments, while the lowest 16.13 kg ha^{-1} under the treatment control (T_1) whereas the second highest uptake of phosphorus by paddy straw was recorded under the treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The significantly higher phosphorus uptake by paddy straw 45.3 kg ha^{-1} was recorded under the treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) than the treatments T_4 and T_7 i.e. 38.7 and 37.7 kg ha^{-1} respectively. The treatment T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea@ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) gave significantly higher phosphorus uptake by paddy straw 37.6 kg ha^{-1} than the treatments T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing)and T_8

(recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing).

Among all the treatments where UAN as foliar application were applied are found to be statistically superior than the treatments where nano urea as foliar application were applied and treatment $T_{3,}$ treatments was statistically at par to $T_{9.}$

4.4.5 Total phosphorus uptake by paddy

The data on total phosphorus uptake by paddy crop is presented in table 4.7 and Fig 4.7 varied from 29.6 kg ha^{-1} to 86.7 kg ha^{-1} . The highest total phosphorus uptake 86.7 kg ha^{-1} by paddy crop was observed under treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) which was significantly higher among all the treatments,. while the lowest total phosphorus uptake was recorded under the treatment control (T_1). The total phosphorus uptake by paddy crop 70.7 kg ha^{-1} was recorded under the treatment T_2(GRD)was significantly higher than the foliar application of Nano urea with different doses these are T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing), T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) i.e. 55.3,47.4,51.4 and 58.4 kg ha^{-1} respectively. The foliar application of UAN at the different doses was found better than the foliar application of Nano urea.

The positive impact of nitrogen on phosphorus uptake by maize grain and straw can be attributed to the unique surface coatings of Nanomaterials present in the Nano fertilizer. These coatings on the fertilizer particles create a larger surface area, leading to more intense nutrient holding capacity compared to conventional fertilizers. As a result, Nano fertilizers facilitate a controlled release of nutrients and reduce the fixation of phosphorus in the soil. The findings from the current study align with previous research conducted by **Mala *et al.* (2017)**, which demonstrated that Nano fertilizer application significantly enhances phosphorus content and uptake compared to conventional fertilizers. This confirms the efficacy of Nano fertilizers in promoting phosphorus uptake and utilization by maize crops. Similarly, **Nirere *et al.* (2021)**

provided further support for the benefits of nutrient management practices involving the application of Nano fertilizers. Their study revealed that combining soil application of 100% recommended dose of fertilizer (RDF) with foliar sprays of NPK at specific growth stages significantly increased maize crop's nitrogen, phosphorus, and potassium uptake. These findings underscore the potential synergistic effects of proper nutrient management, which can further enhance phosphorus uptake in maize crops. Additionally, **Meena *et al.* (2021)** reported a significant increase in phosphorus uptake by both grain and straw of wheat crops through the application of Nano fertilizers via foliar spraying. This indicates that Nano fertilizers have the capacity to improve phosphorus acquisition in various cereal crops, including wheat, further reinforcing their potential in promoting nutrient uptake efficiency. Furthermore, **Zaki (2016)** observed a direct relationship between nitrogen fertilization and phosphorus uptake in rice grain and straw. Increasing nitrogen fertilization resulted in an increase in phosphorus uptake, highlighting the interconnectedness of nutrient interactions in crop plants. In line with the above findings, **Rana *et al.* (2017)** reported that nitrogen application led to elevated phosphorus concentrations in wheat plants during the maximum tillering stage. This suggests that nitrogen fertilization positively influences phosphorus assimilation during crucial growth periods, ultimately contributing to enhanced crop performance.

Overall, the use of Nano fertilizers shows promise in promoting phosphorus uptake and nutrient use efficiency in maize and other cereal crops. The surface coatings of Nanomaterials in Nano fertilizers provide distinct advantages, such as controlled nutrient release and reduced nutrient fixation, resulting in better nutrient availability for plant uptake. As demonstrated by previous studies, proper nutrient management practices, involving the application of Nano fertilizers alongside conventional fertilizers, can lead to improved phosphorus content and uptake, ultimately contributing to enhanced crop productivity and agricultural sustainability.

Table 4.7: Effect of different nitrogenous fertilizers applied to soil and foliar application on P content and uptake by grain and straw of paddy crop

Treatments	Content (%)		Uptake (kg ha^{-1})		Total P uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Control	0.29	0.14	13.0	15.9	29.6
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	0.51	0.23	34.7	35.8	70.7
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL Lit^{-1} of water at recommended time of top dressing for N application.	0.56	0.25	35.9	51.2	86.7
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4ml Lit^{-1} of water	0.43	0.19	22.9	38.7	73.7
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.45	0.20	24.8	30.4	55.3
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4ml Lit^{-1} of water	0.38	0.19	16.4	30.9	47.4
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.43	0.21	23.1	37.7	60.4
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.39	0.20	18.1	33.6	51.4
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.31	0.16	22.9	45.3	68.3
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.32	0.19	20.7	37.6	58.4
SEm±	0.01	0.01	0.9	0.9	1.2
C.D.at5%	0.02	0.03	2.8	2.8	3.5

4.5 Potassium content in grain and straw by

4.5.1 K content in grain

The data on potassium content in grain of paddy rice is presented in table 4.8 and Fig.4.8 varied from 0.30 % to 0.53 %. The highest potassium uptake (0.53 %) by paddy grain was observed under the treatment T_2 (GRD) was significantly higher than the other treatments such as T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing),T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing),T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing),T_7(recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing),T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing), and T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while statistically at par with the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The potassium uptake by paddy grain 32.4 kg ha^{-1} significantly increased the with the treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). Over the treatment T4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while at par with the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing).

4.5.2 K content in straw

The data on potassium content in paddy straw is presented in table 4.8 and Fig. 4.8 revealed that the maximum potassium content in paddy straw 1.53 % was recorded in the treatment T_2 (GRD) and the minimum 0.83 % with the treatment T_1 (control). The significantly more potassium content in paddy straw 1.53 % was observed under the treatment T_2, which was significantly higher among all the treatments. The potassium content in paddy straw (1.36%) was observed significantly more with the treatment T_{10} (recommended dose of nitrogen as basal and foliar application Nano urea @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) than the treatment T_5 (recommended dose of nitrogen as basal and foliar application Nano urea @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while statistically at par with treatment T_6 (recommended dose of nitrogen as basal and foliar application Nano urea @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) whereas non-significant with the treatment T_8 (recommended dose of nitrogen as basal and foliar application Nano urea @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The potassium content in paddy straw (1.44%) in the treatment T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly increased than the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) while at par with the treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and non-significant increased with treatment T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing).

4.5.3 Potassium uptake in grain by paddy

The data on potassium uptake by paddy grain is presented in table 4.8 and Fig. 4.8 varied from 18.2 Kg ha^{-1} to 34.1 Kg ha^{-1}. The highest 34.1 Kg ha^{-1} potassium uptake by paddy grain was observed under the treatment T_2 (GRD) which was significantly more among all the treatments, while lowest 24.82 Kg ha^{-1} with the treatment T_1 (control). The treatment T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly increased the potassium uptake (32.4 kg ha^{-1}) by grain than the treatment T_4 (recommended dose of nitrogen as basal and foliar application UAN @ 4.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly at par with the treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). Similar study was carried out by **Tiwari *et al.* (2020)** and reported that the higher potassium content in grain was recorded with treatment having foliar application of nitrogenous fertilizer applied similarly; the highest potassium uptake.

4.5.4 K uptake in straw

The data on potassium straw uptake by paddy is presented in table 4.8 potassium straw uptake by paddy varied from 49.33 Kg^{-1}(T_1) to 116.79 Kg^{-1}(T_2). Highest 116.79 Kg^{-1}potassium straw uptake by paddy was observed under the treatment T_2. While lowest 49.33Kg^{-1}uptake under the treatment control T_1. From the data whileT_9 and T_3 were at par with T_2 and T_2 is superior than T_3, T_9 and T_4, T_5, T_6, T_7 and T_8 were inferior. In comparison to the T_1 all the treatments were superior.

4.5.5 Total potassium uptake by paddy

The data on total uptake of potassium by paddy crop is presented in table 4.8 and Fig. 4.8 showed that the maximum potassium uptake by paddy crop (151.2 kg ha^{-1}) was observed under the treatment T_2 (GRD) significantly higher than all other treatments while minimum potassium uptake with the T1 (control). The treatment T_3 (recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) significantly increased the potassium uptake by crop (145.2 kg ha^{-1}) significantly increased the potassium uptake by paddy crop than the treatment T_7 (recommended dose of nitrogen as basal and foliar application UAN @ 1.5 mL $^{-1}$ of water at recommended time of nitrogen top dressing) and T_9 (recommended dose of nitrogen as basal and foliar application UAN @ 6.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing) i.e. 134.0 and 132.7 kg ha^{-1} respectively while statistically at with the treatment T_4(recommended dose of nitrogen as basal and foliar application UAN @ 2.0 mL $^{-1}$ of water at recommended time of nitrogen top dressing). The foliar application of UAN showed better than the foliar application of Nano urea on paddy crop.

The higher potassium content and uptake observed in treatment T_2, where 50% of the traditional chemical recommended dose of nitrogen was replaced by Nano N fertilizer, could be attributed to the unique properties of nano structured formulations. Nano fertilizers have the ability to control the release speed of nutrients, aligning with the crop's uptake patterns. The incorporation of nano-sized mineral nutrient formulations may enhance the solubility and dispersion of insoluble nutrients in the soil, ultimately reducing nutrient losses and fixation while increasing nutrient bio availability. This, in turn, leads to improved potash use efficiency and greater potassium uptake by the crops, such as maize. The unique characteristics of nanostructured fertilizers may enable them to enter plant cell walls more easily, reaching the plasma membrane and enhancing nutrient uptake, including potassium. Furthermore, similar research findings were reported by **Das *et al.* (2000)**, who observed that the application of nitrogen fertilizer significantly increased potassium concentration and uptake in cotton crops. This suggests a potential synergistic effect between nitrogen and potassium nutrients, which may be further amplified by the slow nitrogen release pattern of Nano fertilizers. Additionally, **Gunaratne *et* al. (2016)** found that urea-coated hydroxyapatite fertilizer increased potassium uptake by shoots of Gliricidia sepium more effectively than conventional fertilizers added to the soil. This supports the idea that specific nano formulations may promote better nutrient uptake, leading to enhanced crop growth and productivity. The collective evidence from previous research by **Bahmanyar and Mashaee (2010)**, **Zaki (2016)**, and **Rana *et al.* (2017)** further strengthens the notion that nano structured fertilizers can positively impact potassium uptake in various crops. These studies highlight the potential benefits of using Nano fertilizers to enhance nutrient availability, improve nutrient use efficiency, and optimize crop performance.

Table 4.8: Effect of different nitrogenous fertilizers applied to soil and foliar application on K content and uptake by grain and straw of paddy crop

Treatments	Content (%)		Uptake (kg ha^{-1})		Total K uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Control	0.30	0.83	18.2	49.4	67.7
GRD (N=150 kg ha^{-1} recommended dose of N through prilled urea as per recommendation for basal and top dressing.	0.53	1.53	34.1	117.3	151.8
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @2 mL Lit^{-1} of water at recommended time of top dressing for N application.	0.51	1.32	31.4	114.2	145.2
Basal dose of N through prilled urea as per the recommendation and foliar application of UAN@ 4ml Lit^{-1} of water	0.45	1.44	25.3	115.5	141.7
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @2ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.47	0.99	26.1	78.2	104.1
Basal dose of N through prilled urea as per the recommendation and foliar application of Nano urea @4ml Lit^{-1} of water	0.40	1.30	21.3	98.5	119.9
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.38	1.43	20.3	113.3	134.0
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @1.5ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.32	1.35	24.7	92.1	117.5
Basal dose of N through prilled urea as per recommendation and foliar application of UAN @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.50	1.39	32.4	100.2	132.7
Basal dose of N through prilled urea as per recommendation and foliar application of Nano urea @6.0ml Lit^{-1} of water at recommendation time of top dressing for N application.	0.47	1.36	26.6	88.8	114.4
SEm±	**0.01**	**0.01**	**0.42**	**1.2**	**1.7**
C.D.at5%	**0.02**	**0.05**	**1.25**	**3.4**	**4.9**

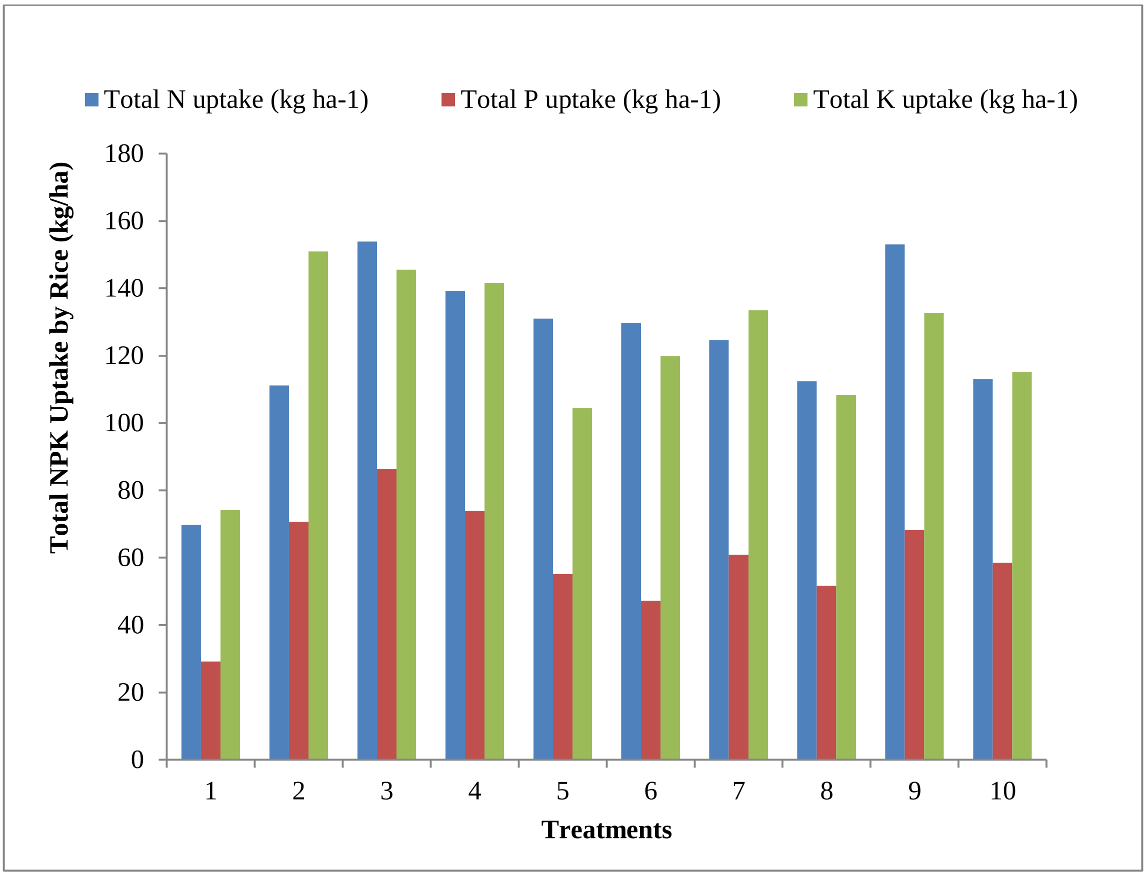

Fig 4.8: Effect of different nitrogenous fertilizers applied to soil and foliar application on K content and uptake by grain and straw of paddy crop

Summary and Conclusions

Chapter-5 SUMMARY AND CONCLUSION

The study **"COMPARISION OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLIED ON PADDY CROP (*Oryza sativa L.*) GROWN IN NORTH WESTERN PLAINS OF INDIA"** was carried out during the kharif season of 2022 at the Norman E. Borlaug Crop Research Centre, G.B.P.U.A & T, Pantnagar, Udham Singh Nagar, Uttarakhand. The field experiment was carried out in RBD (Randomized Block Design) with ten treatments and three replications. The paddy variety HKR 47 was used for the research trial and sown in the *kharif* season of 2022.

There were ten treatment combinations, including Control (T_1) with no treatment, GRD (150:60:40 kg ha^{-1} $N:P_2O_5:K_2O$) (T_2), UAN @2.0 mL ha^{-1}(T_3), UAN @ 4.0 mL ha^{-1} (T_4), Nano Urea @2.0 mL ha^{-1} (T_5), Nano Urea 4.0 mL ha^{-1} (T_6), UAN @1.5 mL ha^{-1} (T_7),Nano Urea @1.5 mL ha^{-1} (T_8), UAN @6.0 mL ha^{-1} (T_9), Nano Urea @6.0 mL ha^{-1}(T_{10}). All treatments include 100% PK and three Nano and UAN fertilizer sprays at 30DAS, 60DAS and 90DAS. Soil samples were collected after crop harvesting to determine soil pH, EC, organic carbon, available N, P, and K. The yield attributes were observed at different stages of crop growth and plant and grain samples were also collected and processed for chemical analysis to determine the nitrogen, phosphorus, and potassium content in paddy grain and straw.

The current study's findings are summarized below:

1. Plant height increased from T_1 to T_{10} at knee height and during the vegetation stage, but there was no statistically significant difference between treatments. Plant height increased as N fertilizer application (foliar) increased. Plant height at active tillering stage was higher than the knee height stage.

2. Maximum plant height attains at harvesting stage it varies from 80 to 123.2 cm. Highest plant height under treatment T_3 (UAN @2.0 mL ha^{-1}) with 123.2 cm while 80 cm lowest plant height observed under T_1 (control). T_3 plants grew 6.43% taller than T_1 plants.T_3 was at par with T_6 followed by T_1, T_2, T_4, T_5, T_6, and T_8.

3. Paddy grain yield ranged from 45.27 to 64.10 q/ha. The treatment control (T_1) produced the lowest grain yield of 45.27 q/ha, while the treatment receiving 2.0 mL

ha^{-1}(T_3) produced the significant highest grain yield of 64.10 q/ha. Grain yield increased by 7.31%when transitioning from T_2 (GRD) to T_3. In terms of grain yield, T_3 was significantly at par with T_6, followed by T_9, T_8, and T_7.

4. Paddy 1000-grain weight (g) ranged from 22g to 32g. The treatment (T1) produced the lowest 1000-grain weight of (22 g), while the treatment receiving UAN 2.0 mL ha^{-1}(T_3) produced the highest 1000-grain weight of (32 g). 1000-grain weight increased by 10.41% when transitioning from T_2 to T_3. In terms of grain yield, T_3 was significantly

5. Paddy straw yield ranged from 59.43 to 88.70 q/ha. The treatment control (T_1) produced the lowest straw yield of 59.43 q/ha, while the treatment receiving 2.0 mL ha^{-1}(T_3) produced the highest grain yield of 88.70 q/ha. Straw yield increased by 7.9% when transitioning from T_2 to T_3. In terms of straw yield, T_3 was significantly

6. Paddy total biomass yield ranged from 104.70 to 152.80 q/ha. The treatment control (T_1) produced the lowest total biomass of 104.70 q/ha, while the treatment receiving UAN 2.0 mL ha^{-1}(T_3) produced the highest grain yield of 152.80 q/ha. Total biomass increased by 7.65% when transitioning from T_2 to T_3. In terms of total biomass, T_3 was significantly

7. After harvest, soil pH was ranged from 6.6 to 6.9 Results from analyzed data found all treatments were non-significant effects for soil pH. The treatment control (T_1) reported the lowest pH with 6.6 while the treatment receiving UAN 2.0 mL ha^{-1} (T_3) reported the highest pH with 6.7 same results demonstrated under T_3.

8. Electric conductivity after paddy crop harvest was measured and results from data analysis revealed that all treatments had a non significant effect. The range of EC obtained was 0.16 dS m^{-1} under T_1 to 0.20 dS m^{-1} under T_3.

9. Soil organic carbon ranged from 0.61 to 0.78 %. The treatment control (T_1) reported the lowest organic carbon with 0.61% while the treatment with UAN 2.0 mL ha^{-1} (T_3) reported the highest organic carbon in soil with 0.77%. Soil organic carbon non significant increased by 8.45% when comparing T_2 to T_3. Treatment received UAN 2.0 mL ha^{-1} (T_3)

10. After harvesting of paddy crops, soil mineralizable N varies from 145.2 to 176.6 kg ha^{-1}. As the increase in the basal dose of N, increased soil nitrogen availability in soil. The treatment control (T_1) reported the lowest mineralizable N with 145.2 kg ha^{-1}, while the treatment with GRD (T_2) reported the highest mineralizable N in soil with 176.6 kg ha^{-1}. Soil mineralizable nitrogen non significantly increased by 33.8% in T_2 when compared with T_1 (control).

11. After harvest of paddy crop, soil extractable P varies from 16.5 to 26.3 kg ha^{-1}. The treatment with GRD (T_2) reported the highest available P with 26.3 kg ha^{-1}, while the treatment T_1 reported the lowest extractable P in soil with 16.5 kg ha^{-1}. Soil extractable phosphorus increased by 53.1% in T_2 when compared with T_1 (control).

12. After harvesting of paddy crop, soil exchangeable K varies from 122.5 to 154.3 kg ha^{-1}. Treatment GRD (T_2) reported the highest exchangeable K with 154.3 kg ha^{-1}, while the treatment control T_1 reported the lowest exchangeable K in soil with 122.5 kg ha^{-1}. Soil exchangeable potassium increased by 24.8% in T_2 when compared with T_1 (control).

13. N content in grain varies from 0.92 to 1.62 %. Treatment control (T_1) observed minimum content with 0.92%, while significant highest under the treatment T_3 with 1.62 % grain nitrogen content in T_3 (UAN 2.0 @ml ha^{-1})increased by 11.72% when compared with (GRD).

14. N uptake in grain varies from 42.3 to 101.6 kg ha^{-1}. Treatment control (T_1) observed minimum uptake with 42.3 kg ha^{-1}, while maximum under the treatment T_3 with 101.6 kg ha^{-1}. Grain nitrogen uptake increased by 33.9% when comparing T_2 to T_3. N content in straw varies from 0.62 to 0.85%. Treatment control (T_1) observed minimum content with 0.62%, while the maximum under treatment T_3 with 0.85%. Straw nitrogen content increased by 1.2% when comparing T_2 to T_3.

15. N uptake in straw varies from 28.1 to 53.9 kg ha^{-1}. Treatment control (T_1) observed minimum straw uptake with 28.1 kg ha^{-1}, while maximum under the treatment T_3 with 53.9 kg ha^{-1}. Straw nitrogen uptake increased by 2.72% when comparing T_3 to T_2.

16. Total N uptake by paddy varies from 69.4 to 154.3 kg ha^{-1}. Treatment control (T_1) observed minimum total uptake with 69.3 kg ha^{-1}, while maximum under the treatment T_3 with 154.3 kg ha^{-1}. Total nitrogen uptake increased by 23.3% when comparing T_3 to T_2.

17. P content in grain varies from 0.29 to 0.56 kg ha^{-1}. Treatment control (T_1) observed minimum P uptake with 0.29 kg ha^{-1}, while maximum under the treatment T_3 with 0.58 kg ha^{-1}. Grain phosphorus content increased by 9.3% when comparing T_3 to T_2.

18. P uptake in grain varies from 13.0 to 35.9 kg ha^{-1}. Treatment control (T_1) observed minimum P uptake with 13.0 kg ha^{-1}, while maximum under the treatment T_3 with 35.9 kg ha^{-1}. Grain phosphorus uptake increased by 1.06% when comparing T_3 to T_2.

19. P content in straw varies from 0.14 to 0.25%. Treatment control (T_1) observed minimum content with 0.14%, while maximum under the treatment T_3 with 0.26%. Straw phosphorus content increased by 8.7% when comparing T_3 to T_2.

20. P uptake in straw varies from 15.9 to 51.2 kg ha^{-1}. Treatment control (T_1) observed minimum straw P uptake with 15.9 kg ha^{-1}, while maximum under the treatment T_3 with 51.2 kg ha^{-1}. Straw phosphorus uptake increased by 42.9% when comparing T_3 to T_2.

21. Total P uptake by paddy varies from 29.6 to 86.7 kg ha^{-1}. Treatment control (T_1) observed minimum total phosphorus uptake with 29.6 kg ha^{-1}, while maximum under the treatment T_3 with 86.7 kg ha^{-1}. Total P uptake increased by 22.3% when comparing T_3 to T_2.

22. K content in grain varies from 0.30 to 0.53%. Treatment control (T_1) observed minimum K content with 0.30%, while the maximum under treatment T_3 with 0.53%. Grain potassium content increased by 3.92% when comparing T_2 to T_3. K content in straw varies from 0.83 to 1.53%. Treatment control (T_1) observed minimum content with 0.83%, while the maximum under the treatment T_{10} with 1.53%. Straw potassium content increased by 15.9% when comparing T_3 to T_2.

23. K uptake in grain varies from 18.2 to 34.1 kg ha^{-1}. Treatment control (T_1) observed minimum K uptake with 18.2 kg ha^{-1}, while maximum under the treatment T_3 with 34.1 kg ha^{-1}. Grain potassium uptake increased by 9.54% when comparing T_2 to T_3. K uptake in straw varies from 49.4 to 117.3kg ha^{-1}. Treatment control (T_1) observed minimum straw K uptake with 49.4 kg ha^{-1}, while maximum under the treatment T_3 with 114.2 kg ha^{-1}. Straw potassium uptake increased by 2.14% when comparing T_2 to T_3.

24. Total K uptake by paddy varies from 67.7 to 151.8 kg ha^{-1}. Treatment control (T_1) observed minimum total potassium uptake with 67.7 kg ha^{-1}, while maximum under the treatment T_2 with 151.8 kg ha^{-1}. Total potassium uptake increased by 3.73% when comparing T_2 to T_3.

Conclusion

The current study demonstrated that foliar application of UAN fertilizer significantly improved paddy crop yield by 7.31% compared to GRD and 41.6% compared to the control. Treatment T_3 (UAN @2.0 mL L^{-1} it ha^{-1}) outperformed other treatments in promoting paddy growth and nutrient availability. Also, foliar application of nitrogenous fertilizer has not declined soil nutrient status. However, as foliar application of nano fertilizers with basal doses in paddy given significant results in Northwestern region of India specifically in Mollisol, further research is necessary to validate these findings and provide practical recommendations for implementation in agricultural practice

Literature Cited

Abdel-Aziz, H. M. M., Abdel-Ghany, H. M. N. and Omer, A. M. 2018. Foliar application of nano chitosan NPK fertilizer improves the yield of wheat plants grown on two different soils. *Egypt. J. Exp. Biol.,* 14(1): 63-72.

Aher, A., and Umesha, C. 2023. Effect of Nano Urea and Zinc on Growth and Yield of Baby Corn *(Zea mays* L.*)* under Prayagraj Condition. *Int. J. Environ. Clim. Change*, 13(6): 285-291.

Ajithkumar, K., Kumar, Y., Savitha, A.S., Ajayakuma M.Y., Narayanaswamy, C., Raliya, R., Krupashankar, M. R. and Bhat, S.N. 2021. Effect of IFFCO nano fertilizer on growth, grain yield and managing *Turcicum* leaf blight disease in maize. *Int. J. Plant Soil Sci.,* 33(16): 19-28.

Akhand, M.I.M., Roy, B.C., Biswas, J.C., Parvin, N. and Paul, S. 2013. Urea spraying as an effective alternate method of nitrogen management. *Ecofriendly Agril. J.*,6(9): 188-192.

Akhlaghi, K. 2008. Formulation and manufacture of sealants for use in the production process sulfur-coated urea. '*In: Petrochemical Conference*' at NPC, Tehran**,** Iran, during. September 13. pp. 47-50.

AL Aasmi, A., Li, J., Hamoud, Y. A., Lan, Y., Alordzinu, K. E., Appiah, S. A., and Yu, C. 2022. Impacts of slow-release nitrogen fertilizer rates on the morpho-physiological traits, yield, and nitrogen use efficiency of paddy under different water regimes. *Agriculture,* 12(1): 86.

AL-Saray, M. K. S. and AL-Rubaee, F. A. H. 2019. Effect of nano-nitrogen and manufacture organic fertilizer as supplementary fertilizer in the yield and its component for three synthetics of maize *(Zea mays L.). Plant Arch.*, 19(2): 1473-1479.

Amanullah, K.M., Khan, A., Khan, I., Shah, Z. and Hussain, Z. 2014. Growth and yield response of maize (*Zea mays* L.) to foliar NPK-fertilizers under moisture stress condition. *Plant Soil Environ*., 33(2): 116–123.

Amrutha, T. G., Jayadeva, H. M., Shilpa, H. D., and Sunil, C. M. (2016). Growth and yield of aerobic paddy as influenced by levels and time of application of nitrogen. *Res. Environ. Sci., 9*(6), 655-657.

Aula, L., Macnack, N., Omara, P., Mullock, J., and Raun, W. 2016. Effect of fertilizer nitrogen (N) on soil organic carbon, total N, and soil pH in long-term continuous winter wheat *(Triticum aestivum L.). Comm. in Soil Sci. Plant Anal*, 47(7): 863-874.

Aulakh, M.S., T.S. Khera, J.W. Doran and K.F. Bronson. 2001. Managing crop residues with green manure, urea and tillage in rice-wheat rotation. *Soil Sci. Soc. Am. J.*, 65(2): 820–827.

Bahmanyar, M.A and Mashaee, S.S. 2010. Influences of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice(*Oryza sativa* L.). *Afr. J. Biotech*., 9(18): 2648-2653.

Bandaogo, A., Bidjokazo, F., Youl, S., Safo, E., Abaidoo, R., and Andrews, O. 2015. Effect of fertilizer deep placement with urea super granule on nitrogen use efficiency of irrigated paddy in Sourou Valley (Burkina Faso). *Nutri.Cycl. agroecosystems*, 102: 79-89.

Bazaya, B. R., Sen, A., and Srivastava, V. K. 2009. Planting methods and nitrogen effects on crop yield and soil quality under direct seeded paddy in the Indo- Gangetic plains of eastern India. *Soil Tillage Res.*, 105(1): 27-32.

Benzon, H., Rubenecia, M., Ultra, V. and Lee, S. 2015. Nano-fertilizer affects the growth, development, and chemical properties of paddy. *Int. J. Agron. Agric.Res.*,**7**(1): 105-117.

Bhalla, G. S., Hazell, P., & Kerr, J. 1999. *Prospects for India's cereal supply and demand to 2020* (Vol. 29). Intl Food Policy Res Inst.

Bhargavi, G., and Sundari, A. 2023. Effect of nano urea on the growth and yield of paddy *(Oryza sativa)* under SRI in the Cauvery delta zone of Tamil Nadu. *Crop Res.*, 58(1and2), 12-17.

Bhatt, R. 2012. Relative performance of neem coated urea viz-a-viz ordinary urea applied to paddy-wheat cropping in sub-tropical soils. *An Asian J. Soil Sci.*, 7(2):353-357.

Bhuva, H.M and Sharma, S. 2015. Influence of nutrient uptake by irrigation, nitrogen and phosphorus and their effect on quality parameters of *rabi* pearl millet. *Am. J. Agric. & Environ. Sci.*, 15(3): 324-327.

Black, C.A. 1965. Methods of soil analysis. Part 2. American Society of Agronomy, inc. Madison, Wisconsin, U.S.A.

Bouyoucos, G. J. 1936. Directions for making mechanical analyses of soils by the hydrometer method. *Soil Sci.*, 42(3): 225-230.

Bower, C.A. and Wilcox, L.V.1965. Methods of Soil Analysis Part2. *Chemical and Microbiological Properties*, 9: 933-951.

Cahill, S., Osmond, D.L., Crozier, C.R. and Weisz, R. 2007. Winter wheat and maize response to urea ammonium nitrate and a new urea formaldehyde polymer fertilizer. *Agronomy J.* 99(6):1645-1653.

Chandana, P., Latha, K. R., Chinnamuthu, C. R., Malarvizhi, P., and Lakshmanan, A. 2021. Impact of Foliar Application of Nano Nitrogen, Zinc and Copper on Yieldand Nutrient Uptake of Paddy. *Int. J. Plant Soil Sci.*, 33(24): 276-282.

Chaturvedi, G., Chakraborty, M., and Singh, A. N. R. 2023. Resource optimization for paddy (*Oryza sativa* L.) under climate change scenario in *Terai* region of Uttarakhand.

Chaudhari, P. R., Tamrakar, N., Singh, L., Tandon, A., & Sharma, D. 2018. Rice nutritional and medicinal properties. *J. Pharmaco. Phytochem.*, *7*(2), 150-156.

Chen, Z., Wang, H., Liu, X., Liu, Y., Gao, S., and Zhou, J. 2016. The effect of N fertilizer placement on the fate of urea^{-1}5N and yield of winter wheat in southeast China. *PLoS One*, 11(4): e0153701.

Chinnamuthu, C.R. and Boopathi, P.M. 2009. Nanotechnology and agroecosystem. *Madras Agric. J.*, 96(1/6): 17-31.

Choudhary, R., Naresh, R. K., Kumawat, L., Gawdiya, S., Tiwari, H., Kumar, S., and Kumar, R. 2022. Soil Microbial and Soil Organic Matter Dynamics with Crop productivity as affected by Organic through Bio-Stimulants and Nano Fertilizers in Indian Mustard under Paddy-Mustard Cropping System. *Agri.mech. asia.*,53(1): 00845841.

Das, A., Jakasaniya, M.S., Patel K.H. and Patel, P.T. 2000. Effect of graded levels of nitrogen and phosphorus on yield and nutrients uptake by hybrid fodder sorghum under rainfed situation. *Ann. Arid Zone*, 39(2): 163-168.

Dawood, A., Majeed, A., Ul-Allah, S., Naveed, M., Farooq, S., Sarwar, N., and Hussain, M.2023. Combined Application of Organic and Inorganic Nitrogen and Seed Inoculation withRhizobacteria (*Stenotrophomonas maltophilia* FA-9) Improved Productivity, Nitrogen Use Efficiency, and Economic Returns of Pearl Millet. *Sustainability*, 15(10): 8248.

DES, 2018. Directorate of economics and statistics, department of agriculture cooperation and farmers welfare. https://eands. dacnet. nic.in/ APY_96_to_06.html.

Deshpande, S. B., Fehrenbacher, J. B. and Ray, B. W. 1971. Mollisols of *Tarai* region of Uttar Pradesh, Northern India 2. Genesis and classification. *Geoderma*, 6(3): 195-201.

Dobermann, A. R. 2002. Nitrogen use efficiency-state of the art. *Agronomy--Faculty Publications*, 316 p.

Dolan, M.S., Clapp, C.E., Allmaras, R.R., Baker, J.M. and Molina, J.A.E. 2006. Soil organic carbon and nitrogen in a Minnesota soil as related to tillage, residue and nitrogen management. *Soil Tillage Res.*, 89 (3): 221–231.

El-sayed, S., Algarni, A. and Shaban, K. 2020. Effect of NPK nano-fertilizers and compost on soil fertility and root rot severity of soyabean plants caused by *Rhizoctonia solani*. *Plant Pathol. J.*,19: 140-150.

Erisman, J. W., Sutton, M. A., Galloway, J., Klimont, Z., and Winiwarter, W. 2008. How a century of ammonia synthesis changed the world. *Nat. Geosci.*, 1(10): 636-639.

Evans, J. R., & Clarke, V. C. (2019). The nitrogen cost of photosynthesis. *J. Experim. Botany*, *70*(1), 7-15.

Fageria, N. K. 2007. Yield physiology of paddy. *J. plant nutri.*, 30(6): 843-879.

FAOSTAT Food and Agriculture Data. Food and Agriculture Organization of the United Nations, Rome 2021. Published by FAO, Rome. 157 p.

Farnia, A. and Omidi, M. M. 2015. Effect of nano-zinc chelate and nano-biofertilizer on yield and yield components of maize *(Zea mays L.),* under water stress condition. *Indian J. Nat. Sci.*, 5(29): 4614-4624.

Fischer, G. (2009, June). World food and agriculture to 2030/50. In *Technical paper from the Expert Meeting on How to Feed the World in* (Vol. 2050, pp. 24-26).

Gagnon, B., Ziadi, N., and Grant, C. 2012. Urea fertilizer forms affect grain corn yield and nitrogen use efficiency. *Canadian J. Soil Sci.*, 92(2): 341-351.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. John Wiley and Sons, New York. Gopakkali, P., Channanaik, D., Rajanna, G.A., Sannathimmappa, H.G., Ramesha,

Good, A. G., and Beatty, P. H. 2011. Fertilizing nature: a tragedy of excess in the commons. *PLoS biology,* 9(8): e1001124.

Gunaratne, G. P., Kottegoda, N., Madusanka, N., Munaweera, I., Sandaruwan,C., Priyadarshana, W. M. G. I., Siriwardhana, A., Madhushanka, B. A.D., Rathnayake, U. A. and Karunaratne, V. 2016. Two new plant nutrient nanocomposites based on urea coated hydroxyapatite: Efficacy and plant uptake. *Indian J. Agric. Sci.*, 86(4): 494-499.

Halvorson, A.D. and Reule, C.A. 1999. Long-term nitrogen fertilization benefits soil carbon sequestration. *Better Crops*, 83(4): 16-20.

Hasegawa, T., Sawano, S., Goto, S., Konghakote, P., Polthanee, A., Ishigooka, Y., Kuwagata, T., Toritani, H. and Furuya, J. 2008. A model driven by crop water use and nitrogen supply for simulating changes in the regional yield of rain-fed lowland paddy in Northeast Thailand. *Paddy Water Environ.*, 6(1): 73-82.

Hati, K. M., Swarup, A., Mishra, B., Manna, M. C., Wanjari, R. H., Mandal, K. G., and Misra, A. K. 2008. Impact of long-term application of fertilizer, manure and lime under intensive cropping on physical properties and organic carbon content ofan Alfisol. *Geoderma*, 148(2): 173-179.

Havlin, J. L., Tisdale, S. L., Nelson, W. L., and Beaton, J. D. 2016. Soil fertility and fertilizers. Pearson Education India.

Heba, M., Abdelghany, H. and Omer, A. 2018. Effect of foliar application of Nano Chitosan NPK fertilizer on the chemical composition of wheat grains. *Egyp. J. Bot.*, 58(1): 87-95.

Jackson, M. L. 1971. Soil Chemical Analysis. Prentice Hall Pvt. Ltd. New Delhi India.498 p.

Jackson, M.L.1967. Soil Chemical Analysis. Prentice Hall of India (P) Ltd., New Delhi. pp. 183-192.

Jamil Mahmud, A. T. M., Shamsuddoha, M.D and Nazmul Haque. 2016. Effect of organic and inorganic fertilizer on the growth and yield of *paddy (Oryza sativa* L.*) Nat. Sci.*,14(2): 45-54.

Kaviani, B., Ghaziani, M.V.F. and Negahdar, N. 2016. Effect of application methods and different concentrations of biologic nano fertilizer, especial for ornamental plants on some morphological, physiological and proliferation traits and enhancingthe quality of buxus hyrcana pojark. *Int. J. Advan. Sci. Engine. Tech.*, 2(4): 92-105.

Khan, M. I., et al. 2020. Nitrogenous fertilizers: A review on its types, modes of action, and environmental impact. *J. Soil Sci. Plant Nutr.*, 20(3): 900-916.

Khatun, A. 2015. Urea deep placement in paddy as an option for increasing nitrogen use efficiency. *Open Access Library Journal*, 2(04): 1.

Khospeyak, S., Haghi, R.S., Ahmadiyan., A. 2016. The effect of application of nano organic fertilizer and nitrogen fertilizer on yield, yield components and essential oil content of fennel. Ira*. J. Field Crop Res.*, 14(4):775-787.

Kothari, S. K., Saha, S., and Mallick, P. 2023. Evaluation of foliar application of nano-fertilizers (nitrogen, zinc, copper) on growth and yield of paddy (*Oryza sativa* L.) in kharif season.*P. Inno. J.*, 12(6): 247-250.

Krishna, M., and Chhabra, V. 2023. Nano Nitrogen for Increasing yield of Maize (*Zea mays* L.). *Int J. and Cli. Change*, 13(8): 1511-1515.

Kumar, A., 2020. Role of nitrogen and its management in paddy cultivation. *Int. J. Current Microbiol.*

Kumar, D., Devakumar, C., Kumar, R., Das, A., Panneerselvam, P., and Shivay, Y. S. 2018. Effect of neem-oil coated prilled urea with varying thickness of neem-oil coating and nitrogen rates on productivity and nitrogen-use efficiency of lowland irrigated paddy under Indo-Gangetic plains. *J. plant nutr*, 33(13): 1939-1959.

Lahari, S., Hussain, S. A., Parameswari, Y. S., and Sharma, S. 2021. Grain yield and nutrient uptake of paddy as influenced by the nano forms of nitrogen and zinc. *Int. J. Environ. Clim. Change*, 11(7): 1-6.

Laxminarayana, K. 2006. Effect of integrated use of inorganic, biological and organic manures on paddy productivity and soil fertility in ultisols of Mizoram. *J. Indian Society Soil sci.*, 54(2): 213-220.

Ling, F. and Silberbush, M. 2002. Response of maize to foliar vs. soil application of nitrogen-phosphorus-potassium fertilizers. *J. Plant Nutr.*,25(11): 2333-2342.

Liu, R., and Lal, R.2015. Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. *Sci. Total Environ.*,514(1): 131–139.

Mala, R., Celsia, R., Sundram, Y.B. and Maheshwari, Y. 2017. Evaluation of nanostructured slow-release fertilizer on the soil fertility, yield and nutritional profile of *vigna radiate*. *Recent Pat.Nanotechnol.,*11(1): 1-10.

Maragatham, N., Martin, G. J. and Poongodi, T. 2010. Effect of nitrogen sources on aerobic paddy production under various paddy soil eco systems. *Proceedings of 19thWorld Congress of Soil Science, Soil Sol. Changing World***.** pp.13-16.

Marscher, A. 2012. Marschner's Mineral Nutrition of Higher Plants**. Edited by P. Marschner. Amsterdam, Netherlands: Elsevier/Academic Press (2011),** pp. 684, US $124.95. ISBN 978-0^{-1}2-384905-2. *Exp. Agric.*, *48*(2), 305-305.

Meena, A. K., Meena, R. N., Choudhary, K., Devedee, A. K., and Meena, K. 2021. Neem coated urea (NCU), an efficient nitrogen source for paddy cultivation: A Review. *Agric. Revi.*, 42(1): 111-115.

Meena, K. S., D.K., Pandey, P.C and Gangadhar N. 2008. Growth, yield, economics, andnitrogen use efficiency of transplanted paddy *(Oryza sativa* L.*)* as influenced by different nitrogen management practices through neem *(Azadirachta indica)* coatedurea. *Int. J. Chem. Stud.*, 6(3): 1388-1395.

Midde, S. K., Perumal, M. S., Murugan, G., Sudhagar, R., Mattepally, V. S., and Bada, M. R. 2021. Evaluation of Nano Urea on Growth and Yield Attributes of Paddy *(Oryza Sativa* L.*). Chem. Sci. Revi. Lett.*, 11(42): 211-214.

Moro, B. M., Nuhu, I. R., Ato, E. and Nathanial, B. 2015. Effect of nitrogen rates on the growth and yield of three paddy (*Oryza sativa* L.) varieties in rain-fed lowland in the forest agro-ecological zone of Ghana. *Int. J. Agri. Sci*. 5(7): 878-885.

Nirere, D., Mbaraka, S. R., Rucamumihigo, F.X., Murorunkwere, F., Musana, F.R. and Rukangantambara, H. 2021. Effect of foliar application of nitrogen-phosphorus-potassium fertilizers on nutrient uptake and protein content of maize. *Afr. J. Biotechnol.*, 20(12): 465-469.

Olsen, S. R. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.

Panse, V. G. and Sukhatme, P. V. 1962. Statistical methods for agricultural workers.2nd edn.I.C.A.R.

Paramesh, V., Kumar, P., Bhagat, T., Nath, A. J., Manohara, K. K., Das, B., and Prasad, P. V. 2023. Integrated Nutrient Management Enhances Yield, Improves Soil Quality, and Conserves Energy under the Lowland Paddy–Paddy Cropping System. *Agron.*, 13(6): 1557.

Peng, S., Sun, J., Ye, M., and Li, Y. 2016. Nitrogen can improve the rapid response of photosynthesis to changing irradiance in paddy *(Oryza sativa* L.*)* plants. *Sci. reports*, 6(1): 31305.

Pradhan, P. P., Dash, A. K., Panda, N., Samant, P. K., and Mishra, A. P. 2019. Effect of graded doses of neem coated urea on productivity of low land paddy. *ORYZA-Int. J. Paddy.*, 56(1): 68-74.

Pramanik, K. and Bera, A. K. 2013. Effect of seedling age and nitrogen fertilizer on growth, chlorophyll content, yield and economics of hybrid paddy *(Oryza sativa* L.*). Int. J. Agron. Plant Prod*., 4(1): 3489-3499.

Rahman, M. M., Soaug, A. A., Darwish, F. H. A., Golam, F., and Sofian-Azirun, M. 2011. Growth and nutrient uptake of maize plants as affected by elemental sulfur and nitrogen fertilizer in sandy calcareous soil. *African J. Biotec.*, 10(60): $12882^{-1}2889$.

Raj, S. K., Bindhu, J. S., and Girijadevi, L. 2014. Nitrogen availability and uptake as influenced by time of application and N sources in semi-dry paddy *(Oryza sativa). J. Crop Weed.*, 10(2): 295-302.

Rajonee, A.A., Nigar, F., Ahmed, S. and Imamul, H. 2016. Synthesis of nitrogen nano fertilizer and its efficacy. *Canadian J. Pure Appl. Sci.,* 10(2): 3913- 3919.

Ram, S., and Singh, V. S. 2022. Synthesized Nano composites of nano silica and reduced graphene with urea for nitrogen fertilizer capsule production and their evaluation. *Res. square.*

Ramesh, B., and Chhabra, V. 2023. Effect of Integrated Nutrient Management on Growth and Yield Parameters of Maize *(Zea mays.) (Poaceae). Int. J. Environ. Clim. Change,* 13(8): 874-880.

Rana, S.S., Sharma, S.K. and Kapoor, S. 2017. Effect of nitrogen, zinc and boron on nutrient concentration at maximum tillering of wheat. *Biomed. J. Sci. Tech. Res.,* 1(7): 1-5.

Ranjan, P., Kumar, B., Mala, A., Priyadarshi, S., Shri, A., Babu, L. and Kumar, B. 2023. Effect of foliar spray of Nano urea on yield and economics of paddy. *P. Inno. J.,* 12(1): 3030-3033.

Raun, W.R., Johnson, G.V., Phillips, S.B. and Westerman, R.L. 1998. Effect of long-term N fertilization on soil organic C and total N in continuous wheat under conventional tillage in Oklahoma. *Soil Tillage Res*., 47(3-4): 323-330.

Ravi, M. V., Rao, K. N., Vishwanath, J. and Umesh, M. R. 2023. Effect of Nano Nitrogen and Nano Zinc on Soil Fertility and Crop Productivity of Paddy-paddy Cropping System. *Int. J. Plant Soil Sci.,* 35(9): 99-110.

Reddy, J. A., Patnaik, M. C., Anjaiah, T., Sreelatha, D. and Reddy, P. 2023. Effect of Nano Nitrogen and Zinc Application on Dry Matter at Different Stages and Grain, Straw Yield of Paddy. *Int. J. Environ. Clim. Change*, 13(6): 404-411.

Rezig, F.A.M., Mubarak, A.R. and Ehadi, E.A. 2013. Impact of organic residues and mineral fertilizer application on soil–crop system: II soil attributes. *Arch.Agron. Soil Sci.,* 59(9): 1245-1261.

Saeed, M. F., Mihoub, A., Naeem, A., Amin, A. E. E. A. Z. and Jamal, A. 2017. Pigeon Manure Tea Improves Phosphorus Availability and Wheat Growth through Decreasing P Adsorption in a Calcareous Sandy Soil. *Comm. Soil Sci. Plant Anal.,* 53(19): 2596-2607.

Sahar, A. E., Awad, A. A. and Khaled, A. H. S. 2020. Effect of NPK nano-fertilizers and compost on soil fertility and root rot severity of soybean plants caused by *Rhizoctonia solani. Plant Pathol. J.*, 19(2): 140^{-1}50.

Saleem, I., Javid, S., Sial, R. A., Ehsan, S. and Ahmad, Z. A. 2013. Substitution of soil application of urea with foliar application to minimize the wheat yield losses. *Soil Environ.*, 32(2): 23-25.

Sannagoudra,H. M., Dasog, G. S.,Patil, P.L and Hanamaratti, N. G. 2012. Yield and nitrogen uptake by drill sown paddy as affected by different coatings of urea under two row spacings. *Karnataka J. Agric. Sci*., 25(4): 535-536.

Sarwar I., Gedam V.B., Gajbhiye P.N., Bhosale A.S. and Deshmukh D.P. 2021. Effect of nano nitrogen on productivity of sweet corn (*Zea mays* var. *Saccharata*) and Soil fertility in Sub-montane Zone of Maharashtra, India.*Biol. Int. J. Forum*,13(3): 246-250.

Selvarajh, G., Ch'ng, H. Y., Md Zain, N., Sannasi, P., and Mohammad Azmin, S. N. H. 2020. Improving soil nitrogen availability and paddy growth performance on a tropical acid soil via mixture of paddy husk and paddy straw biochars. *Applied Sciences*, 11(1): 108.

Sha, Z., Ma, X., Wang, J., Li, Y., Xu, W., Tang, A. and Liu, X. 2022. Model the Relationship of NH3 Emission with Attributing Factors from Paddy Fields in China: Ammonia Mitigation Potential Using a Urease Inhibitor. *Atmosphere*, 13(11): 1750.

Sharma, S. K., Sharma, P. K., Mandeewal, R. L., Sharma, V., Chaudhary, R., Pandey, R. and Gupta, S. 2022. Effect of foliar application of nano-urea under different nitrogen levels on growth and nutrient content of pearl millet *(Pennisetumglaucum L.). Int. J. Plant Soil Sci.*, 34(20): 149^{-1}55.

Shawer, S.S. and Abdalla, I.M. 2019. Effect of organic and nano nitrogen fertilization on soil properties, crop production and nutrients uptake by corn plant in sandy soil.*J. Biol. Chem. Environ. Sci.*, 14(1): 247-262.

Siddaram, K., Murali, M. K., Basavaraja, Krishna Murthy, N. and Manjunatha, B. N. 2010. Effect of nitrogen levels through organic sources on yield attributes, yield and economics of irrigated aerobic paddy. *Mysore J. Agric, Sci.,* 44(3): 485-489.

Singh, P. P., Priyam, A., Singh, J., and Gupta, N. 2023. Biologically synthesized urea-based nanomaterial shows enhanced agronomic benefits in maize and paddy crops during Kharif season. *Scientia Horticulturae*, 315(1): 111988.

Singh, R. N., Singh, S., Prasad, S. S., Singh, V. K., and Kumar, P. 2011. Effect of integrated nutrient management on soil fertility, nutrient uptake and yield of paddy-pea cropping system on an upland acid soil of Jharkhand. *J. Indian society Soil Sci.*, 59(2): 158^{-1}63.

Singh, S. 2020. Effect of nitrogen application through urea and Azolla on yield, nutrient uptake of paddy and soil acidity indices in acidic soil of Meghalaya. *J. Environ. Biol.*, 41(1): 139–146.

Snedecor, G. W. and Cochran, W. G. 1967. Statistical methods 5th ed. Oxford and IBH. Pub. Co. Eton Press, Culcutta.

Snyder, C. S., Bruulsema, T. W., Jensen, T. L., & Fixen, P. E. 2009. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. *Agric., Eco. Environ.*, *133*(3-4), 247-266.

Son, Tran Thi Ngoc., Tran Thi Anh Thu., Nguyen Ngoc Nam and Luu. 2013. Influenceof paddy straw treated by indigenous *Trichoderma* spp. on soil fertility, paddy grain yield and economic efficiency in the Mekong. *Delta. Omon paddy.*,19(1): 145–52.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in paddy soils. *Curr. Sci.*, 25(1): 259-260.

Subehia, S. K., Verma, S., & Sharma, S. P. 2005. Effect of long-term use of chemical fertilizers with and without organics on forms of soil acidity, phosphorus adsorption and crop yields in an acid soil. *J. Indian Soil Sci.*, *53*(3), 308-314.

Sunitha, A., Rajiv K, S., Krunal, C., Vinod, C., and Brijal Kiranbhai, S. 2010. Vermiculture technology: reviving the dreams of Sir Charles Darwin for scientific use of earthworms in sustainable development programs. *Tech. Investment, 2010*.

Tezera, M. 2021. The effect of nano fertilizer on teff yield and yield components in Ethiopia.*Int. J. Applied Agric. Sci*., **7**(5): 237-241.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., and Polasky, S. 2002. Agricultural sustainability and intensive production practices. *Nature,* 418(6898): 671-677.

Tiwari, H., Singh, A.K., Pandey, S.R. and Tiwari, A. 2020. Effect of integrated nutrient management practices on nutrient content and uptake by paddy (*Oryza sativa L.). J. Pharmacogn. Phytochem.,9*(6): 2131-2134.

Trenkel, T. 2021. *Slow-and Controlled-Release and Stabilized Fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture*. International Fertilizer Industry Association (IFA).

Tuyen, T.Q., Phung, C.V. and Tinh, T.K., 2006. Influence of long-term application of N, P, K fertilizer on soil pH, organic matter, CEC, exchangeable cations and some trace elements. *Omonpaddy*, 14(1): $144^{-1}48$.

Walkley, A. and Black, I.A. 1934. An examination of the degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci*., 37(1): 29-38.

Y.M and Veeresha. 2012. Economics and nutrient uptake of paddy (*Oryza sativa L.*) as influenced various levels of FYM and cattle urine application in Bhadra command area of Karnataka. *Crop Res.,*43 (1, 2, 3): 10-4.

Yadav, S. P., Singh, R. K. and Nayak, H. 2023. Assessment of Soil Physico-chemical Properties in Direct Seeded Paddy and Succeeding Lentil Crop under Integrated Nitrogen and Weed Management Practices in Eastern Uttar Pradesh, India. *Int. J. Plant Soil Sci.*, 35(14): 321-329.

Ye, T., Liu, B., Wang, X., Zhou, J., Liu, L., Tang, L. and Zhu, Y. 2022. Effects of water-nitrogen interactions on the fate of nitrogen fertilizer in a wheat-soil system. *European J. Agron.*, 136(1): 126507.

Yogananda, S. B and Reddy, V. C. 2004. Influence of urban compost and inorganic fertilizers nutrient use efficiency, economics and sustainability of paddy *(Oryza sativa)* production.*J. Ecobiology*.16(1): 327-331.

Yogendra, K., Tiwari, K. N., Tarunendu, S., Sain, N. K., Laxmi, S., Ramesh, V., Girish, C. S. and Ramesh, R. 2020. Nano fertilizers for enhancing nutrient use efficiency, crop productivity and economic returns in winter season crops of Rajasthan. *Ann. Plant Soil Res*., 22(4): 324-335.

Zaki, S.S. 2016. Effect of compost and nitrogen fertilization on yield and nutrients uptake of paddy crop under saline soil.*Mod. Chem. appl*., 4(1): 2-8.

http://www.fao.org/faostat FAOSTAT statistical database: FAO, 1997. Rome 9/1/2023.

Appendices

Meteorological data collected during crop growth period

Month	Date	No. of Week	Maximum Temperature	Minimum Temperature	R. Humidity (%) at 0712 AM	R. Humidity(%) at 1412 PM	Rainfall(mm)	Sun-shine hrs.	Wind Velocity(Km/hr)	Evap.(mm)
			Max.	Min.	0712(am)	1412(pm)				
June-July	29-01	26	33.9	26.6	83	65	80.6	4.7	8.1	6.0
July	02-08	27	34.4	27.6	79	60	20.6	6.2	2.9	5.7
July	9-15	28	34.4	27.4	83	64	92.8	7.6	3.5	6.8
July	16-22	29	33.7	27.1	82	66	41.2	7.0	4.6	6.1
July	23-29	30	32.2	26.3	81	70	14.6	6.7	5.6	5.4
July-Aug.	30-05	31	31.3	25.5	92	69	63.6	2.6	2.0	4.0
Aug	06-12	32	32.8	26.3	81	66	16.8	6.1	1.6	4.2
Aug	13-19	33	34.1	26.3	84	67	3.0	8.6	2.9	5.0
Aug	20-26	34	33.9	25.9	88	64	57.8	8.5	2.8	5.2
Aug-Sep	27-02	35	33.4	25.4	94	67	74.5	5.6	2.4	5.4
Sep	03-09	36	33.0	25.1	88	65	2.8	7.1	1.4	3.9
Sep	10-16	37	31.5	24.5	88	70	39.1	6.6	5.3	4.1
Sep	17-23	38	30.5	25.0	89	76	197.4	3.1	1.6	3.1
Sep-Oct	24-30	39	31.1	22.3	87	67	134.6	5.9	4.7	3.8
Oct	01-07	40	32.4	23.0	88	62	60.6	7.8	2.8	3.9
Oct	08-14	41	26.3	19.5	90	69	233.7	3.9	3.8	4.5
Oct	15-21	42	30.7	18.0	85	50	0.0	8.2	0.9	3.3
Oct	22-28	43	30.4	14.3	88	43	0.0	9.5	0.4	3.8
Oct-Nov	29-04	44	28.7	15.3	89	49	0.0	7.0	0.3	2.8

CURRICULUM VITAE

Name : Gurpreet Singh **Phone Number** :9756305907

Mailing Address : Rambhawan ward no.3, bazpur **Permanent Address :** P.O-Bheruchaubatta

, Uttarakhand District-Udham, Singh, Nagar

262401 Uttarakhand, 262401

E-mail **: managewithgurpreet@gmail.com**

Career objective: To work in the field of Soil Science

Educational Qualification:

S. No.	Examination Passed	Institution	Year	Percentage/CGPA
1.	M. Sc. Ag	GBPUA&T, Pantnagar, UK	2023	66.99%
2.	B. Sc. (Hons.) Agriculture	MJPRU,, Bareilly, Up	2021	60.08%
3.	Intermediate	Inter mediate College, Bazpur	2016	64.5%
4.	High School	Inter mediate College, Bazpur	2014	45.1%

Specialization: Major: Soil Science Minor: Nil

Thesis title: "COMPARISION OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLIED ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA"

Publication: Nil

Conference/Seminars/Workshops/Training Attented: 06

List of papers presented in conferences/seminar during degree programme: Nil

Software Skills: MS Word, MS Excel, MS Power Point, C++, SPSS (DMRT), OPSTAT

Professional Skills: Data presentation, Research and analytical skills

Professional Affiliations (Membership, etc.): Nil

Awards/Honours/ Achievements: Awards in several sports events

Place: **Pantnagar**

Date: **September, 2023** **(Gurpreet Singh)**

Name	:	Gurpreet Singh	**Id. No.**	:	58090
Sem. and year of admission	:	1^{st} Sem, 2021-22	**Degree**	:	M.Sc. (Ag)
			Department	:	Soil Science
Major	:	Soil Science			
Thesis title	:	**'COMPARISON OF DIFFERENT FORM OF NITROGENOUS FERTILIZERS APPLEID ON PADDY CROP (*Oryza sativa* L.) GROWN IN NORTH WESTERN PLAINS OF INDIA '**			
Page no.		84	**Advisor**	:	Dr. Swayam Prakash Gangwar

ABSTRACT

The field experiment was set up in randomized block design (RBD) with three replications and ten treatments at Norman E. Borlaug Crop Research Centre, G.B.P.U.A&T, Pantnagar during the spring season of 2022 to examine the effect of different nitrogenous fertilizers on paddy crop productivity. After wheat paddy is second most popular cereal crop. It is a highly exhaustive crop that necessitates a lot of nutrient for growth and development. Liquid fertilizers when compared to conventional chemical fertilizers allow for control nutrient release, reducing nutrient loss and increasing nutrient efficiency. In the current study, the different levels (i.e. 1.5, 2.0, 4.0 and 6.0 mL L^{-1} of water) of Urea ammonium nitrate (UAN) and Nano urea fertilizers were foliar sprayed on the paddy crop at the recommended time of nitrogen top dressing. Among all the treatments, there was non significant change in pH and EC of soil, while the treatment T_2 (GRD) shoed significant change in soil organic matter content after crop harvest. T_2 (GRD) treatment significantly increased the mineralizable nitrogen, Extractable phosphorus and exchangeable potassium among all the treatments in soil after crop harvest.

The treatment T_3 (basal dose of nitrogen through prilled urea as per recommendation and foliar application of UAN @ 2.0mL L^{-1} of water at recommended time of top dressing for N application) significantly increased yield and yield attributes among all the treatments followed by T_2 (GRD). The highest nitrogen, phosphorus and potassium content in grain and paddy straw was recorded with the treatment T_3 (basal dose of nitrogen through prilled urea as per recommendation and foliar application of UAN @ 2.0mL L^{-1} of water at recommended time of top dressing for N application) and the uptake of nitrogen, phosphorus and potassium by grain and starw and total uptake was also recorded highest with the same treatment.

Overall, the two foliar application of UAN @ 2.0 mL L^{-1} at the recommended time of nitrogen top dressing along with the recommended basal dose of nitrogen was better in term of yield and total uptake of nitrogen, phosphorus and potassium than the two foliar spray of Nano Urea @2.0 mL L^{-1} at the recommended time of nitrogen top dressing along with the recommended basal dose of nitrogen application

(Swayam Prakash Gangwar)
Advisor

(Gurpreet Singh)
Author

नाम : गुरप्रीत सिंह परिचयांक संख्या : 58090
सत्र एवं प्रवेश वर्ष : प्रथम, 2021–22 उपाधि : स्नात्कोत्तर (कृषि)
प्रमुख विषय : मृदा विज्ञान मुख्य : मृदा विज्ञान
शोध शीर्षक : "भारत के उत्तर–पश्चिमी मैदानों में उगाई जाने वाली धान की फसल (ओरिजा सैटिवा एस0) पर उपयोग किये जाने वाले नाइट्रोजन उर्वरकों के विभिन्न रूपों की तुलना"

पृष्ठ संख्या : 84 सलाहकार : डा0 स्वयं प्रकाश गंगवार

सारांश

धान की फसल उत्पादकता पर विभिन्न नाइट्रोजन उर्वरकों के प्रभाव की जांच करने के लिए 2022 के बसंत ऋतु के दौरान नॉर्मन ई. बोरलॉग फसल अनुसंधान केंद्र, जीबीपीयूए एंड टी, पंतनगर में तीन प्रतिकृति और दस उपचारों के साथ यादृच्छिक ब्लॉक डिजाइन (आरबीडी) में क्षेत्र प्रयोग स्थापित किया गया था। गेहूं के बाद धान दूसरी सबसे लोकप्रिय अनाज की फसल है। यह एक अत्यधिक संपूर्ण फसल है जिसे वृद्धि और विकास के लिए बहुत सारे पोषक तत्वों की आवश्यकता होती है। पारंपरिक रासायनिक उर्वरकों की तुलना में तरल उर्वरक पोषक तत्वों की रिहाई को नियंत्रित करने, पोषक तत्वों की हानि को कम करने और पोषक तत्वों की दक्षता बढ़ाने में मदद करते हैं। वर्तमान अध्ययन में, नाइट्रोजन टॉप ड्रेसिंग के अनुशंसित समय पर धान की फसल पर यूरिया अमोनियम नाइट्रेट (यूएएन) और नैनो यूरिया उर्वरकों के विभिन्न स्तरों (यानी 1.5, 2.0, 4.0 और 6.0 एमएल एल–1 पानी) का छिड़काव किया गया। सभी उपचारों के बीच, मिट्टी के पीएच और ईसी में कोई महत्वपूर्ण परिवर्तन नहीं हुआ, जबकि उपचार टी2 (जीआरडी) ने फसल की कटाई के बाद मिट्टी में कार्बनिक पदार्थ की मात्रा में महत्वपूर्ण परिवर्तन दिखाया। टी2 (जीआरडी) उपचार से फसल कटाई के बाद मिट्टी में सभी उपचारों के बीच खनिज योग्य नाइट्रोजन, निकालने योग्य फास्फोरस और विनिमेय पोटेशियम में उल्लेखनीय वृद्धि हुई।

उपचार टी3 (सिफारिश के अनुसार प्रिल्ड यूरिया के माध्यम से नाइट्रोजन की बेसल खुराक और एन अनुप्रयोग के लिए शीर्ष ड्रेसिंग के अनुशंसित समय पर 2.0 एमएल एल–1 पानी की दर से यूएएन का पर्ण अनुप्रयोग) ने टी2 के बाद किए गए सभी उपचारों के बीच उपज और उपज विशेषताओं में उल्लेखनीय वृद्धि की। (जीआरडी)। अनाज और धान के भूसे में नाइट्रोजन, फास्फोरस और पोटेशियम की उच्चतम मात्रा उपचार टी3 (सिफारिश के अनुसार प्रिल्ड यूरिया के माध्यम से नाइट्रोजन की बेसल खुराक और शीर्ष ड्रेसिंग के अनुशंसित समय पर 2.0 एमएल एल–1 पानी की दर से यूएएन के पत्ते पर एन अनुप्रयोग के साथ दर्ज की गई थी।) और अनाज और भूसे द्वारा नाइट्रोजन, फास्फोरस और पोटेशियम का ग्रहण और कुल ग्रहण भी उसी उपचार के साथ उच्चतम दर्ज किया गया था।

कुल मिलाकर, नाइट्रोजन की अनुशंसित बेसल खुराक के साथ नाइट्रोजन टॉप ड्रेसिंग के अनुशंसित समय पर 2.0 एमएल एल–1 की दर से यूएएन का दो बार उपयोग, दो पत्तियों वाले स्प्रे की तुलना में उपज और नाइट्रोजन, फास्फोरस और पोटेशियम के कुल सेवन के मामले में बेहतर था। नाइट्रोजन टॉप ड्रेसिंग के अनुशंसित समय पर नाइट्रोजन अनुप्रयोग की अनुशंसित बेसल खुराक के साथ नैनो यूरिया / 2.0 एमएल प्रति लीटर।

(स्वयं प्रकाश गंगवार)
सलाहकार

(गुरप्रीत सिंह)
लेखक