EVALUATION OF TIMING OF NITROGEN APPLICATION IN MAIZE (*Zea mays* L.) GROWN ON COARSE LOAMY TYPIC HAPLUSTEPT SOIL OF PUNJAB

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Soil Science

By

Himanshu Sekhar Behera

Registration Number: 12014367

Supervised By

Dr. Raj Kumar

Professor

Department of Soil Science and Agricultural Chemistry

Lovely Professional University, Punjab

LOVELY PROFESSIONAL UNIVERSITY, PUNJAB
2025

DECLARATION

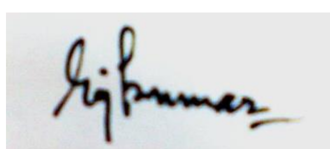
I, hereby declared that the presented work in the thesis entitled "Evaluation of timing of nitrogen application in maize (*Zea mays* L.) grown on coarse loamy Typic Haplustept soil of Punjab" in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of **Dr Raj Kumar**, working as Professor, in the Department of Soil Science and Agricultural Chemistry of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

(Signature of Scholar)

Himanshu Sekhar Behera
Registration No.:12014367
Department of Soil Science and Agricultural Chemistry,
School of Agriculture, Lovely Professional University, Punjab, India

CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled “Evaluation of timing of nitrogen application in maize (*Zea mays L*.) grown on coarse loamy Typic Haplustept soil of Punjab” submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, is a research work carried out by **Himanshu Sekhar Behera, 12014367**, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.



(Signature of Supervisor)

Dr. Raj Kumar (30324)
Designation: Professor
Department of Soil Science and Agricultural Chemistry,
School of Agriculture, Lovely Professional University, Punjab, India

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(Signature of Supervisor)

Date: 06-03-2025

(Signature of External Examiner)

Date: 05.03.2025
(Dr. G.S. Sidhu)
Principal Scientist & Head
R.C. NBSS&LUP-ICAR, N.Del

(Signature of HOD)

Date: 06/03/2025

(Signature of HOS)

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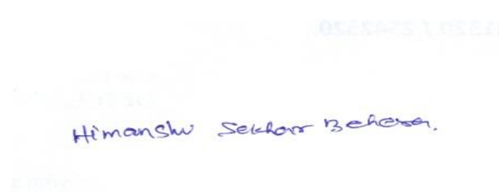

Place: Phagwara (Punjab) **Mr. Himanshu Sekhar Behera**
Date: 05-03-2025 **Regd. No – 12014367**

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Name of student	: Himanshu Sekhar Behera
Registration Number	: 12014367
Name of supervisor	: Dr. Raj Kumar
University	: Lovely Professional University, Phagwara Punjab

ABSTRACT

An investigation was conducted to evaluate the timing of nitrogen application, combined application of neem-coated urea and nano-urea with organic manures in maize (*Zea mays L.*) cultivated in Punjab's coarse-loamy Typic Haplustept soil. The study was carried out at Lovely Professional University's Soil Science research farm in Punjab during the *kharif* seasons of 2022 and 2023.The field investigation was conducted in randomized block design and consisted of sixteen treatments in experiment one and two treatments in experiment two. Both the experiments were conducted with three replications. Treatments comprised of the use of farm yard manure, vermi-compost, nano-urea and neem coated urea in different doses and timing of application. Plant height data indicated four clear cut stages of maize growth at 42, 56, 65 and 89 days of sowing. Plant growth stage at 42 days near to the knee-high stage and 65 days stage near to the tasseling stage of the maize match with the already recommended dose of nitrogen fertilizer. Plant height growth stages of maize at 56 and 89 days needs consideration by further splitting of nitrogen fertilizer application for improving maize productivity and increasing fertilizer urea efficiency. Application of nano-urea did not show any significant advantages as compared to recommended dose of fertilizer nitrogen application**.** Integrated use of vermi-compost @2.5t ha^{-1} along with the RDF application has an added advantage over all other treatments. However, further field trials in different agro-ecological zones are necessary for any final recommendation to the farmers.

Keyword: Nano-urea, vermi-compost, maize, coarse loamy soil

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List of Symbols and Abbreviations

%	:	Per cent
@	:	At the rate of
0C	:	Degree Celsius
CD (P=0.05%)	:	Critical Difference at 5 per cent level
cm	:	Centimetre
DAT	:	Days after transplanting
dS m^{-1}	:	Deci Siemen per metre
EC	:	Electrical conductivity
et al.	:	and others people
FYM	:	Farmyard manure
g	:	Gram
ha^{-1}	:	Per hectare
i.e.	:	That is
K	:	Potassium
K_2O	:	Potassium oxide
kg	:	Kilogram
kg ha^{-1}	:	Kilogram per hectare
m	:	Metre
m^2	:	Square metre
ml	:	Millilitre
N	:	Nitrogen
NS	:	Non-significant
P	:	Phosphorus
P_2O_5	:	Phosphorus penta oxide
pH	:	Potential of hydrogen ion concentration
ppm	:	Parts per million
RBD	:	Randomized Block Design
RDF	:	Recommended dose of fertilizers
RH	:	Relative Humidity
SEm±	:	Standard Error of mean

t	:	Tonne
T	:	Treatment
Viz.,	:	Namely

CHAPTER - I

INTRODUCTION

Introduction

India's third-most important cereal crop is maize (*Zea mays L.*). It is susceptible to flooding. Reduced yields are the effect of water-logging in tropical and subtropical climates. (Rathore *et al.,* 1998). In South Asia, water-logging impacts typically affect maize yield of more than 18 per cent (Zaidi *et al.,* 2001), However, reports from India indicate that average losses in maize output can reach 30 per cent. The stages of the second to seventh leaves are particularly impacted when there are waterlogging (Zhang *et al.*, 2013). Maize belongs to family Poaceae. About 7000 years it originated in Mexico (Mangeisdorf *et al.,* 1964). There are several applications for this crop. These consist of fodder, starch, and nourishment for humans. Different agroclimatic conditions result in varying maturation periods for different varieties of maize (Purseglove, 1972).

Because of its photo-thermo-insensitive qualities, maize is grown all year round. Of all the grains, its genetic output is the highest. Given that a four-carbon molecule is the initial byproduct of carbon fixation, it is incredibly effective at transforming solar energy into dry matter. Over 85 per cent of maize production is consumed as human food. Maize grain has ten per cent protein, four per cent oil and two to three per cent crude fibre. Maize flour and grains are used for preparing many food dishes including chapattis. Green maize plants are source of tender fodder. One way to cook with starch is to crack the corn. Dextrose, sorbitol, starch, glucose, dextrin, high fructose syrup, germ oil, germ meal, maltose, fiber, and gluten products are among the many goods derived from it. These goods are used in a variety of industries, including edible oils, organic chemicals, medicines, textiles, papers, and cosmetics. It is the most adaptable cereal crop to a wide range of agro-climates and has the potential for great yields (Singh *et al.*, 2013).

The yield of maize is influenced by soil, climate, cultivar, and cultural practices. Since maize was first cultivated, researchers have sought to link these processes in order to maximize harvests. The competition from other cereals and marketable crops limits the potential to expand the area planted to maize. So, enhancement of productivity by various management interventions is the only alternative. Insufficient irrigation and low plant population are the yield limiting issues of maize in many areas (Reddy and Devi, 2017). It is grown in a variety of climates, including the dry region of Chitradurga, Karnataka, and the warm, moist plateau of

Chindwara, Madhya Pradesh. When cultivated in rainfed circumstances, crops are sown at the beginning of the monsoon season. Maize is sown from the first of June to the first of July, depending on when the monsoon arrives. Rainy season crops yield less maize than winter-sown crops. Corn that is sown in the winter loves a clear sky and cool temperatures. Productivity increases as a result of longer growing seasons, lower disease and pest infestation rates, and more solar radiation capture (Joshi *et al.*, 2005). Maize crop possesses great genetic diversity and adaptability in varied agro ecological regions (Ferdu *et al.*, 2002). The variation in crop growing environment is responsible for large variation in biomass production. Information of plant and environment interactions is necessary for increasing crop yield.

Crop phenological growth is influenced by variations in weather during the growing season. Understanding various growth and developmental processes is based on a thorough examination of phenological phenomena. Changes in the microclimate caused by crop growth have a direct impact on how resources are used (Hugar and Halikatti, 2015). One of the biggest constraints on corn yield is nitrogen (Meisinger, 1984). Surface and ground water contamination can result from applying too much nitrogen. A lower grain yield and therefore a lower profit can be the consequence of applying nitrogen fertilizer insufficiently. Higher plants use several types of chlorophyll as their main photosynthetic pigment. Leaf nitrogen concentration, nitrogen fertilizer rate and yield are correlated with chlorophyll content (Lohry and Schepers, 1988). Profitable corn production systems require inputs of large quantities of nitrogen. Excess nitrogen fertilizer may move into surface water and groundwater leading to eutrophication of lakes and streams (Wood *et al.*, 1984).

To reduce nitrogen losses to the environment, farmers need to equilibrate the competing goals of supplying enough nitrogen to their crop and risk to water quality. Economic penalties of reduced yields from supplying inadequate nitrogen are substantial. For many dairies and beef animals, maize plant as a whole is used as forage. The crop is comparatively highly nutritious, tasty, and grows quickly, producing a high amount of dry matter. Maize's dry matter yield is influenced by a variety of environmental and genetic factors. Two important environmental elements are temperature and available soil moisture. These in turn affect the growth of the leaf area and the dry matter production (Dwyer and Stewart, 1986). For the production of fodder, the leaf area and canopy cover are crucial growth characteristics. For grain production, the optimal leaf area index is significantly lower than the maximum dry matter yield. More dry matter accumulated mostly on the stem when the leaf area index exceeded five (Goldsworthy *et al.*, 1974). Therefore, increasing the amount of leaf area per plant will boost leaf production. Forage yield and quality are influenced, either directly or indirectly, by agronomic inputs and cultural methods.

The area used for maize cultivation worldwide almost doubled starting in 1961, rising from 106 M ha^{-1} to the current 197 M ha^{-1}. Around the world, maize is expected to surpass wheat by 2030, when the former remains essentially stationary (Erenstein *et al.*, 2021). Asia and the Americas account for nearly one third of the world's total area of maize. Africa comes in second with five, and Europe comes in third with a tenth. Additionally, there are discernible regional variations in corn yields. Half of the world's maize production is attributed to the Americas, both north and south. In Asia, a third comes after it. Africa accounts for 74.4 per cent and Europe for 11 per cent of the remaining portion. Every region on the continent has significant variation.

North America, Central America, and South America make up the Americas' maize-growing regions. East Asia accounts for two thirds of Asia's maize crop (primarily China and South-East Asia). Concerns about the world's maize markets have been raised by the USA's growing bioethanol industry. This could lead to lower exports and higher prices for corn. These might raise the price of food globally. Moreover, it might intensify detrimental environmental effects like more logging and expand the area planted to maize (Ranum *et al.,* 2014; Wallington *et al.,* 2012; Wu *et al.,* 2013). The diversity of maize foodstuffs has some insinuations for its commoditization and trade.

In India, maize is produced and fertilized on an area of 8.5 m ha^{-1}, yielding 21.5 t ha^{-1} and 2.52 t ha^{-1}, respectively. It has an area of 1.8 m ha^{-1} in Uttar Pradesh and produces and is productive at 4.8 t ha^{-1} and 1.4 t ha^{-1}, respectively (Anonymous 2015). One-third of the total area and production of maize is grown in the north Indian states of Himachal Pradesh, Jammu & Kashmir, Punjab, Uttar Pradesh, Rajasthan, Madhya Pradesh, and Bihar. Karnataka and Andhra Pradesh are the two states in south India that produce most of the maize. Maize is cultivated on the broader range of latitudes and altitudes. It is cultivated in a variety of soil types in different agro-climatic regions that range from wet to semi-arid, at temperatures both at hot or cold.

A vital nutrient, nitrogen enhances soil production and crops' ability to absorb nutrients (Kiros *et al.,* 2007). Different nitrogen fertilizers affect maize production in different ways. When nitrogen was applied in splits as opposed to basal application, grain output was higher (Abdelsalam *et al.*, 2019). By lengthening the real grain-filling period, the proper nitrogen fertilizer rate and timing could raise grain weight (Hammad *et al., 2*022).

Experts estimate that 2.50 lakh acres, were planted with spring corn in 2022. According to data provided by the Punjab Mandi Board, the state had received 32 lakh quintals of spring maize as on June 30, 2023. This was fifty percent more than the 21 lakh quintals that were available for purchase during the same period in 2022. Punjab primarily encourages the use of kharif season maize in place of paddy. In the potato belt of the Doaba region, which includes the districts of Hoshiarpur, Jalandhar, and Kapurthala, spring maize is usually sown. The state's districts of Shaheed Bhagat Singh Nagar, Hoshiarpur, Roopnagar, Amritsar, Gurdaspur, and Doaba are the main growing areas for the main season maize harvest. Maize was traditionally grown as a *kharif* crop. With the introduction of new cultivars, its cultivation during the *rabi* season has now begun in several places as well. The Doaba region of the state can now successfully cultivate spring crops. When a maze is fed in a balanced way, other nutrients are used more effectively, which reduces the need for fertilizers (El-Fouly *et al.,* 1990).

Neem coating of urea is considered as imperative strategy to improve efficiency of nitrogen use and reduce nitrogen losses (Rehman *et al.,* 2021). Neem coated urea has been reported to increase the growth, yield, uptake of applied nitrogen in rice, wheat and maize. Mean increases in grain yield by replacing with neem coated urea has been reported to be 5 to 6 per cent (Singh *et al.,* 2019*)*. The government is advising urea companies to produce only-coated urea. It has become important to revisit these generalized recommendations. Modifications are necessary in blanket recommendations on account this new type of urea availability in the market. Neem oil, which is used for coating the urea granules, has the nitrification inhibition properties (Schmutterer, 1990). Quality assurance of the neem cake coated urea is another tricky issue. Neem oil as a substitute to neem cake has been used to coat urea granules to retard nitrification of NH_4^+ nitrogen in the soil. The neem oil covering of urea has some advantages as only 0.5 kg neem oil is required per tonne of urea. The nitrogen content in neem coated urea satisfies the Fertilizer Control Order standards (Prasad *et al.,* 2002)

The only nanofertilizer available is nano-urea from Indian Farmers Fertilizer Cooperative Limited (IFFCO). It is incorporated into the Fertilizer Control Order and approved by the Government of India (GOI). IFFCO is the one who created and patented it. The farmers have recommended applying IFFCO sagarika and nano-urea fertilizers via foliar spray as an alternative to soil application of fertilizers. It is highly recommended for improving plant growth characteristics and productivity. In maize, it recorded the highest benefit to cost ratio. 100 kg of urea are replaced by one litre of IFFCO nano-urea. Therefore, the government's financial burden for producing direct fertilizers may be lessened by the usage of nano fertilizer. It may improve the socio-economic status of the farming community by plummeting production cost *(*Ajithkumar *et al.*,2021). It has been tested in 11,000 locations and on over 90 crops. The trials were conducted in association with research organizations, state agriculture institutions, progressive Indian farmers, and ICAR-KVKs. When sprayed on leaves, nano urea readily penetrates the stomata and is taken up by the plant cells. It moves from source to sink through the phloem cells with ease. Unused nitrogen is stored in plant cell vacuoles. It is gradually released to allow for the plant's healthy growth and development. Because nano urea is so small (20–50 nm), it is more than 80% more available to plants. Maintaining soil fertility and providing plants with the right amount of nutrients is the goal of integrated nutrient management, or INM. INM considerably increased maize production and yield characteristics (Almaz *et al.*, 2021).The consumption of urea fertilizers is more than 50 per cent of world nitrogen fertilizer usage. Due to high nitrogen concentration and low costs, urea is an important high analysis fertiliser for nitrogen translocation and recycling in plants (Arnon *et al.* 1939). Urea fertilizers have 46 per cent nitrogen. It is commonly used during the vegetative stage of plants. Urea fertilizer application rate for maize depends upon the stage of growth of the plant s (Arnon *et al.*,1939). Burying of urea fertilizer in the soil makes it more effective for plants. It also prevents evaporation and leaching. Urea is the fertilizer with the highest content of nitrogen in the world (Liu LH *et al.*, 2003).

The rate and timing of nitrogen fertilizer application might affect the grain yield of maize (Zea mays L.). Applications of different rates of nitrogen, both single and divided, for maize grown on loamy sand under irrigation were studied by Davies *et al.*, (2020). Timing of nitrogen fertilizer application has been shown to have a varied, often site-specific effect on maize grain production. When nitrogen was applied to maize at the two leaf-collar stage or equally divided between the two and six or twelve leaf development phases, there was no discernible difference in grain output in Iowa (Jaynes *et al.,* 2013). When maize biomass reaches around one-fourth of its maximum, about half of the total nitrogen intake by the crop is completed (Abendroth *et al.,* 2011). A study conducted in a greenhouse revealed that soil type can also have an impact on maize's uptake of nitrogen. When comparing silt loam soil to fine sand, the nitrogen concentration was consistently higher (Kaiser *et al.,* 2013). To maximize maize grain yield and raise nitrogen use effectiveness across a variety of soil types and growth situations, there is an obvious requirement for site-specific nitrogen fertilizer management. The economic benefit of using fragmented nitrogen use will further assist growers to sustain high maize yields while minimizing the harmful effects of nitrogen fertilizer on the environment (Davies et al.*,* 2020).

A method for preserving agricultural output and safeguarding the environment for future generations is called integrated nutrient management. Using soil fertility management techniques that optimize the use of fertilizers and organic resources to increase crop productivity could be a good definition for it (Chen *et al.,* 2004). Soil organic matter preservation can be aided by applying organic manure. They also contribute to a healthy physical environment by increasing soil aeration. Furthermore, in a dual cropping system, the usage of organic manures leaves a significant amount of leftover nutrients for the crops that follow. Utilizing crop residues on farms increases crop productivity and soil organic matter. However, to their low nutrient content, a significant amount of organic sources are required. In certain regions of the world, the combined use of several organic and inorganic sources yields greater results. This idea preserves and supports soil fertility in addition to raising crop output. It is also a financially sensible approach for developing countries. Present research investigation entitled 'Evaluation of timing of nitrogen application in maize (*Zea mays L.*) grown on coarse loamy Typic Haplustept soil of Punjab.' has been conducted with the following objectives:

1. To study the uptake of nitrogen in maize plants under different fertilizer treatments

2. To compare the performance of neem coated urea and nano-urea in maize

3. To study the effect of integrated nutrient management on growth and yield of maize

4. To evaluate the economics of different fertilizer treatments in maize

CHAPTER - II

REVIEW OF LITERATURE

Review of literature

In an integrated plant nutrient system, fertilizer doses are adjusted for the nutrients provided by the soil and organic sources. In this chapter research work related to current investigation on ‘Evaluation of timing of nitrogen application in maize (*Zea mays L.*) grown on coarse loamy Typic Haplustept soil of Punjab’ is presented under the following headings:

2.1 Importance of maize crop as a staple food

2.2 Importance of maize at the international level

2.3 Importance of maize crop at national level

2.4 Importance of maize crop at state (Punjab) level

2.5 Research on growth curve in maize

2.6 Importance of nitrogen application timing in maize crop

2.7 Use of neem coated urea and IFFCO nano urea in maize crop

2.8 Role of vermi-compost in maize crop

2.9 Integrated nutrient management studies in maize

2.10 Cost-benefit ratio studies on integrated nutrient management in maize

2.1 Importance of maize crop as a staple food

Alexander (1987) reported that the numerous uses of maize as a supply of food for both people and animals account for a substantial portion of the success of crop. In addition to being eaten straight off the cob, kernels can also be dried, fried, roasted, cooked, crushed, and fermented to make gruel and breads, porridge, cakes, and alcoholic drinks. It is used as food thickeners, sweeteners, oils, and non-consumables through additional processing. Approximately 15 percent of the world's protein and 20 percent of its calories come from maize, which is a staple diet for over 200 million people globally. (Brown *et al.,* 1988). This figure is projected to increase as the global population gets closer to 8 billion people in 2025. (Lutz *et al.,* 2001), USDA (2009).

Nuss and Tanumihardjo (2010) stated that despite the fact that maize kernels contain numerous macro and micronutrients important for meeting human metabolic demands, the levels of several key nutrients are unbalanced or insufficient for consumers who rely on maize as a primary food source. As an illustration, maize kernels are lacking in iron, iodine, ascorbic acid, vitamin C, B vitamins, tryptophan, lysine, and other necessary amino acids. A significant section of the global population prefers white maize, which lacks carotenoids. Though corn is an essential food, malnutrition still exists in underdeveloped, impoverished, and primarily rural areas, especially those in Southeast Asia, Latin America, and sub-Saharan Africa. The health of many people could be considerably improved by exogenous and endogenous maize fortification, two food-based techniques for combating malnutrition.

Kurilich and Juvik (1999) discovered that typical yellow maize is largely vitamin-free, with the significant exception of vitamin B-12. The two main fat-soluble vitamins present in maize kernels are vitamins A and E, which are both tocopherols, provitamin A carotenoids. Along with their many other uses, carotenoids and tocopherols both serve as vital antioxidants.

Growing on more than 4% of the net area sown in the nation. In India, maize is a popular cereal. Since gaining independence, India's maize production has varied greatly. In India, maize is cultivated all year round, but it is primarily a kharif crop, taking up 85% of the land during that time (AICRP 2007)

According to Chaudhary *et al.* (2013) maize is a source of oil that is highly praised for ingestion by people because it lowers blood cholesterol levels. Maize, which is consumed in many forms across the globe has generated a variety of value-added goods as well as fermented foods.

According to Graham (1990), the decreased levels of tryptophan and lysine, two important amino acids, in grain proteins, including regular maize, results in poor nutritional value and can cause growth retardation, protein energy malnutrition, anaemia, pellagra, and damage from free radicals, among other negative effects. Consequently, those who are concerned about their health are using less and less maize as food.

Mehta and Dias (1999) said Animal feed is typically made from maize. It is thoroughly processed to create a wide range of goods, including tortillas, snacks, starches, grits, cornmeal, and morning cereals. Chapatis, or flatbreads, are made with maize flour and are mostly consumed in a few northern Indian regions.

Department of Agriculture, South Africa (2003) reported that Margarine, salad dressings, and cooking oils are created from embryonic oil. Feed for animals and poultry uses the protein, hulls, and soluble portion of the maize kernel.

2.2 Importance of maize at the international level

Fanzo *et al.* (2021) reported that a growing curiosity about the results of the agri-food chain, including food and nutrition, resilience and sustainability of the environment, livelihoods and inclusivity, and the possibility to enhance them through the transformation of food systems, is also reflected in maize. Thus, agri-food systems are essential to achieving the 17 Sustainable Development Goals of the 2030 Agenda for Sustainable Development.

Erenstein *et al.* (2022) found that Maize has become more and more important in the world's food systems. The past few decades have seen a dramatic growth when growing maize worldwide, driven by growing demand as well as a confluence of yield increases, area expansion, and technical advancements. In terms of volume produced, maize leads all cereals and is expected to overtake all other crops as the most frequently farmed and sold crop in the ensuing ten years. In addition to its many non-food uses, this adaptable multipurpose crop is widely used as feed worldwide. It is especially important in Latin America and sub-Saharan Africa as a food crop.

According to Awika (2011) and Kennett *et al*. (2020), the top three staple grains grown worldwide are rice, wheat, and maize; these crops are grown on about 200 million hectares apiece. Southern Mexico was the place where maize was domesticated around 9,000 years ago.

FAO *et al.* (2021) reported the Since 1961, the world's maize yields have increased from 2 t ha to 5.8 t ha^{-1}, almost tripling. Since 1961, maize production has increased five times due to these significant improvements. In 165 nations spread over the Americas, Asia, Europe, and Africa, maize is grown in both developed and rising economies. Maize also exhibits notable yield variations between areas, with the Americas and Asia accounting for more than a third of total yield, Africa following with a fifth Europe coming in at number 10. Thus, the Americas account for half of the world's maize production, with Asia accounting for a third at 32% and Europe and Africa accounting for the remaining 11% and 7%, respectively.

Bellon *et al.* (2005) reported that there are several rainfed maize mega-settings that are distinguished based on the maximum rainfall and temperature throughout the growth season. This is due to the variety of the agro-ecological conditions under which maize is grown, for example, going from wet to dry or from low to mid-altitude to high-altitude. In 2020, there will be 216 million maize farms worldwide, or one-third of all farms. as reported by Erenstein *et al.*, (2021)

Mottet *et al.* (2017) stated that the crop maize is a multipurpose and adaptable one. Worldwide, about 56 per cent of maize grain is used to produce feed, 5 per cent is used for non-food uses, and 13% is used to produce food. These utilization categories, when taken at face value, undervalue maize's contribution to human food and nourishment. The reported food use covers the sole direct path to consuming dried maize grain in processed or unprocessed food products. An indirect route for consumption is created when a sizable portion of the maize grain used for feed is utilized to make animal meals.

Kumar and Singh (2019) reported that the aggregate quantity of maize used has increased noticeably more quickly than the amount of maize food consumed per person, partly due to higher population growth in Asia and Africa. By 2050, 9.7 billion people will live on the earth, up from the current 7.7 billion. This is a 2 billion increase in population. By 2050, If the annual per capita consumption of maize remains constant, there might be a 37 million metric tons increase in the amount of maize produced for food each year. Moreover, the rapid rise in the total amount of maize utilized is a sign of its use as a feed crop as well as its role in some countries as an industrial and energy crop. Five percent of the world's total dietary calories and proteins come from eating maize grains.

According to Graham (1990), The main staple crops consumed by people in Asia are maize, rice, and wheat; however, these foods fall short of meeting daily nutritional demands and are deficient in vital vitamins like vitamin A and minerals like iron and zinc. The undernutrition of approximately 200 million children under five years old with respect to protein is a major national concern. Maize might be essential for the world community in this sense.

Tripathi (2011) revealed that Most of the world's maize growing areas are found in temperate climates. The United States, China, Brazil, and Mexico contribute for seventy percent of global production. India accounts for two percent of global maize production and five percent of the crop's land.

2.3 Importance of maize crop at national level

Kopsell *et al.* (2009) and Shah (2016) described that after rice and wheat, the third-most major food grain is maize. Just 28 per cent of the maize that is produced is used for human use; the remaining 11 per cent is used in India as seed, 12 per cent is used in the wet milling sector (which produces starch and oil, for example), 48 per cent is used for animal feed, and 11 per cent is used for poultry feed.

According to Milind and Isha (2013), the states of Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Haryana, Maharashtra, Andhra Pradesh, Himachal Pradesh, West Bengal, Karnataka, and Jammu & Kashmir collectively produce more than 95 per cent of the country's maize.

According to Shah *et al.* (2016), maize is a nutritious diet that many Indians prefer because it is relatively light in comparison to other meals and contains minerals and phyto-chemicals. It is consumed for breakfast by 83 per cent of Indian youngsters (in the form of cornflakes, corn powder, etc.). Additionally, doctors encourage patients to use it to strengthen their immune systems as a prophylactic strategy.

Kumar *et al.* (2013) outlined the productivity and production of maize in India has seen significant changes during the last few years. The cultivation of maize has changed dramatically since single cross hybrids were used. Thus, its output has shown the highest yearly growth rate of 6.4% among food crops, above the 4% growth rate for agriculture overall and 4.7 per cent for maize specifically, which was the aim set by the Planning Commission, Government of India. Eight states in the nation i.e. Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, and Tamil Nadu contribute more than three-fourths of the land utilized for maize cultivation. The crop has become more and more well-known in these states during the last 20 years, but to varied degrees, especially as a feed crop.

According to Sacks *et al.* (2010) Twenty five per cent of India's maize is cultivated in the Rabi season and 75 per cent is grown in the Kharif season. Rabi maize is now planted on 1.25 million hectares of land, but because of the yield advantage, it is growing more quickly than it does in the Kharif season. It was fascinating to see that, although there had been very little rainfall in many areas throughout the kharif season, the area under many crops had decreased. However, this contraction was far smaller for the maize crop than for other coarse cereals or pulses. The crop grows well on all types of soils, including lateritic, black, red, and alluvium-derived soils, as well as semi-arid, humid, hot, dry, and hot damp conditions. pH of soil within the range

Jansen *et al*. (1990) noted that while a significant portion of the variability in the adoption of contemporary varieties of maize in northern India might be explained by infrastructure variables such as the use of irrigation, access to markets, highways, and fertilizers, as well as population density per unit area.

2.4 Importance of maize crop at state (Punjab) level

The Department of Agriculture Punjab (2013) reported that Because of growing irrigation systems and guaranteed supplies of wheat and rice, the state's maize area has decreased over time. While the state's principal corn-growing districts have all showed a rising trend in yield, during the preceding ten years, the districts with the biggest yield increases were Nawanshahr and Roopnagar. About 42 percent of the state's corn crop is seeing negative growth and little instability. Hoshiarpur district, which is home to 47% of the state's maize acreage, has demonstrated low instability and sluggish growth. Hoshiarpur, Roopnagar, and Nawan Shahar districts accounted for almost 74 percent of the total maize production; throughout the preceding ten years, the yields in these districts had experienced medium growth and volatility.

Gulati (2021) stated in Punjab, maize is currently grown on 0.13 million hectares, or 1.65 percent of the general mixing aptitude. Connecting the processing sector for food and feed (particularly poultry) can increase the area under maize cultivation. There are several applications for maize, and these applications ought to be investigated in order to create demand for a range of maize-based products.

According to Yin *et al.* (2011) To increase maize output in the state, another Programme called the staff scheme or permanent maize scheme is being introduced. Hoshiarpur, Roopnagar, Shaheed Bhagat, Singh Nagar, Amritsar, Gurdaspur, Jalandhar, Kapurthala, Patiala, Ludhiana, Sas nagar, and Fatehgarh Sahib are the state districts that plant maize crops the most.

. While maize was traditionally planted as a kharif crop, new cultivars have allowed some districts to start planting during the Rabi season. Spring crops can now be grown in Kapurthala, Jalandhar, Shaheed Bhagat, Singh Nagar, and Hoshiarpur. The main focus was on increasing the popularity of PAU's high-yielding maize cultivars. which are listed as follows: Short-term varieties: PMH-2, JH-3459, Punjab Sathi-1, long-term varieties: PMH-1, F-9572-A, Parbhat, Kesari, fodder varieties: JH-1006,

Murdia *et al.* (2016) reported that in the state's strategy for crop diversification, maize can be quite significant. It is utilized in the production of cornflakes, starch, and glucose as well as in the feed for animals and poultry. It is also consumed by humans as sustenance during the winter: Among all major grains, including wheat and rice, maize has experienced the fastest growth rate over the past ten years due to the combination of growing consumer health consciousness, newly emerging eating habits, and increased industrial needs.

2.5 Research on growth curve in maize

Plant development is the series of ontogenetic events that involve both growth and differentiation and result in changes to shape and function. On the other hand, growth is the irreversible change in a plant's cell or organ's size. Landsberg (1977). Plant development depends on micronutrients. Micronutrient deficiencies have a significant impact on plant growth, metabolism, and reproductive phases (Cartwright *et al.*, 1983).

Higher yields were achieved by better management approaches during the growth cycle, as reported by (Fageria *et al.*, 2007). Furthermore, understanding the occurrence of growth stages might be useful in numerous physiological investigations to pinpoint the crucial growth stage in plant development that is susceptible to environmental influences.

Thornley and France (2007) explained when examining growth issues quickly, the growth curve model is highly helpful, particularly when examining agricultural crops. A mathematical overview of time data on the growth of an organism or portions of an organism has been produced using growth functions.

According to Eisele (1938), in single-plant hills, the weekly growth in dry weight of maize plants followed an autocatalytic kind of curve; but, in dense plantings, the curve was more or less straight. (Briggs *et al.,* 1920) dry weight gain per square meter of leaf area per week was calculated for maize plants. and discovered that temperature and unit leaf rate had a stronger correlation than any other environmental element.

Jaya *et al. (*2011) sated that since a statistical model just examines if a treatment has a different effect on a plant variable, it is frequently insufficient to understand the specifics of plant growth. Numerous studies have been conducted on the use of non-linear growth models to describe the growth of plants. One such model is the maize leaf curve growth model. The outcome in this instance demonstrated that the Richards and Gompertz growth model was the best fit.

Fageria *et al.* (1992) stated that changes in an organism's form, such as when a crop plant moves from a vegetative to a reproductive stage or from a reproductive to a mature condition, are the most visible examples of development. It is possible to study the development by looking at both morphological and physiological changes. During the vegetative phase of maize development, plant height is a crucial measure of plant growth and is associated with nitrogen nutrition. (Karadavut *et al.*, 2010)

In non-limiting situations, crop growth models have advanced significantly in recent years, and their predictive power is now rather respectable. Their predictive value is still low in nutrient-limited environments, though. Currently, the reduced biomass production is frequently attributed to a so-called "stress factor," but it is unclear which precise phases in the biomass production process are impacted by nutritional deficiencies (Pelerin and Mollier, 2001).

Palta (2011) reported There are certain benefits to studying the growth process nonlinearly, including the ability to estimate the relationships between plant organs and provide a mathematical explanation of growth. Moreover, the identification of the economic information in the mechanism of plant growth may be aided by nonlinear estimation approaches. It is discovered in this investigation that the Richards growth model fits the data on maize leaf growth well. To examine all of the maize growth data, a maximum likelihood nonlinear mixed-effect model was used. (Peek *et al.*, 2002 and Zhao *et al.*, 2005)

Chomba *et al.* (2013) reported there are certain benefits to studying the growth process nonlinearly, including the ability to estimate the relationships between plant organs and provide a mathematical explanation of growth. Moreover, the identification of the economic information in the mechanism of plant growth may be aided by nonlinear estimation approaches. It is discovered in this investigation that the Richards growth model fits the data on maize leaf growth well. To examine all of the maize growth data, a maximum likelihood nonlinear mixed-effect model was used.

Richards (1969) reported the roots and branches of maize plants were separated at each sampling. After being oven-dried, the plants were weighed to determine the shoot weight. Since growth functions consider the structure of the growth processes, nonlinear growth functions are best suited to describe variations in weight over time. inadequate intake of nutrients reduced dry matter buildup in different varieties of maize. In particular, it inhibits plant development during the vegetative and reproductive stages of plant growth (Goldbach, 1997).

Pearl *et al.* (1928) and Reed *et al.* (1919) observed that growth curve evaluates Increases in dry weight or leaf area, as well as the rate of elongation, have been used to measure the impact of environmental factors on plant development. Whole plants, only the aerial portions, leaves, and fruit have all been measured using dry weight. Size growth has been quantified using several plant components, such as roots, stems, leaves, or seedling structures, or as the total height of the plant. Numerous researchers have tried to mathematically express the plant growth curve using these measurements.

Hsiao *et al.* (1970) reported that in the growth chamber, A leaf on a maize plant received lots of water grew very steadily. According to current research, there was no discernible variation in the rate among different plants. The rate varied between 53 and 61 µ min, with the majority occurring at 59 t min, between the 16 plants' youngest, growing leaves (10 days old and well-watered), with a total length ranging from 20 to 30 cm. Only 6.3 percent of the data had a coefficient of variability. Nevertheless, when statistics were based on measurements from various plants, plants were chosen for growing leaves of comparable length.

2.6 Importance of nitrogen application timing in maize crop

According to Jokela and Randall (1989), timing and rate of nitrogen injection are crucial management choices for the development of maize. Nutrient management aims to reduce loss and increase crop absorption.

Asibi *et al.* (2019) suggested that in order to increase maize output, nitrogen fertilizers are required. Biofuels, the livestock industry, and human nutrition all heavily rely on maize. Less than half of the nitrogen applied worldwide is collected by maize. While applying nitrogen fertilizer might increase maize yield, overdoing it because one does not fully understand the processes governing nitrogen use efficiency can seriously jeopardize environmental sustainability. Better methods for using nitrogen in maize cultivation are required due to growing environmental awareness and an ever-growing human population. Improved comprehension of the dynamics of maize nitrogen recovery and the link between productivity and growth in maize are crucial. To increase maize productivity and yield, a deeper comprehension of the genetic and metabolic regulation of nitrogen uptake and remobilization during the vegetative and reproductive stages is essential.

Masclaux *et al.* (2010) and Hammad *et al.,* (2017) described when soil nitrogen levels rise, above-ground maize biomass usually accumulates more nitrogen. Conversely, if crop demand exceeds soil nitrogen availability, above-ground biomass may decrease. The ability for nitrogen uptake by maize is also influenced by the production of above-ground biomass. Grain and stover have different amounts of the nitrogen found in maize biomass, with luxury nitrogen uptake occurring when nitrogen supply above the minimal needs for maximum grain output. Maize's ability to absorb nitrogen is influenced by a number of variables, the most significant of which are bulk density, temperature, structure, and soil moisture. Thus, sufficient nitrogen delivery and uptake by maize are necessary for improvements in above-ground biomass production.

Ogola *et al*. (2002) reported one of the biggest obstacles to crop growth is the availability of nitrogen, and applying nitrogen through mineral and organic fertilizers is essential to maintaining crop productivity. Applying nitrogen can also significantly increase soil fertility. In maize, nitrogen fertilization can raise biomass and grain production.

According to Jaynes (2013), there have been inconsistent and frequently site-specific findings regarding the timing of nitrogen fertilizers application on maize grain output. When nitrogen was supplied to maize at the two leaf-collar stage or sent similarly between the two leaf-collar stages and possibly six or twelve, there was no discernible difference in grain yield in Iowa.

Venterea and Coulter (2015) discovered that there was no appreciable difference in maize grain output whether nitrogen was added at planting or in an equal three-way split between planting at the six leaf-collar stage and the fourteenth leaf-collar stage on a silt loam soil. In another study, divided nitrogen application on a clay loam soil increased maize grain yield by 4.5 per cent as compared to a single preplant application (Randall *et al.*,2003).

Abendroth *et al.* (2011) reported that when maize starts to grow quickly in the vegetative stage, the amount of nitrogen that can accumulate in the soil at its maximum depends on that nitrogen. The global estimate of maize nitrogen use efficiency is 33%; this is partly because of denitrification, soil and plant-derived volatilization, and the loss of nitrogen from fertilizers leaching below the root zone. Approximately half of the total nitrogen uptakes by maize occur by the time maize biomass is approximately one-fourth of the maximum. As shown in a greenhouse study, silt loam soil consistently had a higher concentration of nitrogen in the maize tissue when compared to fine sand. This suggests that soil type can also affect the uptake of nitrogen by the corn (Kaiser D E and Rubin J C 2013).

2.7 Use of neem coated urea and IFFCO nano urea in maize crop

Ramappa *et al.* (2022) elaborated that The Government of India has been implementing the policy of mandatory production and distribution of neem coated urea since 2015. This indicates that farmers in six key states i.e. Karnataka, Maharashtra, Madhya Pradesh, Bihar, Punjab, and Assam. Assam produce six major crops: rice, maize, sugarcane, tur, jute, and soybean. have recognized the benefits of neem coated urea. The findings show that using neem coated urea has, to varying degrees, improved net returns and primary product and by-product yield levels for nearly all reference crops. Because neem coated urea uses less urea and other fertilizers and pesticides, production costs have decreased.

Chagwiza *et al.* (2016) Fageria *et al.,* (2003) elaborated that per hectare consumption of Nitrogen, Phosphorus, Potassium amounts to 128.02 kg ha in India. Additionally, the ratio of nitrogen, phosphorus, and potassium consumed increased from 6.10: 2.46: 1 in 2014–2015 to 7.23: 2.9: 1 in 2019. This is higher than the optimal ratio of 4:2:1. This demonstrates that the government of India's introduction of neem coated urea in 2014 and 2015, with the goal of enhancing soil health by preventing the overuse of regular urea, has only slightly improved the consumption of fertilizers ratios over the previous five years. It demonstrates that there is still room to improve soil health by altering the way chemical fertilizers are used. The three primary crops are rice, wheat, and maize.

In order to establish sustainable and socially responsible solutions, the Indian government decided to make neem coated urea mandatory and to distribute it throughout the nation in place of regular urea (Jadhav *et al.,* 2020). When urea is coated with a negligible amount of neem (neem oil), a bio-based substance, the effect on other eco-systems is lessened than with nano urea. Neem coated urea has several advantages, such as lowering the usage and emissions of dangerous chemicals, improving safety and health, and reducing the need for urea and other fertilizers as well as other chemicals used in plant preservation. stops urea from being illegally diverted to industry, controls termites, nematodes, pests, and insects, enhances soil biodiversity, reduces the cost of cultivation, and deteriorates soil fertility, among other benefits.

Patra *et al.* (2002) reported that neem oil coated urea demonstrated an increase in apparent recovery by 20 per cent to 30 per cent compared to the uncoated urea. In this regard, utilizing natural nitrification inhibitor would be a viable technique to reduce soil nitrogen losses in environmentally friendly manner. Frank and Husted (2023) reported that A liquid fertilizers based on nanotechnology, called nano-urea, was recently created and patented by the IFFCO. Remarkably, according to the producers, A 45 kg bag of normal urea, which contains 21 kg of nitrogen, may now be replaced by foliar application of just 20 g of nitrogen in the form of nano urea. If accurate, the nitrogen from this cutting-edge, high-tech fertilizer product should be able to increase crop nitrogen use efficiency by over 1000 times when compared to regular urea. The Indian government and IFFCO said in 2023 that they would greatly increase production by constructing ten new facilities, which would allow them to produce 440 million bottles of nano urea annually by 2025. They also intended to increase the product's export to twenty-five more nations, mostly

Ajithkumar *et al.* (2021) stated that in place of applying synthetic fertilizers through soil application, IFFCO sagarika and nano urea fertilizers were applied through foliar spray, which proved to be a very effective method of increasing the maximum B:C ratio and yield as well as other yield-attributing parameters for maize. The only nano fertilizers listed in the FCO and authorized by the Indian government are IFFCO nano urea. The use of nano fertilizers lessens the financial burden on government investment for the manufacturing of direct fertilizers, enhancing the socioeconomic position of the farming community by lowering the cost of production. One liter of IFFCO nano urea replaces 100 kg of urea. It is patent-protected and was made by IFFCO. At least one bag of urea can be successfully replaced with one bottle of nano urea.

It has been tested in association with ICAR-KVKs, research centers, state agriculture institutions, and forward-thinking Indian farmers on over 90 crops at 11,000 locations. After being applied on leaves, nano urea is rapidly absorbed by plant cells through stomata and other gaps. It is easily transported from the source to the inner of the plant via the phloem in accordance with its needs. For healthy plant growth and development, unused nitrogen is gradually released from the plant cell vacuole. More than 80% more nano urea is available to the crop when it is smaller in size (20–50 nm).

According to Seleiman *et al*. (2021), gradual release in the last ten years, there has been an increased interest in nano fertilizers. By using them, it is hoped that plant nutrient uptake efficiency would increase, greenhouse gas emissions will drop, leaching will reduce, and nitrogen release timing will be better matched to crop needs.

Babu *et al.* (2022a) reported If the IFFCO's assertions turn out to be exaggerated and untrue, this might result in significant yield losses, have a negative impact on farmers' livelihoods and food security, and erode public confidence in both the science and novel sustainable products. It is somewhat confusing from the standpoint of plant nutrition how 20 g of nitrogen from nano urea can substitute 20.7 kg of nitrogen from regular urea.

Raliya *et al.* (2020) and Raliya (2021) reported that the product (nano urea) is protected by Indian Patent No. 400681, which states that at high temperatures, urea combines with linear fibers that are 50–500 nm long and formed of a naturally occurring glucose polymer to generate 20–50 nm big spherical to rod-shaped nano particles.

Upadhyay *et al.* (2023) claimed that the same yield was obtained by applying two foliar sprays of nano urea together with 75 percent of the necessary nitrogen dose to the soil. This was equivalent to applying 100 per cent conventional urea to the soil. The authors draw the conclusion that using nano urea can result in a 25 per cent reduction in nitrogen utilization. The conclusion, however, is not quite accurate when it claims that in six of the eight seasons under investigation, the yields from the 75 percent nitrogen treatments with and without nano urea were equal. As a result, the data suggest that nano urea could be skipped without lowering yield. It is hard to separate the effects of the nano method since, once again, the foliar application of nano urea was compared to the foliar application of a traditional nitrogen source, although the study lacked an appropriate control condition. The reported increase in production for nano urea could be the result of unexplained growth-stimulating side effects of N and P, such as scavenging reactive oxygen species to lessen oxidative damage and boost plant stress tolerance, rather than nitrogen fertilization (Seleiman *et al.,* 2021).

According to Babu *et al*. (2022a), nano urea sticks to plant leaves and is absorbed by stomatal, hydathode, and other leaf apertures. Following this, particles enter the phloem and are able to cross the plasmodesmata that link individual cells. Nano urea can enter cells by attaching to transport proteins, which allows it to cross ion channels, aquaporins, and endocytosis. When required, nano urea can be kept in vacuoles and extracted from the particles by a regulated procedure.

IFFCO (2022) stated that the product is effective when applied to soil. According to IFFCO, nano urea was tested for biotoxicity in accordance with the Department of Biotechnology, Government of India's "Guidelines for Evaluation of Nano-based-agri-input & Food products in India 2020." In the Indian market, the price of nano urea is purposefully set 10 per cent lower than the price of a bag of regular urea (Baboo, 2021).

2.8 Role of vermi-compost in maize crop

Guo *et al.* (2015) described the excessive use of chemical fertilisers and the widespread discharge of livestock waste is the main causes of ecosystem pollution in agriculture. Therefore, there is a need for properly disposing of manure, such as by turning it into useful compost. However, traditional composting takes a long period and results in significant nutrient losses.

According to Chaoui *et al*. (2003), vermi-composts are effective plant fertilizers and are less likely than compost and synthetic fertilizers to cause salinity stress in containers. As a result, plants fertilized with vermi-compost or cattle manure grew more quickly than those fertilized with traditional compost later on.

Vermi-compost has components that control plant growth, including humic acids, auxins, gibberellins, and cytokinin, according to Atiyeh *et al.*, (2002). Earthworms and microorganisms like fungus and actinomycetes bacteria produce these regulators, which boost plant growth and agricultural productivity in a variety of ways.

Vermi-compost and regular compost serve as slow-release fertilizers, but the former develops different from the latter since it is broken down and stabilized by the interaction with organic materials with earthworms and microorganisms (Singh *et al.*, 2008).

Arancon *et al.* (2005) revealed that during the flowering stage, the application of traditional compost and vermi-compost made from cattle dung had an impact on the dry weight of the total biomass above ground. In comparison to the plots fertilized with cattle manure vermin-compost, the dry weight of total aboveground biomass in the traditional compost-fertilized plots was 7.1 per cent greater. That could be as a result of conventional compost's initial higher concentration of primary nutrients. Nonetheless, the vermi-compost-fertilized plots had a 7.7% higher dry weight of total above-ground biomass at harvest time.

Edwards and Burrows (1988) elaborated the amounts of accessible potassium and phosphorus, as well as total organic matter and nitrogen, were considerably more in standard compost than in vermi-compost. This could be the case since nitrogen is needed to make proteins and carbon is needed by microorganisms and earthworms as an energy source. While carbon and nitrogen were being consumed, a large number of additional earthworms were simultaneously obtained. The cattle dung was converted by the earthworms' activities into a finely divided vermi-compost that resembled peat and had increased levels of microbiological activity, porosity, aeration, drainage, and water-holding capacity. These results suggested that vermi-composting could potentially fully utilize the nutrients in the waste cattle manure and transform it into a valuable, environmentally friendly organic fertilizers.

Srivastava and Beohar (2004) reported that when applied to soil, vermi-compost improves and preserves soil fertility, gives the soil a dark color that helps regulate soil temperature, and is a good alternative to commercial fertilizers because it contains more nitrogen, phosphorus, and potassium than regular heap manure. One of the manures that farmers use to cultivate crops is vermi-compost since it is readily available and contains nearly all of the nutrients that plants need.

Rathier and Frink (1989) reported that the usage of synthetic fertilizers has a negative environmental impact and is becoming more and more expensive. To cut expenses and lessen their environmental impact, farmers must raise their products through organic farming. Furthermore, organic farming will lessen the additional environmental contamination that results from the source of these synthetic fertilizer’s manufacturing.

Martin (1976) suggested that vermi-compost improves soil porosity, aeration, and water-holding capacity. It also increases surface area, offers high nutrient absorption and retention, and helps retain more nutrients for longer. Vermi-compost-amended soil has been found to have a much higher bulk density and to avoid compaction. According to Ramasamy *et al.*, (2011), vermi-composts are organic materials that undergo a mesophilic breakdown through interactions between earthworms and microorganisms, resulting in fully stabilized organic soil additions with low C:N ratios.

According to Jeyabal and Kuppuswamy (2001) Due to its enormous particle surface area, vermi-compost offers a high nutrient retention capacity and a multitude of micro-sites for microbial activity. In particular, gibberellins, cytokinin, auxins, and group B vitamins are among the many biologically active metabolites found in vermi-compost. These nutrients can be used to increase the quantity and quality of a range of crops, either by themselves or in conjunction with organic or inorganic fertilizers.

Senthil and Surendran (2002) reported the activity of the enzymes evolved in the mineralization of nutrients is significantly impacted by the breakdown of organic matter and the recycling of carbon. The health of the soil is greatly influenced by soil enzymes. One such workable method for increasing the amount of organic matter in soil is vermi-composting. The use of vermi-compost affects the soil's chemical, biological, and physical characteristics. It increases the soil's ability to hold water. It is recommended to use vermi-composting to maintain soil fertility in a variety of field crops.

2.9 Integrated nutrient management studies in maize

Sanginga and Woomer (2009) said that One technique that supports agricultural productivity and safeguards the environment for coming generations is integrated nutrient management. It can be summed up as the application of soil fertility management strategies to maximize the utilization of organic resources and fertilizers in order to boost crop productivity.

Sharma *et al.* (2020) described in addition to degrading the soil's structure, excessive inorganic fertilizers supplementation has also decreased the amount of soil organic matter (SOM) and microbial activity. Given the high nutrient requirements of both crops and their greater response to higher levels of nutrient treatment, integrated nutrient management, or INM, is a workable strategy for maintaining crop productivities. Improving crop yield in a sustainable manner requires balanced nutrient utilization (Mani *et al.*, 2011).

The Food and Agriculture Organization defines integrated nutrient management as: preserving or enhancing soil productivity either by mixing organic and inorganic fertilizers or by using balanced fertilizers; enhancing soil nutrient stocks; and boosting plant nutrient efficiency, thereby reducing losses to the environment. These are the three main components of integrated nutrient management, according to FAO (1998). Thus, by combining the advantages of all potential plant nutrient sources, integrated nutrition management seeks to maintain or modify soil fertility and deliver plant nutrients to an ideal level for maintaining crop yield.

Gruhn *et al.* (2000) elaborated Presently, INM is seen to be a strategy that, by increasing food production and quality as well as soil fertility, can assist small-holder farmers in reducing a number of problems, including poverty and food insecurity.

Almaz *et al.* (2017) said that combining the advantages of all possible plant nutrient sources can result in enhanced plant nutrient uptake, maintenance of soil nutrient status in cropping systems based on maize, correction of soil fertility, and optimal plant nutrient delivery to sustain crop productivity. Various sources of organic manures can be used in varying dosages with inorganic fertilizers to achieve this. Through integrated nutrition management, maize yield characteristics and productivity were significantly increased.

Palm *et al.* (1997) reported that it has been demonstrated that a balanced application of plant nutrients through the integration of organic and inorganic fertilizers enhances maize yield and soil fertility. For the development of every stage, maize needs more nitrogen and phosphorus than other critical components in order to yield a high crop and maintain soil fertility. It serves to supply essential nutrients in appropriate amounts. Improved synchronization of nitrogen uptake and release by crops and synergistic effects were the outcomes of integrated nutrient management.

Sheoran *et al.* (2017) reported that because organic manures have low levels of accessible nutrients, they cannot completely replace all the nutrients needed for sustainable production. However, the entire nutrient requirement of agricultural plants cannot be met by supplemental fertilization using chemical fertilizers alone. Therefore, it has been determined that integrated nutrient management is a workable solution for enhancing soil health and maintaining agricultural output over the long run. For example, the yield results of the maize cropping system were enhanced when nutrients were given utilizing both farm yard waste and inorganic fertilizers as opposed to solely using inorganic fertilizers (Brar *et al.*, 2015).

According to Hashim *et al.* (2017) When compared to their starting level, the use of integrated nutrient management showed a considerable improvement in accessible nitrogen contents. This improvement may have been caused by the nitrogen mineralization from the administered fertilisers during decomposition. The reason for the increased nitrogen availability in the treatments containing farm yard manures may be attributed to the organically bound nutrients from FYM slowly releasing into the soil. This process enhances the complexation of metal ions, which in turn raises the nutrient elements' bioavailability to plants.

Wailare and Kesarwani (2017) reported that integrated application of 50 per cent RDF along with either 5 t ha^{-1} Poultry manure or farm yard manure gave maximum productivity in maize than 100 per cent RDF in maize

Dhaliwal *et al.* (2021) revealed that the soil's organic carbon content and microbial population were significantly improved in the maize-wheat cropping system by the use of chemical fertilizers in conjunction with farmyard waste. By applying chemical fertilizers and farm yard waste together, a balanced amount of nutrients was supplied, and the accumulation of macronutrients (N, P, and K) and DTPA-extractable micronutrients (Zn, Cu, Fe, and Mn) improved considerably. It was found that the treatment that provided 50% more nitrogen to the soil than was recommended would maintain the maize-wheat system's agricultural outcomes in Punjab's loamy sand soil.

2.10 Cost-benefit ratio studies on integrated nutrient management in maize

Gittenger (1982) and Jehanzeb (1999) reported the ratio that results from dividing the benefit stream by the cost's present value, or B:C Benefits to Costs is the ratio. The costs outweigh the benefits if the ratio is less than one. The advantages outweigh the disadvantages, though, if the ratio is greater than one.

Muhammad *et al.* (2007) described the maize crop is also used by manufacturing facilities as a raw material and as animal feed. Both conventional and automated techniques are employed in the crop's cultivation. 200 respondents 130 mechanized and 70 traditional were chosen at random for the current study. The Peshawar District's field data from the 2004 kharif revealed notable variations between the output and input usage of mechanized and traditional farms. The advantage of small farms over large farms was that their cost ratio was higher at both mechanized and traditional farms. In a similar vein, the proportion of tenant farms exceeded that of owner farms. The mechanized farms' yield per hectare was 26.66% higher than the traditional farms. Compared to conventional farms, mechanized farms had a superior benefit-to-cost ratio by 26.6%. This indicates that by utilizing agricultural machinery, mechanized farms have increased both their revenue and benefit cost ratio.

Using survey data, Chahal and Kataria (2005) calculated the price and yield of maize in Punjab. In comparison to the native variety, which costs Rs. 6427 (USD 146) per hectare, and the composite varieties, which costs Rs. 8009 (USD 182) per hectare, hybrid maize had a total operating cost of Rs. 8956 (USD 203.4) per hectare. Over one-third of the operating costs were attributed to the cost of labor, both human and animal. According to estimates, the gross and net returns for hybrid maize are Rs. 19637 (USD 446) and Rs. 10682 (USD 242.6) per hectare, respectively.

Shaheen *et al.* (2007) elaborated Because mechanized farms achieved higher yields per hectare than traditional farms, their net revenue was higher. This can primarily be ascribed to the mechanized farms' improved tillage techniques and timely ground preparation. Traditional farms required more labor, which increased their costs relative to mechanized farms. The use of animal power was also restricted to conventional farms. This demonstrates that work and animal power cannot be replaced by machinery. Thus, mechanization may contribute to higher output and, consequently, income. The need for work may grow as input and income levels rise.

Raman *et al.* (2018) said that the growth and yield components of the crop, such as plant height, leaf area index, dry matter production, cob length, cob diameter, and number of grains cob^{-1}, as well as soil health, fertility, and productivity, must all be significantly increased in order to achieve a sustainable hybrid maize yield. Pressmud compost at 5 t ha^{-1} combined with 100 per cent RDF would be used to obtain these components.

Kannan *et al.* (2013) disclosed that in comparison to the control and recommended fertilizers dose, the integrated nutrient management practice, which included vermi-compost and the recommended fertilizers dose, enhanced the growth parameters (plant height, dry matter output, and leaf area index) substantially and yield parameters (number of grains per cob, seed index, and yield).

Ariraman *et al*. (2020) described that integration of organic sources and chemical fertilizers for nutrient supplement to maize aids in the better growth and yield attributes leading to higher productivity increasing the benefit cost ratio as well as sustaining the soil fertility.

CHAPTER - III

MATERIALS AND METHODS

Materials and methods

During the *kharif* season of the years 2022 and 2023, two-field experiments were conducted at the Lovely Professional University's Soil Science Research farm in Phagwara, Punjab, to meet the objectives of investigation entitled, 'Evaluation of timing of nitrogen application in maize (*Zea mays L.*) grown on coarse loamy Typic Haplustept soil of Punjab'. The detailed information regarding materials used and the procedures followed in this study are presented in the subsequent paragraphs.

3.1 Geographical location

The experimental farm is located at latitude at 31°14'30.5''N and longitude 75°41'52.1" E (Figure 3.1 and 3.2) The field experimental area belongs to central plain zone of Punjab and is situated at 234 m above the mean sea level.

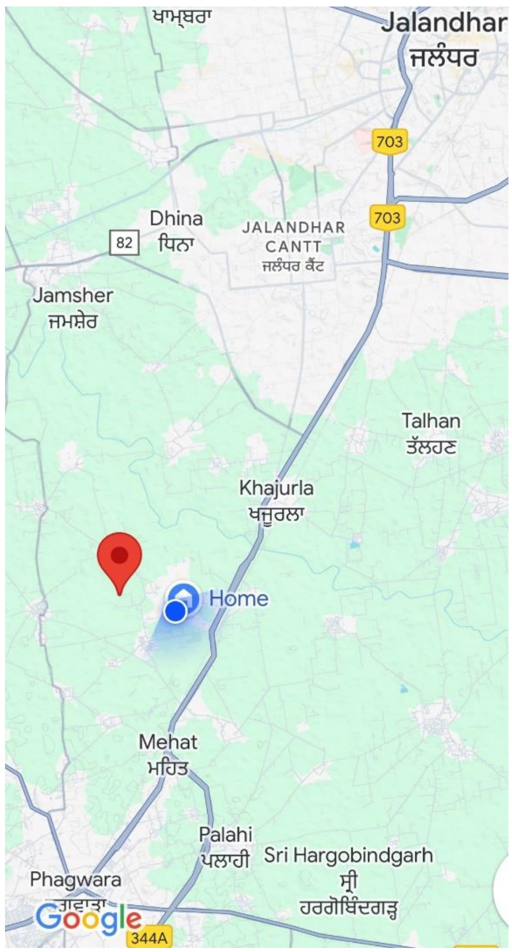

Figure 3.1 Location of experimental field in terrain view

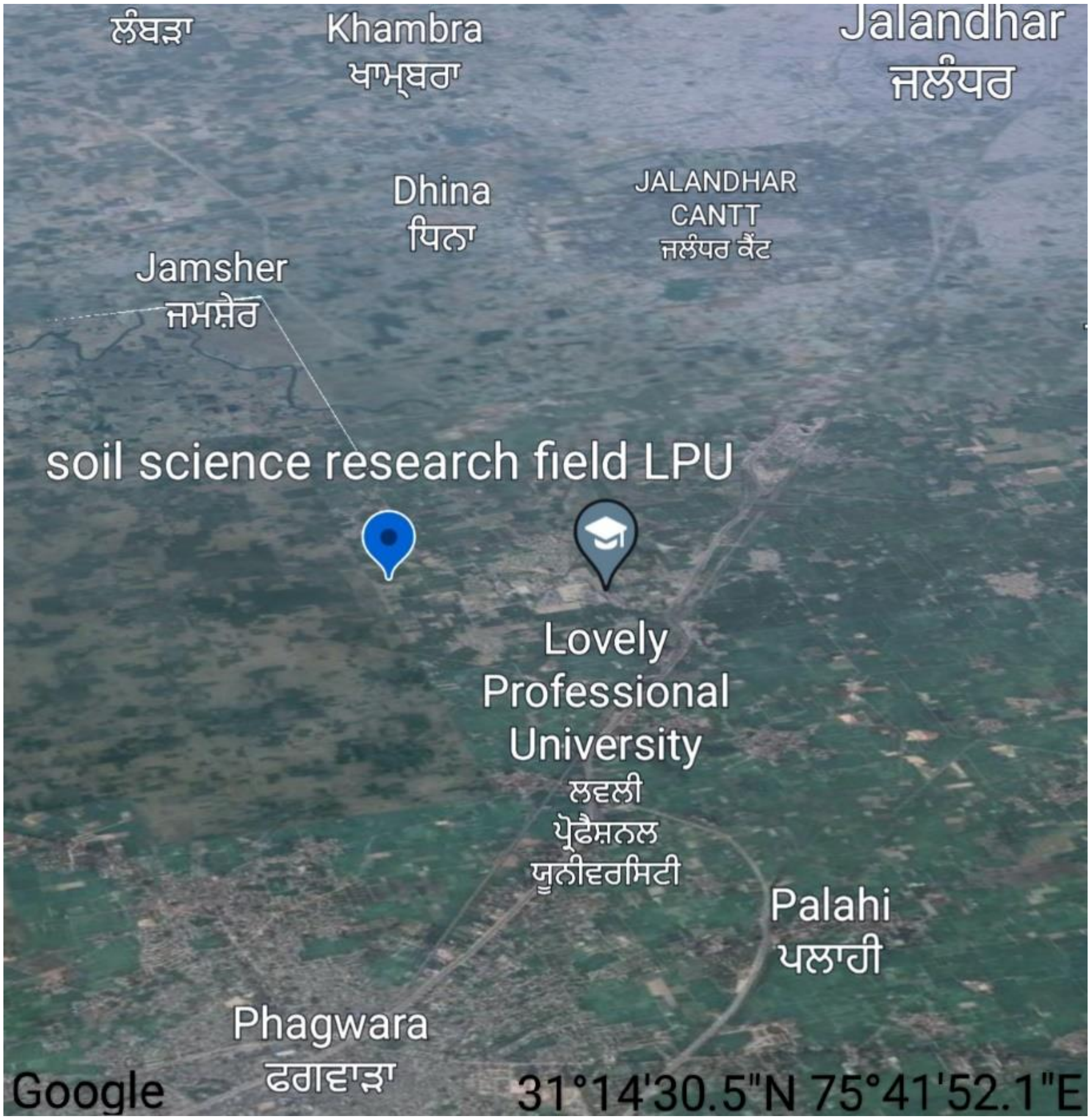

Figure 3.2 Location of experimental field in satellite view

3.2 Climate

The experimental site is located in semi-arid semi-tropical monsoon type climate that are generally favourable for maize cultivation. The climate was warm and humid. It received low precipitation in winter compared to summer. The average temperature (maximum and minimum), relative humidity percentage, and rainfall during the experimental period of May, June, July, August and September 2022 and 2023 are presented in table 3.1, 3.2 and figure 3.3, 3.4, 3.5, 3.6, 3.7, 3.8.

Table 3.1 Meteorological data for the maize (*Zea mays* L.) growing season 2022

Month	Average relative humidity (%)	Average temperature (°C)		Average rainfall (mm)
		Maximum	Minimum	
May	35.3	39.3	23.5	30.2
June	48.1	42.7	28.9	92.4
July	75.3	41.2	27.8	243.1
August	82.1	38.3	25.2	214.7
September	75.4	36.7	27.5	101.3

Table 3.2 Meteorological data for the maize (*Zea mays* L.) growing season 2023

Month	Average relative humidity (%)	Average temperature (°C)		Average rainfall (mm)
		Maximum	Minimum	
May	34.8	39.1	26.4	34.3
June	49.5	43.6	29.8	89.1
July	73.1	40.1	27.5	219.7
August	84.5	38.5	27.1	189.5
September	73.9	39.6	26.7	103.7

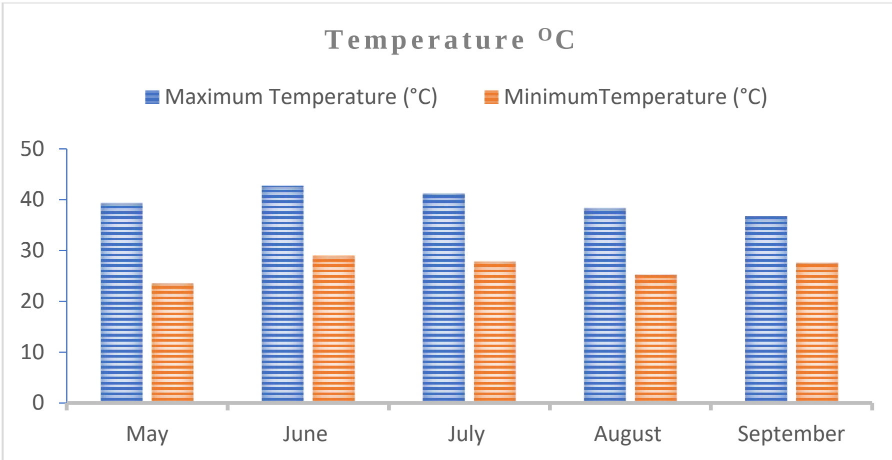

Figure 3.3 Temperature during the field experiment 2022

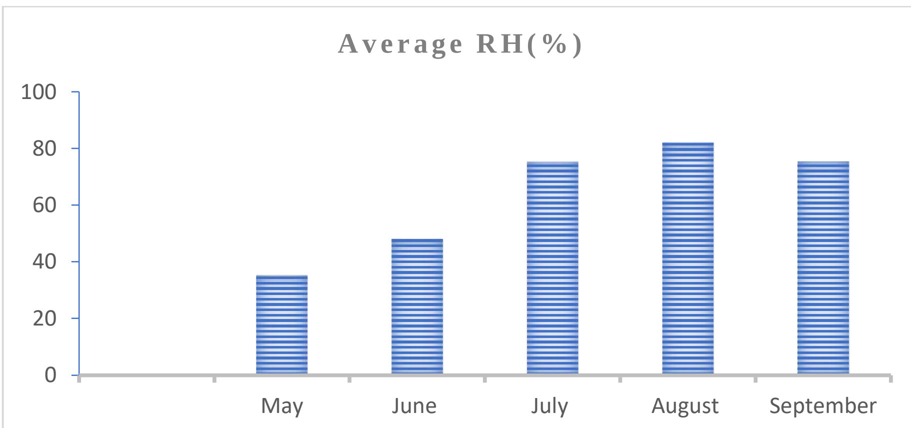

Figure 3.4 Average relative humidity (%) during the field experiment 2022

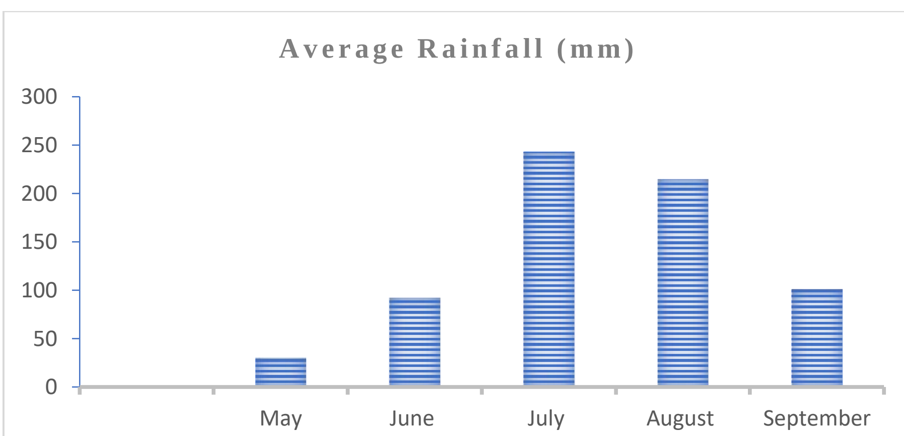

Figure 3.5 Average rainfall (mm) during the field experiment 2022

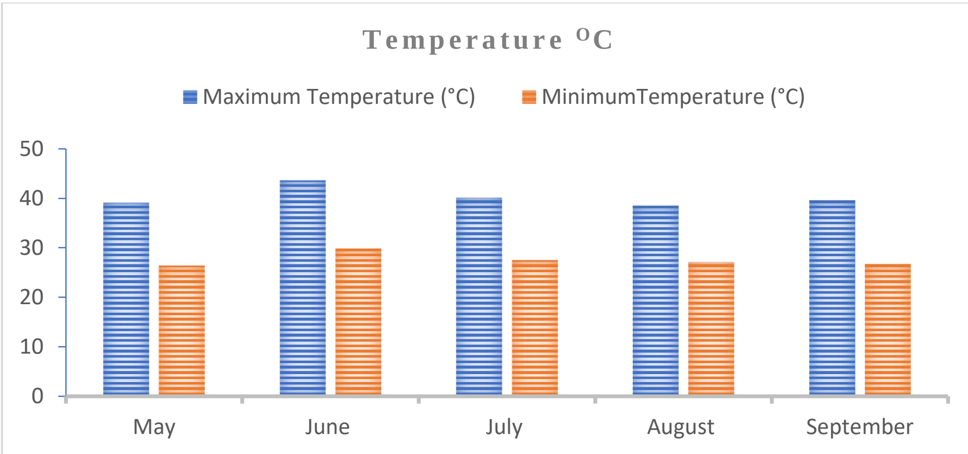

Figure 3.6 Temperature during the field experiment 2023

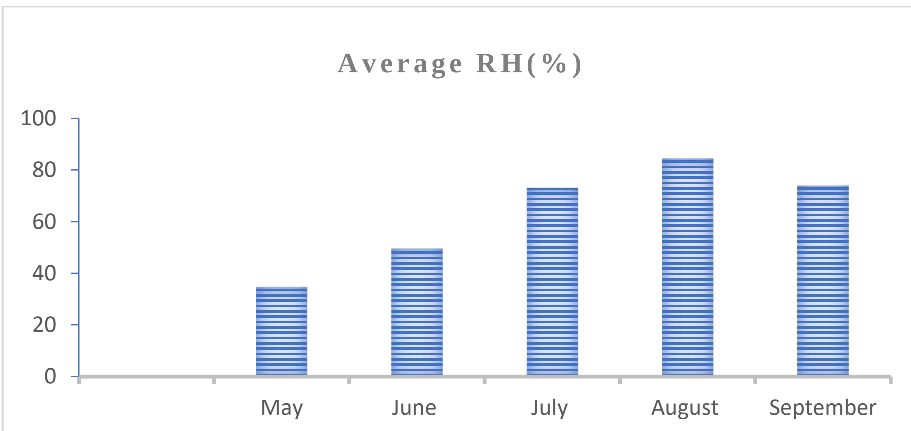

Figure 3.7 Average relative humidity (%) during the field experiment 2023

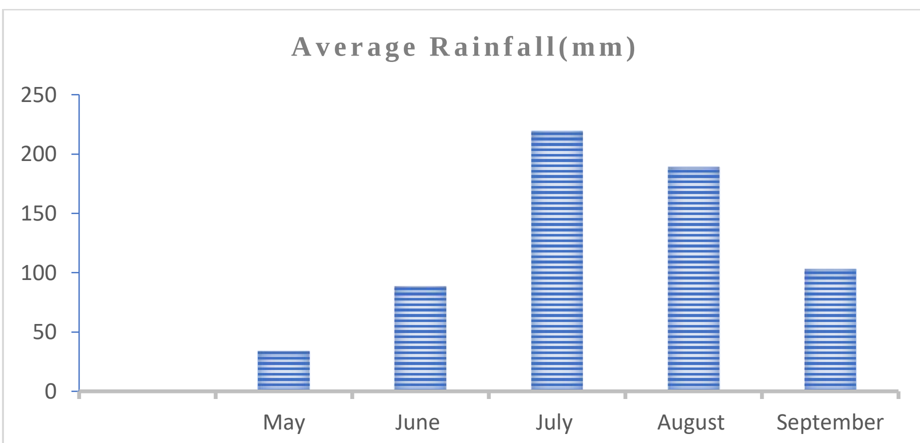

Figure 3.8 Average rainfall (mm) during the field experiment 2023

3.3 Field experiments

3.3.1 Experiment 1

To compare the performance of neem coated urea and nano-urea in maize and impact of integrated nutrient management on maize yield and growth; a field experiment was conducted with treatments for two years as approved by the research advisory committee during SOTA presentation

3.3.1.1 Soil mechanical analysis

3.3.1.1(a) Physical properties of the soil

Soil of the experimental site was alkaline in reaction, sandy loam in texture. The physical properties that were studied are mentioned below table 3.3.

Table 3.3 Details of the physical properties of the experimental field

Sr. no	Parameters	2022
1	Sand (%)	45.22
2	Silt (%)	35.65
3	Clay (%)	19.13
4	Textural class	sandy loam

3.3.1.2 Soil details

The experimental site's soil is alkaline in reaction and sandy loam in texture. Sand 45.22(%), silt 35.65(%), clay 19.13(%), soil pH 7.9, soil EC 0.31(dSm^{-1}), organic carbon 3.57(g/kg), cation exchange capacity 4.19(meq100g^{-1}), available nitrogen 172 (kg ha^{-1}), available phosphorus 7.82 (kg ha^{-1}) and available potassium 113.1 (kg ha^{-1}). It is classified as coarse loamy mixed hyper-thermic family of Typic Haplustept as per Soil Taxonomy (Figure 3.9, 3.10).

Table 3.4 Details of soil morphological profile

Soil type: Alluvial		File No. 1
Area: Soil science experiment farm	Date: 25-05-2022	Stop No. 1
Classification: coarse loamy mixed hyper thermic family of Typic Haplustept		
Location: LPU farm, Soil science experiment field		
Vegetation(crop): Maize (*Zea Mays L*)		Climate: semi-arid sub-tropical
Parent Material (geology) Alluvium		
Landform: Level to gently sloping		
Relief: gently sloping	Drainage: well drained	Salt or alkali: nil
Elevation: 234 m	Ground Water: 60 feet	Stoniness and rockiness: nil
Slope: 3% to 5 %	Moisture: Ustic soil moisture	
Aspect: not applicable	Root Distribution: ----	
Erosion: slight		
Permeability: moderate		
Additional notes, Photos, etc.: -----		

Table 3.5 Macro-morphology of soil profile at experimental site

Sr no	Horizon	Depth(cm)	Color (moist)	Texture	Structure	Consistency			Reaction	Boundary	Coarse fragments
						Dry	Moist	Wet			
1	AP	0-22	10YR 4/3(dry)	loamy sand	2wsbk	dsh	mfr	wss/wsp	e	iw	-----
2	AB	22-47	10YR 4/4	sandy loam	3msbk	dh	mfr	wss/wsp	e	ds	-----
3	BW1	47-80	10YR 4/4	sandy loam +	3msbk	dh	mfr	ws/wp	e	ds	-----
4	BW2	80-105	10YR 4/4	loam	3msbk	dh	mfi	ws/wp	es	gs	-----
5	BC	105-140	10YR 5/3	loam +	3msbk	dh	mfi	wbs/wbp	eb	gs	2-3%
6	C	140-170	10YR 5/2	silt loam	3msbk	dh	mfi	wbs/wbp	es	-----	2-3%

Figure 3.9 Macro-morphology of profile studied at experimental site

Figure 3.10 Soil profile details at the experimental field

3.3.1.2.1 The characteristics of taxonomical categories:

Classification: coarse loamy mixed hyper- thermic family of Typic Haplustept as per Soil Taxonomy

Order: Soils which are identified by the presence of one or more pedogenic horizons of alteration or little accumulation of translocated materials are classified in Inceptisol order

Suborder: Inceptisols which qualify for Ustic moisture regime are classified in Ustept suborder

Great group: Haplustept: Ustepts which do not qualify for Durustepts, Calciustepts, Humustepts Dystrustepts are classified as Haplustepts great group.

Subgroup: Haplustepts which do not qualify for any of the 23 subgroups are classified in Typic subgroup.

Family: coarse loamy textural family, mixed mineralogy, hyper-thermic temperature regime

3.3.1.2.2 The extent of similar soils in the state:

Typic Haplustepts: These deep soils have a high base saturation throughout the layers below the surface layer but do not have a calcic horizon. The soils are dry for moderate periods in normal years. Soils that have expanding clays and deep cracks are excluded. Most of the soils are gently sloping .The native vegetation consists mostly of grass, shrubs, and trees. Most of the less sloping soils are intensively used for cereal crops. Typic Haplustepts occur extensively in the piedmont and alluvial plain eco-subregion of the state of Punjab occupying about 28.39% area of state (Raj Kumar *et al*., 2008).

3.3.1.3. Experimental parameters

The experimental parameters for 2022 and 2023 remain the same, including the crop, variety, design, plot size, number of treatments and replications, total required area, number of plots, recommended fertilizer dose, and spacing. (Table 3.6)

Table 3.6 Details of the experimental parameter's maize (*Zea mays L.*) growing season 2022 and 2023

Sr.no	Experimental parameters	Year	
		2022	**2023**
1	Crop	Maize (*Zea mays L.*)	Maize (*Zea mays L.*)
2	Variety	PMH-13	PMH-13
3	Design	Randomized block design	Randomized block design
4	Plot size	3m x 5m	3m x 5m
5	Number of replications	3	3
6	Number of treatments	16	16
7	Total requirement area	$720m^2$	$720m^2$
8	Number of plots	48	48
9	Recommended dose of fertilizer	N @ 125 kg ha^{-1}, P_2O_5 @ 60 kg ha^{-1}, K_2O @ 30 kg ha^{-1}	N @ 125 kg ha^{-1}, P_2O_5 @ 60 kg ha^{-1}, K_2O @ 30 kg ha^{-1}
10	Spacing	60cm x 30 cm	60cm x 30 cm

3.3.1.4 Treatment Details

Total sixteen treatments we have used our experimental field 2022 and 2023 *kharif* season**,** all treatment details described below the table 3.7

Table 3.7 Treatment details of the field experiment on maize (*Zea mays L.*) for growing season 2022 and 2023

Sr. No	Treatment details
1	T_1 = Absolute control
2	T_2 = 75% RDF (recommended dose of fertilizer)
3	T_3 = 75% RDF + FYM @5t ha^{-1} (farm yard manure)
4	T_4 = 75% RDF + vermi-compost @2.5t ha^{-1}
5	T_5 = 75% RDF + nano urea
6	T_6 = 75% RDF (3 application timings)
7	T_7 = 75% RDF (2 application timings)
8	T_8 = 75% RDF (4 application timings)
9	T_9 = 75% RDF (basal application timings)
10	T_{10} = 100% RDF (3 applications)
11	T_{11} = 100% RDF + FYM @5t ha^{-1}
12	T_{12} = 100% RDF + vermi-compost @2.5t ha^{-1}
13	T_{13} = 100% RDF + nano urea
14	T_{14} = 100% RDF (4 application timings)
15	T_{15} = 100% RDF (2 application timings)
16	T_{16} = 100% RDF (basal application timings)

*Recommended dose of fertilizer (RDF) = N @ 125 kg ha^{-1} (neem coated urea 46% N, neem oil coating@ 3-4%), P_2O_5 @ 60 kg ha^{-1} (Single superphosphate 16% P_2O_5), K_2O @ 30 kg ha^{-1} (Muriate of potash 60% K_2O)

Nitrogen (N) was applied @ of 125 kg ha^{-1} from urea, phosphorus (P) was applied @ 60 kg ha^{-1} from single super phosphate and potassium (K) was applied @ 30 kg ha^{-1} from muriate of potash. Only neem-coated urea was used in all recommended dosage fertilizer applications. In the field experiment phosphorous, potassium, vermi-compost and farm yard manure were applied as basal. One-third of remaining nitrogen in recommended dose of fertilizer was top dressed at the knee-high stage and the remaining one-third at the pre-tasseling stage. Nitrogen was applied as top-dressing in all other treatments. First dose of nitrogen was applied at the time of sowing. In treatments where, N was applied in 2 splits, it was applied at 25 and 45 days of sowing. In treatment where N was applied in 3 splits it was applied at 25,45 and 65 days after sowing. In treatment where N was applied in 4 splits was applied 25,45,65 and 80 days after sowing. Nano urea uses two split dosages. First dose was applied 30 days after sowing, and second dose was applied in the experimental field 50 days after sowing.

3.3.1.5 Layout of the experimental field

Road				
Irrigation channel				
Irrigation channel	R_1	R_2	Irrigation channel	R_3
	T_1	T_{16}		T_8
	T_2	T_{15}		T_9
	T_3	T_{14}		T_{10}
	T_4	T_{13}		T_{11}
	T_5	T_{12}		T_{12}
	T_6	T_{11}		T_{13}
	T_7	T_{10}		T_{14}
	T_8	T_9		T_{15}
	T_9	T_8		T_{16}
	T_{10}	T_7		T_1
	T_{11}	T_6		T_2
	T_{12}	T_5		T_3
	T_{13}	T_4		T_4
	T_{14}	T_3		T_5
	T_{15}	T_2		T_6
	T_{16}	T_1		T_7

Figure 3.11 Layout of the field experiments during 2022 and 2023

3.3.1.6 Cultural operations

Date wise details of various pre-sowing and post-sowing cultural operations conducted in field experiments during 2022 and 2023 are indicated in table 3.8 and 3.9

Table 3.8 Details of the pre-sowing operations

Sr.no	2022	2023	Pre-sowing operations
1	28-Apr-22	25-Apr-23	Field excursion
2	12-May-22	10-May-23	Field layout work
3	13-May-22	16-May-23	Before sowing soil sample collection
4	16-May-22	18-May-23	Irrigation channel preparation
5	21-May-22	20-May-23	Organic and inorganic fertilizer application before sowing

Table 3.9 Details of the cultural operations in the field experiment

Sr.no	2022	2023	Details of cultural operations
1	25-May-22	25-May-23	Sowing of the maize
2	25-May-22	26-May-23	Light irrigation to field
3	6-Jun-22	9-Jun-23	Gap filling
4	7-Jun-22	10-Jun-23	Irrigation to the maize crop
5	15-jun-22	15-jun-23	Fertilizer application
6	24-Jun-22	24-Jun-23	Fields data collection
7	25-Jun-22	27-Jun-23	Herbicide spray (Atrazine)
8	5-Jul-22	5-Jul-23	Fertilizer application
9	25-Jul-22	26-Jul-23	Fields data collect
10	28-Jul-22	27-Jul-23	Irrigation to the maize crop
11	29-Jul-22	29-Jul-23	Insecticides spray (Thiamethoxam 25% WG)
12	5-Aug-22	2-Aug-23	Fertilizer application
13	8-Aug-22	10-Aug-23	Irrigation to the maize crop
14	9-Sep-22	6-Sep-23	Harvesting of the maize crop
15	10-Sep-22	7-Sep-23	Soil sample collection after harvesting

3.3.1.7 Land preparation

Field was cultivated finely and loosened up to 25-30 cm depth using dual harrow and planking three times. Maize crop was sown on ridges to avoid impact of water logging. Weeds were uprooted and removed from the field to avoid their reoccurrence. Bunds were made to differentiate different plots and irrigation channels (Figure 3.11,3.12, 3.13)

3.3.1.8 Sowing and seed rate

The crop was sown at a seed rate of 25 kg ha^{-1} on May 25, 2022 and May 25 2023. There was a 60 cm gap between rows and a 30 cm gap between plants. Seeds were planted at a depth of roughly 3 cm. (Figure 3.14)

3.3.1.9 Seed treatment

Maize seeds of variety PMH 13 were treated with chloropyriphos fungicide @3g /kg. Seeds were sown, after half an hour of treatment (Figure 3.15)

3.3.2. Intercultural operations

3.3.2.1 Gap filling

The ability of seed to germinate is hindered by improper moisture, prey and pest attack, or low germination rate. Gap filling was done to overcome this problem. Seeds were sown in gaps where germination was not observed. It was done 10-12 days after sowing (DAS) (Figure 3.17, 3.18).

3.3.2.2 Thinning

Thinning is a process in which excessive or unwanted crop seedlings are uprooted. It was performed after 20 days of sowing to maintain spacing and to reduce competition

3.3.2.3 Inorganic fertilizer application

RDF N @ 125 kg ha^{-1}(neem coated urea 46% N, neem oil coating@ 3-4%), P_2O_5 @ 60 kg ha^{-1}(Single superphosphate 16% P_2O_5), K_2O @ 30 kg ha^{-1} (Muriate of potash 60% K_2O). Nitrogen (N) was applied @ of 125 kg ha^{-1} from urea, phosphorus (P) was applied @ 60 kg ha^{-1} from single super phosphate and potassium (K) was applied @ 30 kg ha^{-1}from muriate of potash. Only neem-coated urea was used in all recommended dosage fertilizer applications. In the field experiment phosphorous, potassium, vermi-compost and farm yard manure were applied as basal. At the knee-high stage, one-third of the residual nitrogen in RDF was top dressed, while the remaining one-third was at the pre-tasseling stage. For all other treatments, a top dressing of nitrogen was used. The initial nitrogen dose was sown at the time of planting. In treatments where, N was applied in 2 splits, it was applied at 25 and 45 days of sowing. In treatment where N was applied in 3 splits it was applied at 25,45 and 65 days after sowing. In treatment where N was applied in 4 splits was applied 25,45,65 and 80 days after sowing. Nano urea uses two split dosages. First dose was applied 30 days after sowing, and second dose was applied in the experimental field 50 days after sowing.

3.3.2.4 Irrigation

The main requirement of water is during critical stages. The important stages for irrigation in the maize crop are at tasselling and silk formation stage. Maize crop required 4-5 irrigations. Shortly after sowing, first irrigation was provided. Subsequent irrigations were given during its growth period as required by the crop (Figure 3.16)

3.3.2.5 Weed management

First weeding was done at 15 DAS and the second at 30 DAS. *Cyperus rotundus*, *Cyanodon dactylon*, and *Amaranths viridis* were major weeds found in maize during cultivation. Using herbicide spray to control weeds in the field after 21 days of sowing, Atrazine@ 0.25 kg ha^{-1}was applied in 500 L/ha of water. After 43 days, manual weeding was also done (Figure 3.19).

3.3.2.6. Plant protection

Insects and diseases cause a drastic reduction in crop yield by feeding directly on both the vegetative and the reproductive part of the crop. In order to reduce the impact of insects and disease, it is essential to use pesticides to avoid yield loss. In the present study, seeds were given a Thiamethoxam at the time of sowing to avoid insect impact. Nurocombi (50% chloropyriphos + 5% cypermethrin (500mL:5g), in 1000 L of water per hectare and thiamethoxam 25% WG 2.0 g/ L of water was sprayed on crop.

3.3.2.7 Harvesting and threshing

When the whole plants turned yellow and the cobs were partially dried, the crop was harvested. Harvested cobs were completely dried in the sun. The Stover was separately dried under the sun to record the weights. Cob shelling was done with a power operated Sheller, when the grain moisture content varied between 15 and 20%. Grains collected from each plot were stored separately and were sun dried (Figure 3.20, 3.21, 3.22, 3.23, 3.24).

Figure 3.12 Field excursion before sowing

Figure 3.13 Experimental field preparation before sowing

Figure 3.14 Sowing of the experimental field

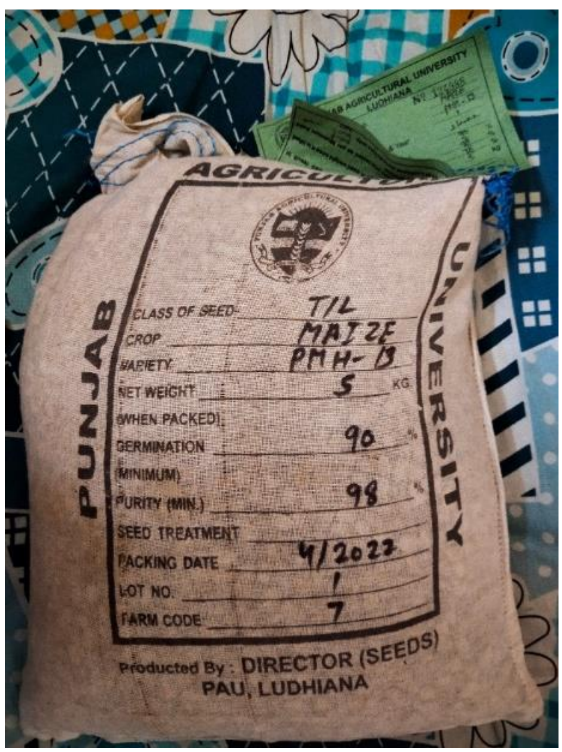

Figure 3.15 PMH-13 seed packet

Figure 3.16 Irrigation channel of the experimental field

Figure 3.17 View of field experiment at 15 days after sowing

Figure 3.18 Gap filling of the experimental field

Figure 3.19 Hand weeding at experimental field

Figure 3.20 Maize crop at the experimental field

Figure 3.21 Maize cobs at the experimental field

Figure 3.22 Final stage of maize crop at the experimental field

Figure 3.23 Harvesting of maize crops at the experimental field

Figure 3.24 Maize samples collect from the experimental field

3.3.3 Observations

Soil samples were collected treatment-wise before sowing and after harvesting of the crop. Observations were taken for plants height, dry matter weight of the treatment, the length of the maize cobs, the weight of the maize cobs after harvest and the weight of the grain of maize.

3.3.3.1. Pre-harvest observations

In order to study the effect of different treatments, at various growth stages, differences were seen in the factors related to growth and yield. Parameters of growth and yield were recorded at 30, 60 and at harvest.

3.3.3.2. Plant height (cm)

Randomly selected seven plants in each plot were manually tagged. The height of the plant was recorded at 30, 60 and at harvest using the measurement tape from the ground level to the tip of the topmost leaf and expressed in cm.

3.3.3.3 Dry matter accumulation

Per plant, the amount of dry matter was stated in grams. For the purpose of recording the total dry matter accumulation, seven randomly chosen plants from the sampling area were employed at 30,60, and harvest. After reaching a steady weight, the plants were dried in an oven at 60 to 70 °C.

3.3.4. Post-harvest observations

3.3.4.1. Number of cobs/plots

Numbers of cobs were randomly counted from selected plants. For further statistical analysis, the mean value was calculated.

3.3.4.2. Cob length (cm)

Cob length was measured from randomly selected plants. Mean value was calculated and used for further statistical analysis.

3.3.4.3. Number of grains/cobs

It was counted on the selected cobs from the tagged plants. Afterwards, mean value was obtained.

3.3.4.4. Grain yield/plot (q/ha)

Grain was separated from cobs after drying in shades. Then total grain weight was measured from each plot using weighing machine to check yield. Grain yield was expressed in q ha^{-1}.

3.3.4.5. Straw yield/plot (q/ha)

Grain and straw yields from the net plot area were recorded after sun drying at maturity. The yield was expressed in q/ha.

3.3.5. Soil analysis

Soil chemical properties were determined by taking soil samples randomly from 0-15 cm depth throughout the experimental area with the help of screw auger. Soil Samples were air dried, sieved through 2mm sieve and analysed.

Various physico-chemical properties such as soil texture, soil pH, EC, cation exchange capacity, organic carbon, available nitrogen, and available phosphorous, available potassium were estimated using procedure given in table 3.10.

3.3.5.1 Details of the soil analysis methods

Table 3.10 Details of the experimental Fields soil analysis methodology

Sr. no	Determination	Methodology	Reference
1	Soil texture	International pipette method	Piper, 1966
2	Soil pH	Electronic glass electrode method	Jackson, 1967
3	Soil EC	Electrical conductivity	Jackson, 1967
4	Organic carbon	Walkley - Black method	Walkley and Black 1934
5	Soil cation exchange capacity	Sodium acetate method	Jackson, 1967
6	Available nitrogen	Alkaline permanganate method	Subbiah and Asija 1956
7	Available phosphorus	Olsen's method	Olsen's *et al.*, 1954
8	Available potassium	Ammonium acetate method	Merwin and Peech, 1951

3.3.5.2. Soil texture

Soil of the experimental site was neutral in reaction, sandy loam in texture. It was examined using the International Pipette Method. (Piper, 1966)

3.3.5.3. Soil pH and EC

Soil pH and EC was determined in 1:2 soil-water suspensions after occasional shaking for half an hour using a combined glass electrode pH meter (Systronics pH system 361) and EC meter (Systronics EC Conductivity 7DS meter 308), respectively.

3.3.5.4. Organic carbon (%)

Using potassium dichromate as a carbon oxidizer and ferrous ammonium sulphate as a carbon titrant in the presence of diphenylamine indicator, the Walkley-Black method was used to assess the organic carbon content of the soil. (Walkley and Black, 1934).

3.3.5.5. Available nitrogen

Available nitrogen in soil was estimated by alkaline permanganate method (Subbaiah and Asija, 1956), where soil was treated with $KMnO_4$ and NaOH, evolved ammonia / ammonium hydroxide was absorbed in boric acid and titrated against sulphuric acid.

3.3.5.6. Available phosphorous

Available phosphorus in soil was extracted with 0.5N Sodium bicarbonate. Afterwards, phosphorus was estimated colorimeter at 760 nm wavelength by reacting the extracted solution with ammonium molybdate in the presence of ascorbic acid (Olsen *et al.,* 1954). Sample phosphorous concentration was enumerated using a standard curve (Systronics visible spectrophotometer 168).

3.3.5.7. Available potassium

Soil available potassium was extracted using IN ammonium acetate as an extractant (Merwin and Peech, 1951). Potassium in extracted solution was quantified using a flame photometer (Labtronics Digital Flame Photometer Model LT-66). A standard curve was prepared to determine potassium concentration in soil.

3.3.5.8. Cation exchange capacity

Soil was made saturated with sodium by shaking with IN sodium acetate solution (Jackson, 1967). Sodium saturated soil was then made free from free sodium salts by repeated washings with alcohol. Sodium from sodium saturated soil was released by repeated washing with ethanol and estimated in a flame photometer (Labtronics Digital Flame Photometer Model LT-66).

3.3.6 Plant sample analysis

The plant sample collected in experimental field were washed with distilled water and dried in a hot air oven at a temperature between 60 and 70 ^{O}C. Dried samples, were ground into a powder in a mixer, and the resulting powder was gathered in packets. This powder was used for analysis at total potassium, total phosphorus, and total nitrogen in laboratory

Table 3.11 Details of the experimental plant analysis methodology

Sr. no	Determination	Methodology	Reference
1	Total nitrogen	Kjeldhal's method	Kjeldahl, 1883
2	Total phosphorus	Vanado-molybdo phosphoric yellow colour method	Jackson, 1973
3	Total potassium	Flame Photometric Method	Chapman *et al.*, 1961

3.3.7 Total nitrogen

The most common method used to determine soil fertility is to measure the total nitrogen content of plant samples. Kjeldahl's approach is how it is determined. In a Kjeldahl flask, 10mL of concentrated sulfuric acid and a salt mixture (50:10:1 of K_2SO_4:$CuSO_4$:5H_2O metallic selenium) were used to digest 0.5 g of dried material. Following the transfer of the digested sample to the Kjeldahl distillation apparatus, 4mL of 40% NaOH solution was added, and the mixture was distilled to yield 4 per cent boric acid with mixed indication. After titrating the distilled ammonia absorbed in boric acid with standard (0.1N) H_2SO_4, the percentage of N was determined.

3.3.7 Wet digestion

A 250 mL conical flask containing one gram of powdered leaf sample was used to digest it using a di-acid mixture (HNO_3 + $HClO_4$ at a 4:1 ratio). The sample digest was diluted to a volume of 100 milliliters using two glasses of distilled water. It was then filtered through Whatman No. 1 filter paper, and the clear extract was utilized to determine P and K.

3.3.8 Total phosphorus

The Vanado-molybdo phosphoric yellow color method was used to assess the total phosphorus in the plant's extract. according to Jackson (1973)

3.3.9 Total potassium

It was determined from the digest by using Flame photometer following the procedure given by Chapman *et al.*, (1961)

3.4.1 Experiment 2

To understand the growth and nitrogen uptake pattern of maize plants, a field experiment was conducted with the treatments for two years as approved by the research advisory committee during SOTA presentation.

3.4.1.1 Soil details

Soil of the experimental site was alkaline in reaction, sandy loam in texture. Sand 45.22(%), silt 35.65(%), clay 19.13(%), soil pH 8.0, soil EC 0.30 (dSm^{-1}), organic carbon 3.65(g/kg), cation exchange capacity 4.22 ($meq100g^{-1}$), available N 169 (kg ha^{-1}), available P 7.72 (kg ha^{-1}), available K 115.7 (kg ha^{-1}).

3.4.1.2 Details of the field experiments

Table 3.12 Details of the experimental parameter's maize (*Zea mays L.*) growing season 2022 and 2023

Sr.no	Experimental parameters	2022	2023
1	Crop	Maize (*Zea mays L.*)	Maize (*Zea mays L.*)
2	Variety	PMH-13	PMH-13
3	Design	Randomized block design	Randomized block design
4	Plot size	3m x 5m	3m x 5m
5	Number of replications	3	3
6	Number of treatments	2	2
7	Total requirement Area	$90m^2$	$90m^2$
8	Number of plots	6	6
9	Recommended dose of fertilizer	N @ 125 kg ha^{-1}, P2O5 @ 60 kg ha^{-1}, K2O @ 30 kg ha^{-1}	N @ 125 kg ha^{-1}, P2O5 @ 60 kg ha^{-1}, K2O @ 30 kg ha^{-1}
10	Spacing	60cm x 30 cm	60cm x 30 cm

3.4.1.3 Treatment Details

Table 3.13 Treatment details of the field experiments maize (*Zea mays L.*) growing season 2022 and 2023

Sr.no	Treatments
1	T_1-Absolute control
2	T_2-100% RDF (3applications)

*(RDF) = N @ 125 kg ha^{-1}(neem coated urea 46% N, neem oil coating@ 3-4%), P_2O_5 @ 60 kg ha^{-1}(Single superphosphate 16% P_2O_5), K_2O @ 30 kg ha^{-1} (Muriate of potash 60% K_2O)

Nitrogen (N) was applied @ of 125 kg ha^{-1} from urea, phosphorus (P) was applied @ 60 kg ha^{-1} from single super phosphate and potassium (K) was applied @ 30 kg ha^{-1} from muriate of potash. Only neem-coated urea was used in all recommended dosage fertilizer applications. In the field experiment phosphorous, potassium, vermi-compost and farm yard manure were applied as basal. At the knee-high stage and the pre-tasseling stage, accordingly, one-third of the remaining nitrogen in the required fertilizer dose was top dressed. In all other treatments, a top dressing of nitrogen was applied. The first nitrogen dose was sown at the time of sowing. Treatments where N was applied in three splits was so at 25, 45, and 65 days after sowing.

3.4.1.4 Layout of the experimental field

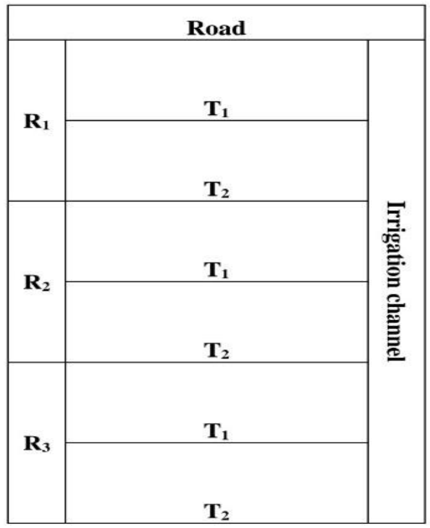

Figure 3.25 Layout of the field experiments 2022 and 2023

3.4.1.5 Cultural operations

Date wise details of various pre-sowing and post-sowing cultural operations conducted in field experiments during 2022 and 2023 are indicated in table 3.14 and 3.15

Table 3.14 pre-sowing operations of the field experiment

Sr.no	2022	2023	Pre-sowing operation
1	28-Apr-22	25-Apr-23	Field excursion
2	12-May-22	10-May-23	Field layout work
3	13-May-22	16-May-23	Before sowing soil sample collection
4	16-May-22	18-May-23	Irrigation channel preparation
5	21-May-22	20-May-23	Organic and inorganic fertilizer application before sowing

Table 3.15 Details of the cultural operations of the field experiment

Sr.no	2022	2023	Details of cultural operations
1	25-May-22	25-May-23	Sowing of the maize
2	25-May-22	26-May-23	Light irrigation to field
3	6-Jun-22	9-Jun-23	Gap filling
4	7-Jun-22	10-Jun-23	Irrigation to the maize crop
5	15-Jun-22	15-Jun-23	Fertilizer application
6	24-Jun-22	24-Jun-23	Fields data collection
7	25-Jun-22	27-Jun-23	Herbicide spray (Atrazine)
8	5-Jul-22	5-Jul-23	Fertilizer application
9	25-Jul-22	26-Jul-23	Fields data collect
10	28-Jul-22	27-Jul-23	Irrigation to the maize crop
11	29-Jul-22	29-Jul-23	Insecticides spray (Thiamethoxam 25% WG)
12	5-Aug-22	2-Aug-23	Fertilizer application
13	8-Aug-22	10-Aug-23	Irrigation to the maize crop
14	9-Sep-22	6-Sep-23	Harvesting of the maize crop
15	10-Sep-22	7-Sep-23	Soil sample collection after harvesting

3.4.1.6 Land preparation

Field was cultivated finely and loosened up to 25-30 cm in depth using dual harrow and planking three times. Maize crop was sown on ridges to avoid impact of water logging. Weeds were uprooted and removed from the field to avoid their reoccurrence. Bunds were made to differentiate different plots and irrigation channels. (Figure 3.26)

3.4.1.7 Sowing and seed rate

The crop was sown at a seed rate of 25kg ha^{-1} on May 25, 2022 and May 25 2023. Row to Row distance was 60 cm, and plant to plant distance was 30 cm. Seeds were placed at about 3 cm depths

3.4.1.8 Seed treatment

Maize seeds of variety PMH 13(PAU variety) were treated with chloropyriphos fungicide @3g /kg. Seeds were sown, after half an hour of treatment

3.4.2. Intercultural operations

3.4.2.1 Gap filling

The ability of seed to germinate is hindered by improper moisture, prey and pest attack, or low germination rate. Gap filling was done to overcome this problem. Seeds were sown in gaps where germination was not observed. It was done 10-12 days after sowing.

3.4.2.2 Thinning

Thinning is a process in which excessive or unwanted crop seedlings are uprooted. It was performed after 20 days of sowing to maintain spacing and to reduce competition (Figure 3.28)

3.4.2.3 Inorganic fertilizer application

The full dose of single super phosphate, muriate of potash, vermi-compost and farm yard manure were applied during the last preparation of filed. Urea was applied in 3 splits. The first dose applied as top dressing at the time of sowing and the second split dose was given at the knee-high stage and the third dose was given at the stage of tasselling, in the recommended dose of fertilizer plots nitrogen three application timing is 25, 45 and 65 days after sowing.

3.4.2.4 Irrigation

Artificial application of water to fulfil the moisture demand of the crop is called as irrigation. The main requirement of water is during critical stages. The important stages for irrigation in the maize crop are at tasselling and silk formation stage. Maize crop required 4 to 5 irrigations. Shortly after sowing, first irrigation was provided. Subsequent irrigation was given during its growth period as required by the crop (Figure 3.27)

3.4.2.5 Weed management

First weeding was done at 15 DAS and the second at 30 DAS. *Cyperus rotundus*, *Cyanodon dactylon*, and *Amaranths viridis* were major weeds found in maize during cultivation. Using herbicide spray to control weeds in the field after 21 days of sowing, Atrazine@ 0.25 kg/ha applied in 500 L/ha. After 43 days, manual weeding was also done

3.4.2.6. Plant protection

Insects and diseases cause a drastic reduction in crop yield by feeding directly on both the vegetative and the reproductive part of the crop. In order to reduce the impact of insects and disease, it is essential to use pesticides to avoid yield loss. In the present study, seeds were treated with Thiamethoxam at the time of sowing to avoid insect impact. Nurocombi (50% chloropyriphos + 5% cypermethrin (500mL:5g), in 1000 L of water and thiamethoxam 25% WG 2.0 Gm / litre of water was sprayed on crop.

3.4.2.7 Harvesting and threshing

When the whole plants turned yellow and the cobs were partially dried, the crop was harvested. Harvested cobs were properly sun-dried. To record the weights, the Stover was dried in the sun separately. Cob shelling was done with a power operated Sheller, when the grain moisture content varied between 15 and 20%. Grains collected from each plot were stored separately and were sun dried. (Figure 3.29)

Figure 3.26 Field visit with supervisor and HOD.

Figure 3.27 Experimental field

Figure 3.28 View of field experiment at 20 days after sowing

Figure 3.29 Field experiment at soil science research farm

3.4.3 Observation

Before sowing Soil, samples were collected treatment-wise. After sowing, plant samples (above ground part) collected every 3 days till maturity or harvest of plants from the above treatments, observations were taken of the plant's height, plant weight every 3 days till maturity or harvest, length of the maize cobs, weight of the maize cobs and weight of the grain, recorded and soil sample collection after harvest.

3.4.3.1. Pre-harvest observations

Parameters of growth were recorded at every 3 days till maturity.

3.4.3.2. Plant height (cm)

Randomly selected plants in each plot were manually tagged. The height of the plant was recorded at every 3 days till harvest using the measurement tape from the ground level to the tip of the topmost leaf and expressed in cm.

3.4.3.3 Dry matter accumulation

Per plant, the amount of dry matter was given in grams. The sampling area's collected plant samples were utilized to record the total amount of dry matter accumulated every three days until harvest or maturity. After reaching a steady weight, the plants were dried in an oven at 60 to 70 °C.

3.4.4. Post-harvest observations

3.4.4.1. Number of cobs/ plots

Numbers of cobs were randomly counted from selected plants. For further statistical analysis, the mean value was calculated.

3.4.4.2. Cob length (cm)

Cob length was measured from randomly selected plants. Mean value was calculated and used for further statistical analysis.

3.4.4.3. Number of grains/cobs

It was counted from the tagged plants' selected cobs. Afterwards, mean value was obtained.

3.4.4.4. Grain yield/plot (q/ha)

Grain was separated from cobs after drying in shades. Then total grain weight was measured from each plot using weighing machine to check yield. Grain yield was expressed in q/ha.

3.4.4.5. Straw yield/plot (q/ha)

The yields of grain and straw from the net plot area were measured at maturity and sun drying. The yield was given in terms of q/ha.

3.4.5. Details of the soil and plant analysis

Details of the methods used for soil and plant analysis for the samples of experiment 2 are same as discussed in para 3.3.5 and para 3.3.6 respectively.

3.4.6 Economic analysis

The economics of different treatments were calculated by considering the cultivation cost, gross and net return hectare^{-1}and net return rupee^{-1} invested. The existing sale price for various inputs and outputs were also considered.

3.4.6.1. Cost of cultivation

The calculation was based on the cost of various agricultural inputs, such as labour, fertiliser, compost, and other essential inputs, as well as local charges.

3.4.6.2. Gross return

The produce value was calculated based upon minimum support price in the farm area and was expressed in Rs/ha. The selling price of maize cob was Rs. 20/kg.

3.4.6.3 Net return

This was calculated by subtracting the cost of cultivation from the gross return

3.4.6.4 Net returns per rupee invested

This was calculated by using the formula given below:

Net returns per rupee invested = Net return (Rs/ha) / cost of cultivation (Rs/ha)

3.4.7. Statistical analysis:

The data resulted from present study was subjected to the determination of analysis of variance (ANOVA) via requisite statistical computation by following the procedure given by Gomez and Gomez (1984) to calculate the cause and effect relationship among various parameters. For comparison, the critical difference (CD) at the five percent probability level was calculated whenever statistical significance was noted.

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CHAPTER – IV

RESULTS AND DISCUSSION

Results and discussion

Field experiments were carried out at the Soil Science Research Farm of Lovely Professional University, Phagwara, Punjab, during the *kharif* season of 2022 and 2023. To fulfill the objectives of the investigation entitled, 'Evaluation of timing of nitrogen application in maize (*Zea mays L.*) grown on coarse loamy Typic Haplustept soil of Punjab'. Results of the experiments are presented and discussed here under in the succeeding paragraph.

4.1 Experiment 1

It was conducted with the following objectives:

(a) To compare the performance of neem coated urea and nano-urea in maize

(b) Effect of integrated nutrient management on growth and yield of maize

(c) To evaluate the economics of different fertilizer treatments in maize

Experiment was conducted in field on a coarse loamy mixed hyper thermic family of Typic Haplustept soil in *kharif* season for two years. Results obtained from various field and laboratory analysis are presented and discussed here

4.1.1 Growth attribute studies

Under these studies data related to plant height at 30, 60 days of sowing and maturity, cob length, dry matter yield, cobs weight, grains weight were recorded. Same are presented and discussed in table number 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7 and figure number 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7. are discussed below

4.1.1.1 Plant height at 30 days of sowing

Plant height (cm) data were recorded at 30 days after sowing in an experimental field during 2022 and 2023.The data of the same are presented in table 4.1 and figure 4.1

Table 4.1 Plant height (cm) at 30 days of sowing

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	31.43	32.67	32.05
2	T_2 = 75% RDF (Recommended dose of fertilizer)	34.52	32.00	33.26
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	34.80	31.33	33.07
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	31.07	31.23	31.15
5	T_5 = 75% RDF + Nano urea	32.10	33.47	32.79
6	T_6 = 75% RDF (3 Application timings)	29.93	32.00	30.97
7	T_7 = 75% RDF (2 Application timings)	33.31	34.33	33.82
8	T_8 = 75% RDF (4 Application timings)	33.17	31.41	32.29
9	T_9 = 75% RDF (Basal application timings)	32.43	31.33	31.88
10	T_{10} = 100% RDF (3 Applications)	33.90	30.33	32.12
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	31.13	33.28	32.21
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	29.83	31.45	30.64
13	T_{13} = 100 % RDF + Nano urea	30.57	35.33	32.95
14	T_{14} = 100% RDF (4 Application timings)	34.20	32.19	33.20
15	T_{15} = 100% RDF (2 Application timings)	31.37	30.00	30.69
16	T_{16} = 100% RDF (Basal application timings)	29.50	32.65	31.08
C.D.(P=0.05)		1.39	1.41	1.35
S.E.m. (±)		0.66	0.67	0.64

Figure 4.1 Plant height at 30 days

Data pertaining to maize plant height at 30 days of sowing was recorded in field for two years. Same is presented in table 4.1 and figure 4.1. Plant height at 30 days in different treatments ranged from 29.50 cm to 34.80 cm in 2022 it varied between 30.00 cm and 35.33 cm in 2023. Plant height average of 2022 and 2023 varied from 31.07 to 32.65. It was highest in T_3 treatment and lower T_{16} treatments. A perusal of data indicates that maize height was maximum in T_3 (34.80) in 2022; where it was maximum in T_{13} (35.33) in 2023.Plant height was minimum in T_{16} (29.5) in 2022; where it was minimum in T_{15} (30) in 2023. By considering the C.D. some of the treatments difference may look significant or non-significant. it is dangerous to draw any conclusion at this 30-day stage; as treatment are still incomplete. A little decrease in plant height was seen as crop growth progressed. The reason for the same plant height on all sowing dates was guaranteed germination, manual seed planting using the dabbling method in the right soil conditions, and guaranteed irrigation facilities for the duration of the crop's growth. Similar findings were made by Anonymous (2012) and Singh *et al.*, (1992), who found no variation in plant height in maize crops treated with different fertilizers. Plant height generally rose as crop growth progressed.

4.1.1.2 Plant height at 60 days of sowing

Plant height (cm)were recorded at 60 days after sowing in an experimental field during 2022 and 2023.The data of the same are presented in table 4.2 and figure 4.2

Table 4.2 Plant height(cm) at 60 days of sowing

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	87.51	73.71	80.61
2	T_2 = 75% RDF (Recommended dose of fertilizer)	74.33	83.00	78.67
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	84.65	83.67	84.16
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	92.64	78.50	85.57
5	T_5 = 75% RDF + Nano urea	90.33	78.33	84.33
6	T_6 = 75% RDF (3 Application timings)	97.20	82.39	89.80
7	T_7 = 75% RDF (2 Application timings)	92.15	77.67	84.91
8	T_8 = 75% RDF (4 Application timings)	90.00	80.33	85.17
9	T_9 = 75% RDF (Basal application timings)	88.33	76.20	82.27
10	T_{10} = 100% RDF (3 Applications)	97.67	77.12	87.40
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	85.33	77.00	81.17
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	96.21	74.54	85.38
13	T_{13} = 100 % RDF + Nano urea	89.63	76.67	83.15
14	T_{14} = 100% RDF (4 Application timings)	90.69	79.33	85.01
15	T_{15} = 100% RDF (2 Application timings)	90.25	83.45	86.85
16	T_{16} = 100% RDF (Basal application timings)	98.00	82.23	90.12
C.D.(P=0.05)		3.92	3.35	3.40
S.E.m. (±)		1.87	1.59	1.62

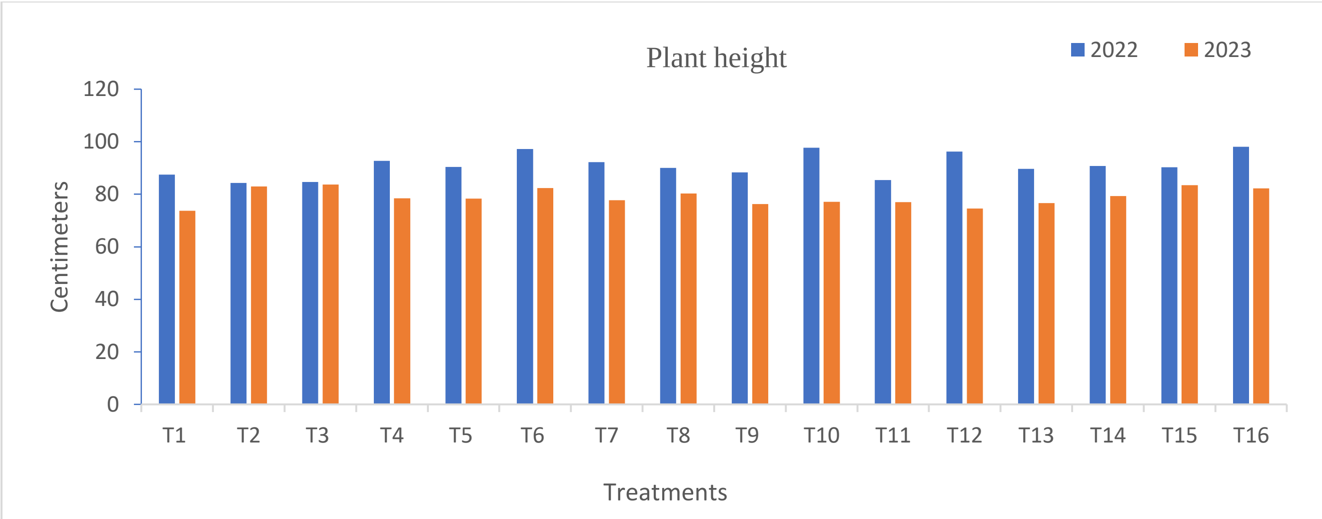

Figure 4.2 Plant heights at 60 days

For two years, data on the height of maize plants was recorded in the field. Same is presented in table 4.2 and figure 4.2. Plant height at 60 days in different treatments ranged from 74.33 cm to 98 cm in 2022 and it varied between 73.71 cm and 83.67 cm in 2023. Plant height average of 2022 and 2023 varied from 74.33 to 79.33. It was highest in T_{16} treatment and lowest in T_1 treatments. A scrutiny of data indicates that maize height was maximum in T_{16} (98) in 2022; where it was maximum in T_3 (83.67) in 2023.Plant height was minimum in T_2 (74.33) in 2022; where it was minimum in T_1 (73.71) in 2023. The plant height at 60 days was maximum in the T_{16} treatment because of the basal application of all the nutrients at the time of sowing which led to enhanced vegetative growth. In 2022 T_{16} treatments is significantly higher in all treatments and in 2023 T_3 treatments is significantly higher in all treatments. Different fertilizer applications have been found to cause variations in plant height by Beiragi *et al.,* (2011). Irmak and Djaman (2016) who reported that plant density did not greatly affect the height of maize plants. Thus, plant height data at 60 days stage indicated increased growth in treatments receiving more fertilizer dose in terms of basal application.

4.1.1.3 Plant height at harvest

Plant height recorded after harvest in an experimental field during 2022 and 2023.The data of the same are presented in table 4.3 and figure 4.3

Table 4.3 Plant height (cm) at harvest during 2022 and 2023

Sr. no	Treatments	2022	2023	Mean
1	T1 = Absolute control	172.33	171.33	171.83
2	T2 = 75% RDF (Recommended dose of fertilizer)	174.00	171.20	172.60
3	T3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	169.00	170.00	169.50
4	T4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	170.12	169.67	169.90
5	T5 = 75% RDF + Nano urea	173.33	172.00	172.67
6	T6 = 75% RDF (3 Application timings)	172.67	173	172.84
7	T7 = 75% RDF (2 Application timings)	168.59	173.32	170.96
8	T8 = 75% RDF (4 Application timings)	175.00	169.33	172.17
9	T9 = 75% RDF (Basal application timings)	174.60	170.00	172.30
10	T10 = 100% RDF (3 Applications)	171.56	167.61	169.59
11	T11 = 100% RDF + FYM 5 t ha^{-1}	174.00	173.67	173.84
12	T12 = 100% RDF+ vermi-compost 2.5 t ha^{-1}	174.23	175.40	174.82
13	T13 = 100 % RDF + Nano urea	171.67	171.75	171.71
14	T14 = 100% RDF (4 Application timings)	172.33	168.33	170.33
15	T15 = 100% RDF (2 Application timings)	170.59	173.00	171.80
16	T16 = 100% RDF (Basal application timings)	173.69	170.33	172.01
C.D.(P=0.05)		7.00	7.02	6.84
S.E.m. (±)		3.33	3.51	3.26

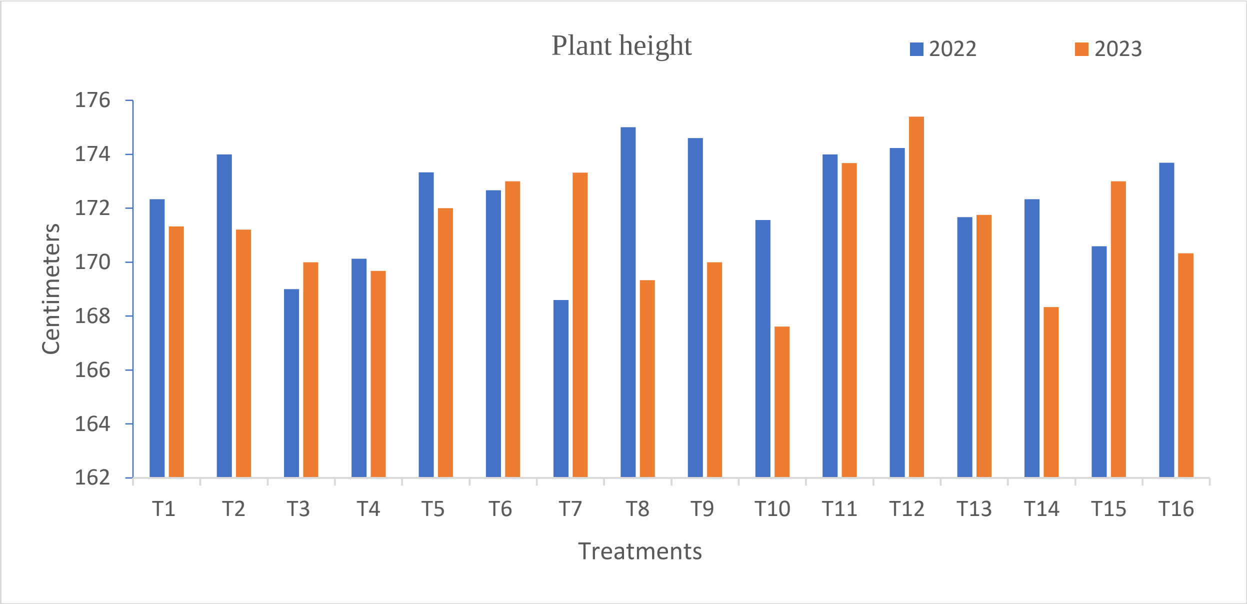

Figure 4.3 Plant height (cm) at harvest

Data pertaining to maize harvest plant height was recorded in field for two years. Same is presented in table 4.3 and figure 4.3. Plant height at harvest in different treatments ranged from 168.59 cm to 175 cm in 2022 and it varied between 167.61 cm and 175.40 cm in 2023. Plant height average of 2022 and 2023 varied from 170.12 to 171.33. It was highest in T_8 treatment and lowest in T_{14} treatments. A scrutiny of data indicates that maize height was maximum in T_8 (175) in 2022; where it was maximum in T_{12} (175.40) in 2023.Plant height was minimum in T_7 (168.59) in 2022; where it was minimum in T_{10} (167.61) in 2023. In 2022 T_{12} (100% RDF+ vermi-compost 2.5 t ha^{-1}) treatment is significantly higher in all treatments and in 2023 The significantly higher plant height given by 175.40 cm was might be due to more growth and development triggered by nitrogen as compared to other treatments. In general, the plant height was higher in almost in almost treatment in 2022 as compare to 2023. This may be due to the effect that 2022 maize growing season receive more rain fall than the 2023. These results are in good agreement with those of Hammad *et al.*, (2011), who found that increased nutrient intake, especially nitrogen, led to increased vegetative and reproductive growth. These findings are entirely consistent with those of Ali *et al.*, (1998), who observed increased growth following the administration of larger nitrogen dosages. According to research, plant height is a crucial measure of a plant's growth and development. For maize, differing nitrogen levels were found to have a major impact on plant height Iqbal, M. A. *et al*., (2015). Thus, seasonal variation in climate in both the years led to significant variation in the plant height data.

4.1.1.4 Length of maize cobs at harvest

Length (cm) of maize cobs recorded after harvest in an experimental field during 2022 and 2023. The data of the same are presented in table 4.4 and figure 4.4

Table 4.4 Length (cm) of maize cobs at harvest

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	18.9	17.93	18.42
2	T_2 = 75% RDF (Recommended dose of fertilizer)	20.23	19.90	20.07
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	19.83	19.50	19.67
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	20.03	20.53	20.28
5	T_5 = 75% RDF + Nano urea	19.93	19.57	19.75
6	T_6 = 75% RDF (3 Application timings)	19.17	19.83	19.50
7	T_7 = 75% RDF (2 Application timings)	19.00	19.33	19.17
8	T_8 = 75% RDF (4 Application timings)	19.73	20.37	20.05
9	T_9 = 75% RDF (Basal application timings)	18.83	19.43	19.13
10	T_{10} = 100% RDF (3 Applications)	19.20	19.53	19.37
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	20.40	20.83	20.62
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	20.30	19.97	20.14
13	T_{13} = 100 % RDF + Nano urea	20.70	20.67	20.69
14	T_{14} = 100% RDF (4 Application timings)	20.10	19.83	19.97
15	T_{15} = 100% RDF (2 Application timings)	20.90	20.87	20.92
16	T_{16} = 100% RDF (Basal application timings)	20.20	22.87	21.54
C.D.(P=0.05)		0.84	0.91	0.77
S.E.m. (±)		0.40	0.44	0.37

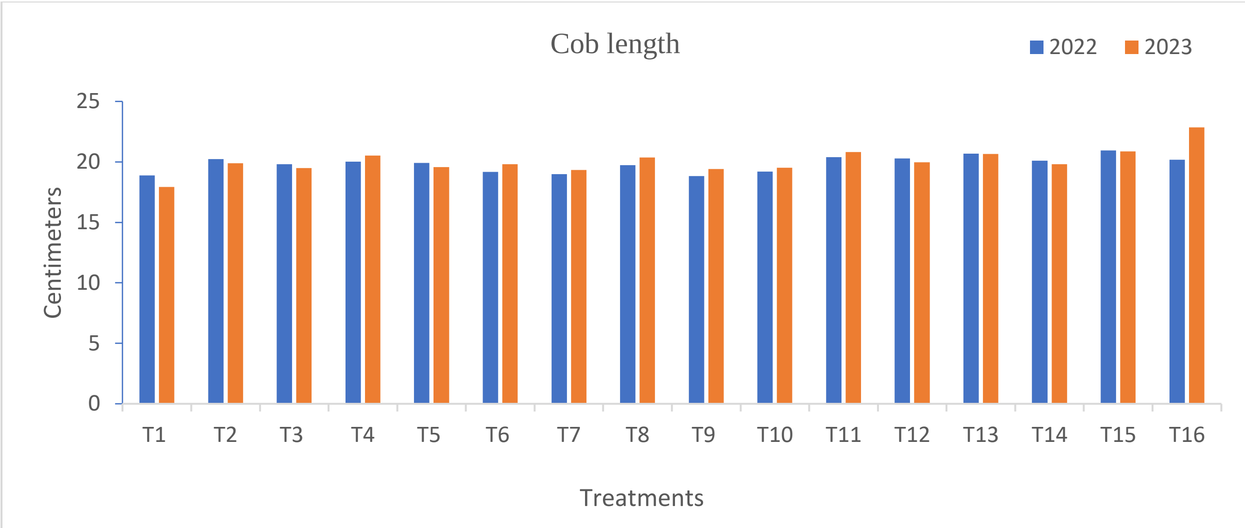

Figure 4.4 After harvest length of maize cobs

For two years, data on the length of cobs in maize plants was recorded in the field. Same is presented in table 4.4 and figure 4.4. Length (cm) of cobs at harvest in different treatments ranged from 18.83 cm to 20.97 cm in 2022 and it varied between 17.93cm and 22.87cm in 2023. Length (cm) of cobs at maize average of 2022 and 2023 varied from 18.83 to 19.37. It was higher T_{15} treatment and lower T_1 treatments. A scrutiny of data indicates that length (cm) of cobs was maximum in T_{15} (20.97) in 2022; where it was maximum in T_{16} (22.87) in 2023. Length (cm) of cobs was minimum in T_1 (18.9) in 2022; where it was minimum in T_1 (17.93) in 2023.significantly T_{15} treatments is higher than T_{11} and T_{14} treatments in 2022, T_{16} treatments is higher than T_{13} and T_{11} treatments in 2023. Because there was intense competition for nutrients, cob length reduced as plant population grew. Additionally, the shadowing impact of more plants resulted in smaller cobs. Increased competition among plants for resources such as water, sunlight, and nutrients may have inhibited the growth of individual plants, resulting in smaller cobs spaced closer together. The outcome perfectly aligns with the findings of Gaire *et al*., (2020)

4.1.1.5 Dry matter yield of maize

After harvesting of maize crop, dry matter yield was recorded during 2022 and 2023. The data of the same are presented in table 4.5 and figure 4.5

Table 4.5 Dry matter yield of maize (q/ha)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	34.11	30.29	32.20
2	T_2 = 75% RDF (Recommended dose of fertilizer)	61.92	53.76	57.84
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	55.01	46.68	50.85
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	59.44	49.75	54.59
5	T_5 = 75% RDF + Nano urea	55.34	46.68	51.01
6	T_6 = 75% RDF (3 Application timings)	55.13	43.00	49.07
7	T_7 = 75% RDF (2 Application timings)	63.70	52.64	58.17
8	T_8 = 75% RDF (4 Application timings)	65.81	56.62	61.22
9	T_9 = 75% RDF (Basal application timings)	60.09	52.06	56.08
10	T_{10} = 100% RDF (3 Applications)	71.30	66.14	68.72
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	67.05	63.07	65.06
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	71.61	60.02	65.81
13	T_{13} = 100 % RDF + Nano urea	63.95	56.36	60.16
14	T_{14} = 100% RDF (4 Application timings)	65.07	60.84	62.95
15	T_{15} = 100% RDF (2 Application timings)	62.83	52.15	57.49
16	T_{16} = 100% RDF (Basal application timings)	60.14	56.84	58.49
C.D.(P=0.05)		2.86	2.65	2.75
S.E.m. (±)		1.36	1.26	1.31

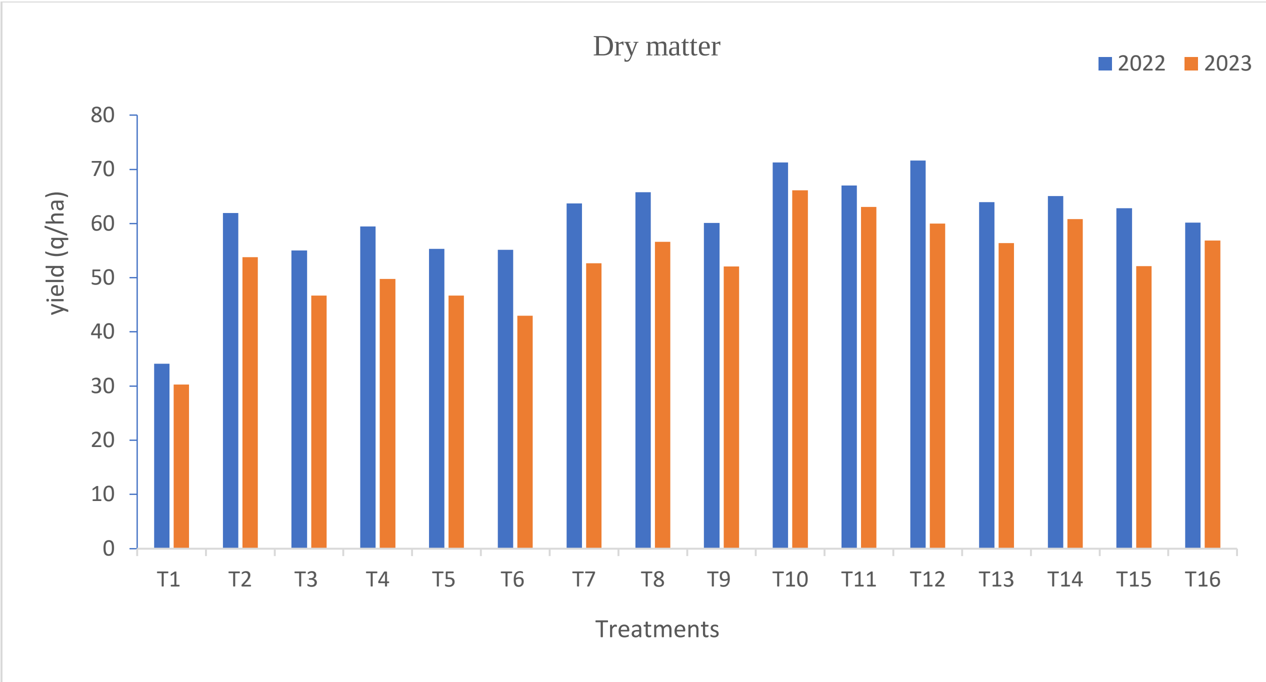

Figure 4.5 Dry matter yield of maize

Data pertaining to dry matter yield of maize (without cobs) (q/ha) was recorded in field for two years. Same is presented in table 4.5 and figure 4.5. dry matter yield of maize in different treatments ranged from 34.11 q/ha to 71.61 q/ha in 2022 and it varied between 30.29 q/ha and 66.14 q/ha in 2023. dry matter yield of maize average of 2022 and 2023 varied from 46.68 to 67.05. It was highest T_{12} treatment and lowest T_1 treatments. An examination of data indicated that dry matter yield of maize was maximum in T_{12} (71.61) in 2022; where as it was maximum in T_{10} (66.14) in 2023. Dry matter yield of maize was minimum in T_1 (34.11) in 2022; where it was minimum in T_1 (30.29) in 2023. In 2022 T_{12} (100% RDF+ vermi-compost 2.5 t ha^{-1}) treatment is significantly higher in T_{10} treatments and in 2023 T_{10} (100% RDF 3 Applications) treatments significantly higher than others treatments. Where fertilizers are an instantaneous source of nutrients and they also accelerate the mineralization of organic compounds Kováčik P (2009). rainfall and temperature play key role in production of dry matter, Similar findings were reported by Keerthi, *et al.*, (2017), Umesh *et al.*, (2017) The outcomes are consistent with the research conducted by Mohapatro *et al*., (2021), Zhang *et al*., (2023), and Liu *et al.*, (2023).

4.1.1.6 Weight of maize cobs after harvest

After harvest the plants weight of cobs were recorded during 2022 and 2023. The data of the same are presented in table 4.6 and figure 4.6

Table 4.6 Weight of maize cobs after harvest (q/ha)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	71.70	68.60	70.15
2	T_2 = 75% RDF (Recommended dose of fertilizer)	83.50	80.63	82.07
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	81.83	69.77	75.80
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	87.19	70.10	78.65
5	T_5 = 75% RDF + Nano urea	87.27	67.59	77.43
6	T_6 = 75% RDF (3 Application timings)	82.87	69.10	75.99
7	T_7 = 75% RDF (2 Application timings)	84.03	80.43	82.23
8	T_8 = 75% RDF (4 Application timings)	87.00	82.90	84.95
9	T_9 = 75% RDF (Basal application timings)	90.13	86.10	88.12
10	T_{10} = 100% RDF (3 Applications)	86.83	79.03	82.93
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	89.27	87.90	88.59
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	89.63	92.57	91.10
13	T_{13} = 100 % RDF + Nano urea	83.67	84.37	84.02
14	T_{14} = 100% RDF (4 Application timings)	94.97	90.83	92.90
15	T_{15} = 100% RDF (2 Application timings)	85.17	80.00	82.59
16	T_{16} = 100% RDF (Basal application timings)	75.70	77.20	76.45
C.D.(P=0.05)		3.80	3.70	3.29
S.E.m. (±)		1.81	1.76	1.57

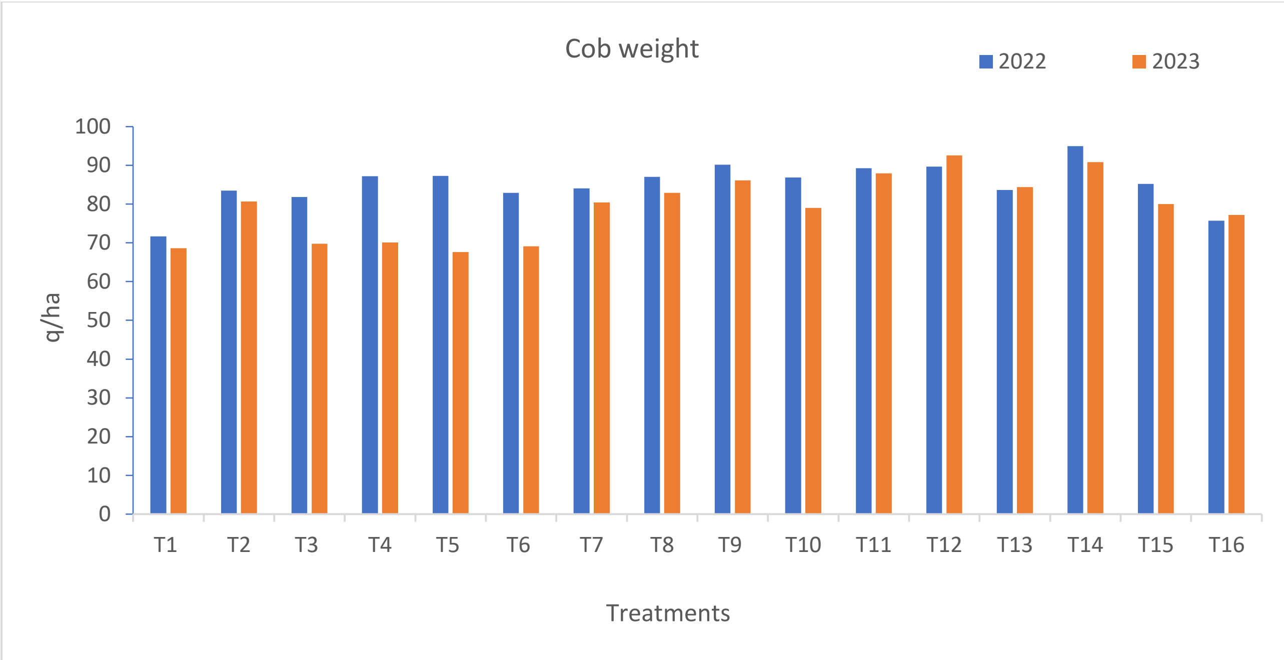

Figure 4.6 weight of maize cobs after harvest (q/ha)

For two years, data on weight of maize cobs (q/ha) was recorded in field for two years. Same is presented in table 4.6 and figure 4.6, weight of maize cobs in different treatments ranged from 71.7q/ha to 94.97q/ha in 2022 and it varied between 68.6 q/ha and 92.57 q/ha in 2023. Weight of maize cobs average of 2022 and 2023 varied from 68.6 to 90.83. It was higher T_{14} treatment and lower T_1 treatments. An examination of data indicated that weight of maize cobs was maximum in T_{14} (94.97) in 2022; where it was maximum in T_{12} (92.57) in 2023. weight of maize cobs was minimum in T_1 (71.7) in 2022; where it was minimum in T_1 (68.6) in 2023. The weight of cobs with cornhusk illustrates the amount of photosynthates that are transferred to cobs. Wibowo *et al.*, (2017) and Govind *et al.*, (2017) investigated the performance of maize hybrids with regard to growth indices and phenological early phases under various treatment planting in *kharif* season.

4.1.1.7 Weight of the maize grains

Air dry weight of maize grain data was recorded in between 2022 and 2023. The data of the same are presented in table 4.7 and figure 4.7

Table 4.7 Weight of the maize grains (q/ha)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	22.89	20.33	21.61
2	T_2 = 75% RDF (Recommended dose of fertilizer)	41.56	36.08	38.82
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	36.92	31.33	34.13
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	39.89	33.39	36.64
5	T_5 = 75% RDF + Nano urea	37.14	30.33	33.74
6	T_6 = 75% RDF (3 Application timings)	37.00	28.86	32.93
7	T_7 = 75% RDF (2 Application timings)	42.75	35.33	39.04
8	T_8 = 75% RDF (4 Application timings)	44.17	38.00	41.09
9	T_9 = 75% RDF (Basal application timings)	40.33	34.94	37.64
10	T_{10} = 100% RDF (3 Applications)	47.85	40.39	44.12
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	45.00	42.33	43.67
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	48.06	44.28	46.17
13	T_{13} = 100 % RDF + Nano urea	42.92	37.83	40.38
14	T_{14} = 100% RDF (4 Application timings)	43.67	40.83	42.25
15	T_{15} = 100% RDF (2 Application timings)	42.17	35.00	38.59
16	T_{16} = 100% RDF (Basal application timings)	40.36	38.17	39.27
C.D.(P=0.05)		1.92	1.77	1.85
S.E.m. (±)		0.92	0.85	0.88

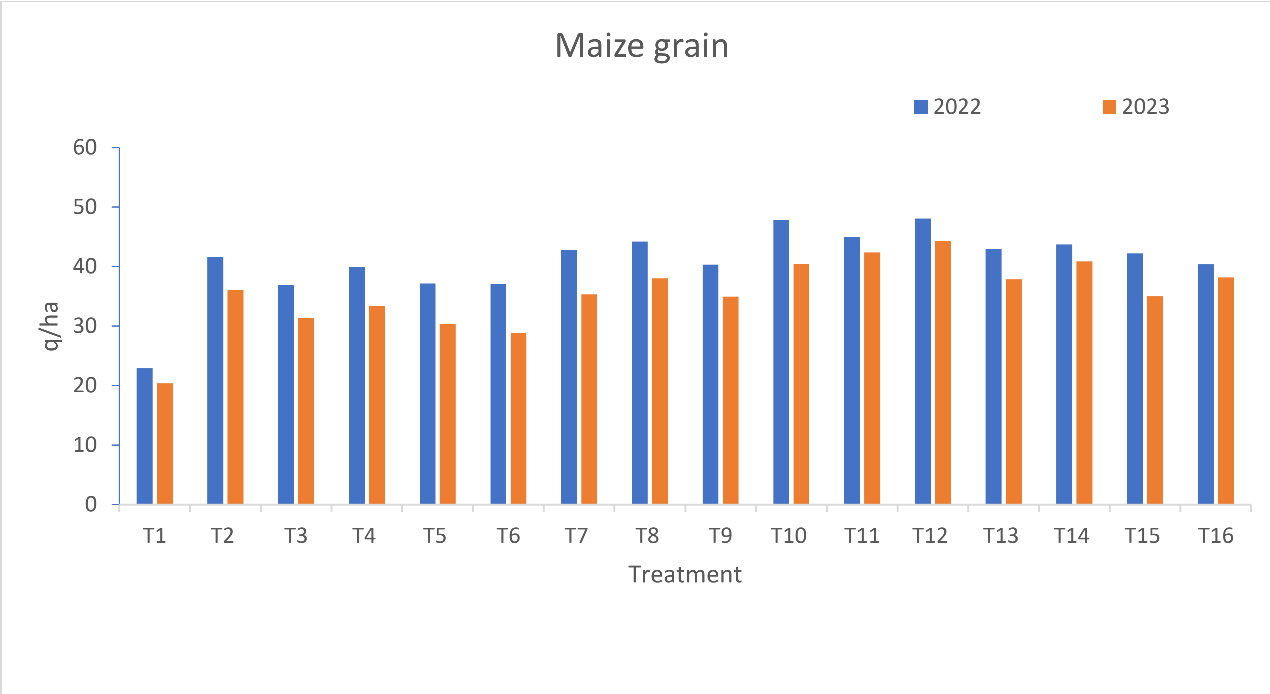

Figure 4.7 weight of the maize grains

Data pertaining to weight of maize grains (q/ha) was recorded in field for two years. Same is presented in table 4.7 and figure 4.7. Weight of maize grains in different treatments ranged from 22.89 q/ha to 48.06 q/ha in 2022 and it varied between 20.33 q/ha and 44.28 q/ha in 2023. Weight of maize grains average of 2022 and 2023 varied from 37.14 to 40.39. It was highest T_{12} treatment and lowest T_1 treatments. An examination of data indicated that weight of maize grains was maximum in T_{12} (48.06) in 2022; where it was maximum in T_{12} (44.39) in 2023. weight of the maize grains was minimum in T_1 (22.89) in 2022; where it was minimum in T_1 (20.33) in 2023. In 2022 T_{12} (100% RDF+ vermi-compost 2.5 t ha^{-1}) treatments significantly higher all treatments and in 2023 T_{12} (100% RDF 3 Applications) significantly higher all treatments, in measuring the impact of technologies or other factors on a crop and ensuring a viable yield for farmers, grain yield is an essential metric. In the end, the amount of dry matter that the plant produces throughout its vegetative growth time determines the crop's economic yield. With respect to grain yield the performance of T_{13} where nano urea has been used in along with RDF was not superior than the treatment T_{10} were only RDF was applied. However, the treatment T_{12} where the vermi-compost was applied along with recommended dose of fertilizer produced maximum yield this may be due to the integrated effect of the vermi-compost along with inorganic fertilizers. The grain yield of hybrid maize PMH-13 was significantly influenced by both different doses of nitrogen doses and fertilizer application of nitrogen in coarse loamy soils of Punjab during *kharif* season of 2022 and 2023. One of the most important metrics for agricultural development is crop productivity per unit area. Estimating crop area and harvested product quantities are integral parts of estimating agricultural yield. According to Sud *et al.*, (2016), grain yields decreased with delayed planting, but increased when planting was finished by early May. The lengthier growth period and relatively mild temperatures throughout the grain formation period may be the cause of this yield discrepancy. may use the season predictions to guide their decision-making. Solomon *et al*., (2017) suggested that to maximize chances for increased yields, seasonal weather forecasts should guide the choice of densities for maize plants. The increased grain yield with reduced spacing may result from effective use of the light, water, and fertilizer resources that are available Golla *et al*., (2018)

4.1.2 Laboratory analysis of plant samples

Under these studies experiments were conducted in laboratory to understand nutrient content in different plant attributes. The percentage of nitrogen, percentage of phosphorous and percentage of potassium data in dry matter and grain of maize are appended in appendix 1 to appendix 6. Data on total nitrogen uptake, total phosphorous uptake, total potassium uptake, were recorded and are discussed in table number 4.8, 4.9, 4.10, 4.11, 4.12, 4.13.and figure number 4.8, 4.9, 4.10, 4.11, 4.12, 4.13.

4.1.2.1 Nitrogen uptake in dry matter of plant

After harvest in plant, plant sample had analyzed in laboratory and total nitrogen data are estimated in between 2022 and 2023. The data of the same are presented in table 4.8 and figure 4.8

Table 4.8 Total nitrogen uptake in dry matter of plant (kg ha^{-1})

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	20.15	21.39	20.77
2	T_2 = 75% RDF (Recommended dose of fertilizer)	23.89	20.67	22.28
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	27.54	27.98	27.76
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	29.09	31.54	30.32
5	T_5 = 75% RDF + Nano urea	30.01	30.98	30.50
6	T_6 = 75% RDF (3 Application timings)	25.38	24.78	25.08
7	T_7 = 75% RDF (2 Application timings)	24.56	24.90	24.73
8	T_8 = 75% RDF (4 Application timings)	27.05	28.54	27.80
9	T_9 = 75% RDF (Basal application timings)	22.42	20.14	21.28
10	T_{10} = 100% RDF (3 Applications)	24.67	23.56	24.12
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	27.87	29.32	28.60
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	32.45	33.29	32.87
13	T_{13} = 100 % RDF + Nano urea	31.29	30.84	31.07
14	T_{14} = 100% RDF (4 Application timings)	27.67	26.79	27.23
15	T_{15} = 100% RDF (2 Application timings)	24.75	25.11	24.93
16	T_{16} = 100% RDF (Basal application timings)	23.51	22.71	23.11
C.D.(P=0.05)		1.35	1.38	1.42
S.E.m. (±)		0.62	0.63	0.65

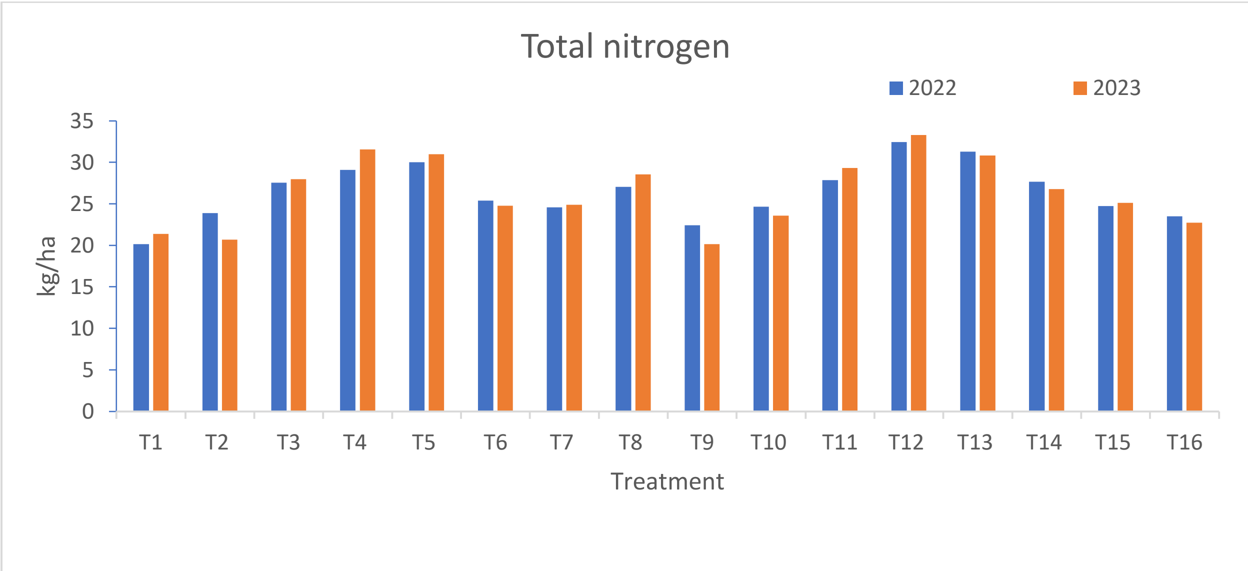

Figure 4.8 Total nitrogen uptake in dry matter of plant

Total nitrogen uptake in dry biomass of maize, for the two-year experimental period is presented in table 4.8 and figure 4.8. Total nitrogen uptake dry matter in plant on different treatments ranged from 20.15 kg ha^{-1} to 32.45 kg ha^{-1} in 2022 and it varied between 20.67 kg ha^{-1} and 33.29 kg ha^{-1} in 2023. Total nitrogen uptake dry matter in plant average of 2022 and 2023 varied from 24.78 to 30.84. It was highest T_{12} treatment and lowest T_1 treatments. An examination of data indicates that total nitrogen uptake dry matter in plant was maximum in T_{12} (32.45) in 2022; where it was maximum in T_{12} (33.29) in 2023. total nitrogen uptake dry matter in plant was minimum in T_1 (20.15) in 2022; where it was minimum in T_2 (20.67) in 2023. In 2022 this treatment T_{12} (32.45) kg/ha significantly higher among T_{13} and T_5 treatments and in 2023 this T_{12} (33.29) kg/ha treatments significantly higher in T_{13} and T_{11} treatments. This may be due to the effect that 2022 maize growing season received more rain fall than the 2023. According to Bak *et al.*, (2016), maize is a crop that reacts delicately to applied mineral fertilization, which has an impact on plant biomass nitrogen buildup as well as yields (George *et al.,* 2016). The uptake of N, P, and K nutrients is essential for increasing yield and nutrient content. Nutrient intake may be enhanced by a significant increase in yield or nutrient content. Any nutrient's absorption depends on its composition and the crop's ability to produce dry matter. The relevant cause for increased nutrient intake may be attributed to enhanced biomass production in maize and higher nutrient content in products. These results closely match the ones that were published by Pandey and Awasthi (2014), Subbaiah and Ram (2019) and Verma and Bindra (2019)

4.1.2.2 Total phosphorus uptake in dry matter of plant

After harvest in plant, plant sample were analysed in laboratory and total phosphorus data were recorded for 2022 and 2023. The data of the same are presented in table 4.9 and figure 4.9

Table 4.9 Total phosphorus uptake in dry matter of plant (kg ha^{-1})

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	6.00	5.6	5.80
2	T_2 = 75% RDF (Recommended dose of fertilizer)	7.70	6.6	7.15
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	6.10	4.9	5.50
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	9.60	8.00	8.80
5	T_5 = 75% RDF + Nano urea	9.80	9.20	9.50
6	T_6 = 75% RDF (3 Application timings)	11.30	8.10	9.70
7	T_7 = 75% RDF (2 Application timings)	7.90	5.80	6.85
8	T_8 = 75% RDF (4 Application timings)	6.70	4.60	5.65
9	T_9 = 75% RDF (Basal application timings)	11.80	11.00	11.40
10	T_{10} = 100% RDF (3 Applications)	10.80	8.10	9.45
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	10.20	8.60	9.40
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	12.30	9.60	10.95
13	T_{13} = 100 % RDF + Nano urea	10.20	10.40	10.30
14	T_{14} = 100% RDF (4 Application timings)	9.60	8.40	9.00
15	T_{15} = 100% RDF (2 Application timings)	11.10	9.50	10.30
16	T_{16} = 100% RDF (Basal application timings)	11.40	9.60	10.50
C.D.(P=0.05)		0.49	0.44	0.27
S.E.m. (±)		0.23	0.21	0.13

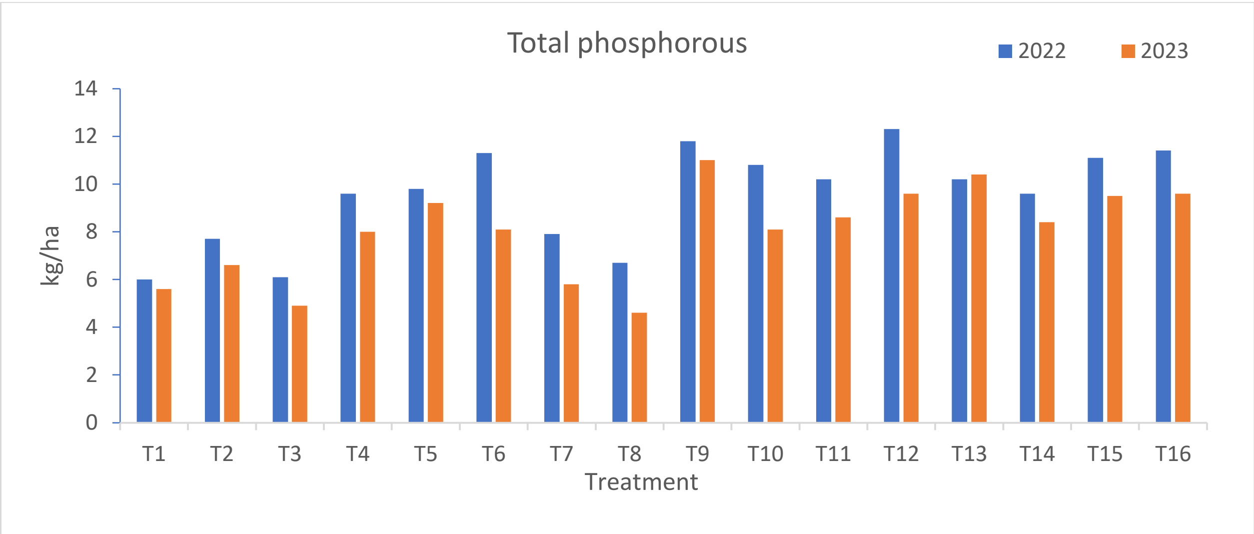

Figure 4.9 Total phosphorus uptakes in dry matter of plant

Total phosphorus uptake in the dry matter of maize, for the two-year experimental period is presented in table 4.9 and figure 4.9. Total phosphorus dry matter in plant on different treatments ranged from 6 kg ha^{-1} to 12.3 kg ha^{-1} in 2022 and it varied between 4.6 kg ha^{-1} and 11 kg ha^{-1} in 2023. Total phosphorous dry matter in plant average of 2022 and 2023 varied from 6 to 12.3 It was highest T_{12} treatment and lowest T_1 treatments. An examination of data indicates that total phosphorus dry matter in plant was maximum in T_{12} (12.3) in 2022; where it was maximum in T_9 (11) in 2023. total phosphorus dry matter in plant was minimum in T_1 (6) in 2022; where it was minimum in T_8 (4.6) in 2023. In 2022 this treatment T_{12} significantly higher in treatments and in 2023 this T_9 (75% RDF Basal application timings) kg/ha treatments significantly higher in all treatments. The results of the experiment could have been influenced by variations in the weather and soil conditions throughout the course of the two years, as the phosphorus values were the lowest in 2023 and differed significantly from the other data. The exceptionally hot summer of 2022 may have been a prerequisite for plants' reduced phosphorus uptake. Many variables, including soil pH, temperature, and humidity, the presence of various ions in the solution, and the soil's organic matter content, affect how much phosphorus is available to plants, (Shep-pard and Racz 1984).

4.1.2.3 Total potassium in dry matter of maize plants

After harvesting, grain samples were analyzed in laboratory and total potassium data were recorded for 2022 and 2023. The data of the same are presented in table 4.10 and figure 4.10

Table 4.10 Total potassium uptake in dry matter of plant (kg ha^{-1})

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	16.12	15.92	16.02
2	T_2 = 75% RDF (Recommended dose of fertilizer)	16.32	17.72	17.02
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	27.56	26.68	27.12
4	T_4 = 75% RDF+ Vermi-compost 2.5 t ha^{-1}	27.60	27.12	27.36
5	T_5 = 75% RDF + Nano urea	29.24	28.68	28.96
6	T_6 = 75% RDF (3 Application timings)	19.40	29.48	24.44
7	T_7 = 75% RDF (2 Application timings)	15.08	19.92	17.50
8	T_8 = 75% RDF (4 Application timings)	20.72	18.00	19.36
9	T_9 = 75% RDF (Basal application timings)	16.00	17.13	16.57
10	T_{10} = 100% RDF (3 Applications)	22.40	19.72	21.04
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	29.12	30.76	29.94
12	T_{12} = 100% RDF+ Vermi-compost 2.5 t ha^{-1}	20.04	22.72	21.38
13	T_{13} = 100 % RDF + Nano urea	21.60	20.32	20.96
14	T_{14} = 100% RDF (4 Application timings)	19.36	19.44	19.40
15	T_{15} = 100% RDF (2 Application timings)	15.68	16.16	15.92
16	T_{16} = 100% RDF (Basal application timings)	16.60	17.36	16.98
C.D.(P=0.05)		1.17	1.23	1.20
S.E.m. (±)		0.56	0.59	0.57

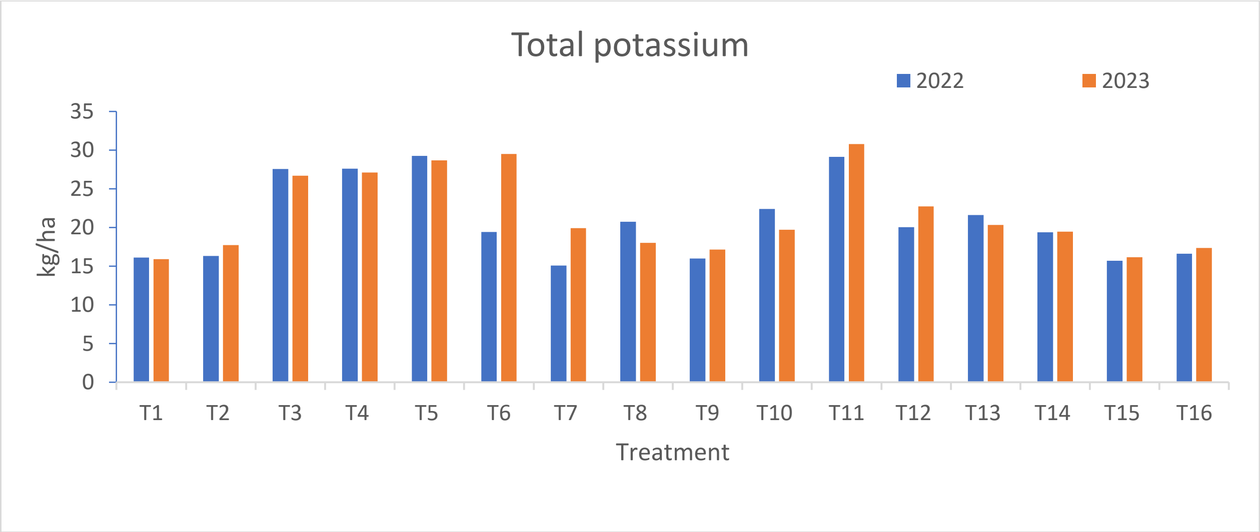

Figure 4.10 Total potassium uptake in dry matter of plant

Total potassium uptake in the dry matter of maize, for the two-year experimental period is presented in table 4.10 and figure 4.10. Total potassium dry matter in plant on different treatments ranged from 15.08 kg ha^{-1} to 29.24 kg ha^{-1} in 2022 and it varied between 15.92 kg ha^{-1} and 30.76 kg ha^{-1} in 2023. Total potassium dry matter in plant average of 2022 and 2023 varied from 15.08 to 30.76 It was highest T_{11} treatment and lowest T_7 treatments. An examination of data indicates that total potassium dry matter in plant was maximum in T_5 (29.24) in 2022; where it was maximum in T_{11} (30.76) in 2023. Total potassium dry matter in plant was minimum in T_7 (15.08) in 2022; where it was minimum in T_1 (15.92) in 2023. In 2022 this treatment T_5 (75% RDF + Nano urea) significantly higher among T_{11} and T_4 treatments and in 2023 this T_{12} treatments significantly higher in T_6 and T_5 treatments. In different treatments, like nitrogen and phosphorus, the dry biomass's potassium level fluctuated. The T_5 and T_{11} treatments had the highest potassium concentration. The study conducted by Bak *et al*., (2016) revealed that the potassium level in the maize stems was likewise greater.

4.1.2.4 Total nitrogen uptake in maize grain

After harvesting grain samples were analyzed in laboratory and total nitrogen data were recorded for 2022 and 2023. The data of the same are represented in Figure 4.11 and Table 4.11

Table 4.11 Total nitrogen uptake in maize grain (kg ha^{-1})

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	30.23	28.34	29.29
2	T_2 = 75% RDF (Recommended dose of fertilizer)	34.11	33.28	33.70
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	41.29	44.38	42.84
4	T_4 = 75% RDF+ Vermi-compost 2.5 t ha^{-1}	44.58	48.69	46.64
5	T_5 = 75% RDF + Nano urea	43.56	47.78	45.67
6	T_6 = 75% RDF (3 Application timings)	48.90	47.40	48.15
7	T_7 = 75% RDF (2 Application timings)	35.76	39.12	37.44
8	T_8 = 75% RDF (4 Application timings)	45.78	48.53	47.16
9	T_9 = 75% RDF (Basal application timings)	36.88	35.94	36.41
10	T_{10} = 100% RDF (3 Applications)	38.67	37.59	38.13
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	39.89	47.85	43.87
12	T_{12} = 100% RDF+ Vermi-compost 2.5 t ha^{-1}	48.93	51.25	50.09
13	T_{13} = 100 % RDF + Nano urea	47.19	51.34	49.27

14	T_{14} = 100% RDF (4 Application timings)	39.75	44.57	42.16
15	T_{15} = 100% RDF (2 Application timings)	39.54	39.17	39.36
16	T_{16} = 100% RDF (Basal application timings)	35.10	34.39	34.75
C.D.(P=0.05)		1.96	2.05	2.00
S.E.m. (±)		0.93	0.98	0.95

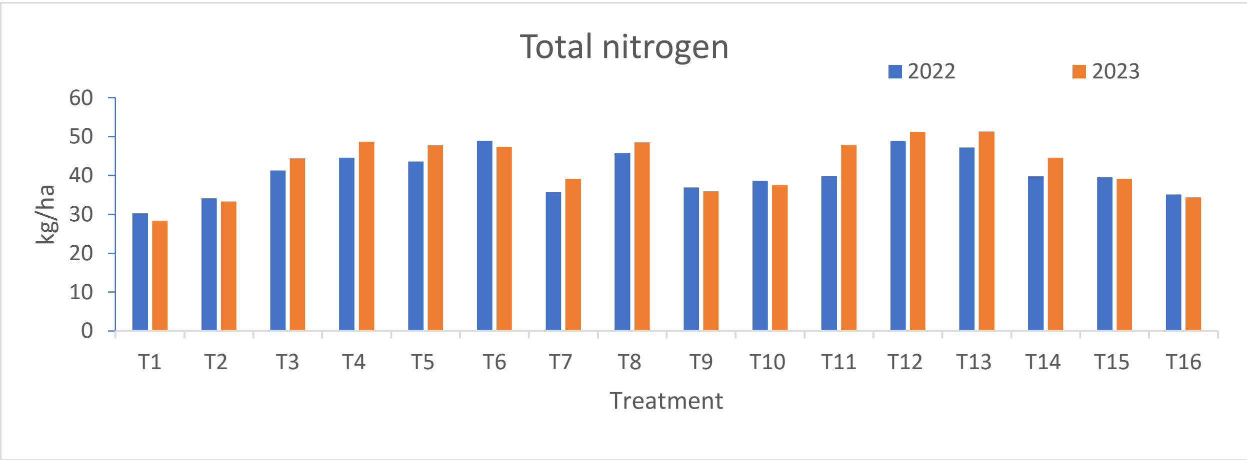

Figure 4.11 Total nitrogen uptake in maize grain

Data pertaining to total nitrogen in maize grain (kg ha^{-1}) was recorded two years. Same is presented in table 4.11 and figure 4.11. Total nitrogen uptake in maize grain in different treatments ranged from 30.23 kg/ha to 48.93 kg ha^{-1} in 2022 and it varied between 28.34 kg ha^{-1} and 51.34 kg ha^{-1} in 2023. Weight of maize grains average of 2022 and 2023 varied from 35.76 to 48.53. It was highest T_{15} treatment and lowest T_1 treatments. An examination of data indicates that total nitrogen in maize grain was maximum in T_{12} (48.93) in 2022; where it was maximum in T_{13} (51.34) in 2023. Total nitrogen in maize grain was minimum in T_1 (30.23) in 2022; where it was minimum in T_1 (28.34) in 2023. In 2022 T_{12} (100% RDF+ Vermi-compost 2.5 t ha^{-1}) treatments significantly higher in T_{13} treatments and in 2023 T_{13} treatments significantly higher in T_{12} treatments, depending on the year of the experiment, there was a greater variation in the proportion of nitrogen in the maize grain; also, the grain had accumulated nitrogen in 2022 and 2023. However, in this case, it was statistically significant. This could be explained by the nitrogen losses brought on by the heavy rains in 2020. Variations in fertilizations contributed a certain proportion of variance and had a notable effect. When examining the grain's nitrogen percentage content in relation to various fertilizer doses, it was observed that, at the highest fertilizer dose (T_{13} treatments), the nitrogen content somewhat decreased in comparison to T_{14} and T_{15} treatments, where the grain's nitrogen values were higher and significantly different from those of the control treatment. The amount of fertilizer applied had a significant impact on the average nitrogen content of maize grains. Similar results were obtained by Bak *et al.*, (2016) They found that average nitrogen content of the maize grain of the variants with fertilization was about 1.51% to1.53%.

4.1.2.5 Total phosphorus uptake in maize grain

After harvesting grain samples were analyzed in laboratory and total phosphorus data were recorded for 2022 and 2023. The data of the same are presented in table 4.12 and figure 4.12

Table 4.12 Total phosphorus uptake in maize grain (kg ha^{-1})

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	7.21	7.20	7.21
2	T_2 = 75% RDF (Recommended dose of fertilizer)	8.32	7.56	7.94
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	11.45	10.65	11.05
4	T_4 = 75% RDF+ Vermi-compost 2.5 t ha^{-1}	11.68	10.19	10.94
5	T_5 = 75% RDF + Nano urea	10.76	9.33	10.05
6	T_6 = 75% RDF (3 Application timings)	8.31	7.90	8.11
7	T_7 = 75% RDF (2 Application timings)	7.43	7.10	7.27
8	T_8 = 75% RDF (4 Application timings)	9.17	9.06	9.12
9	T_9 = 75% RDF (Basal application timings)	8.08	9.28	8.68
10	T_{10} = 100% RDF (3 Applications)	9.85	9.52	9.69
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	11.98	10.38	11.18
12	T_{12} = 100% RDF+ Vermi-compost 2.5 t ha^{-1}	11.10	12.62	12.36
13	T_{13} = 100 % RDF + Nano urea	10.89	11.30	11.10
14	T_{14} = 100% RDF (4 Application timings)	8.67	8.94	8.81
15	T_{15} = 100% RDF (2 Application timings)	8.10	7.12	7.61
16	T_{16} = 100% RDF (Basal application timings)	8.04	7.91	7.98
C.D.(P=0.05)		0.48	0.52	0.47
S.E.m. (±)		0.23	0.25	0.21

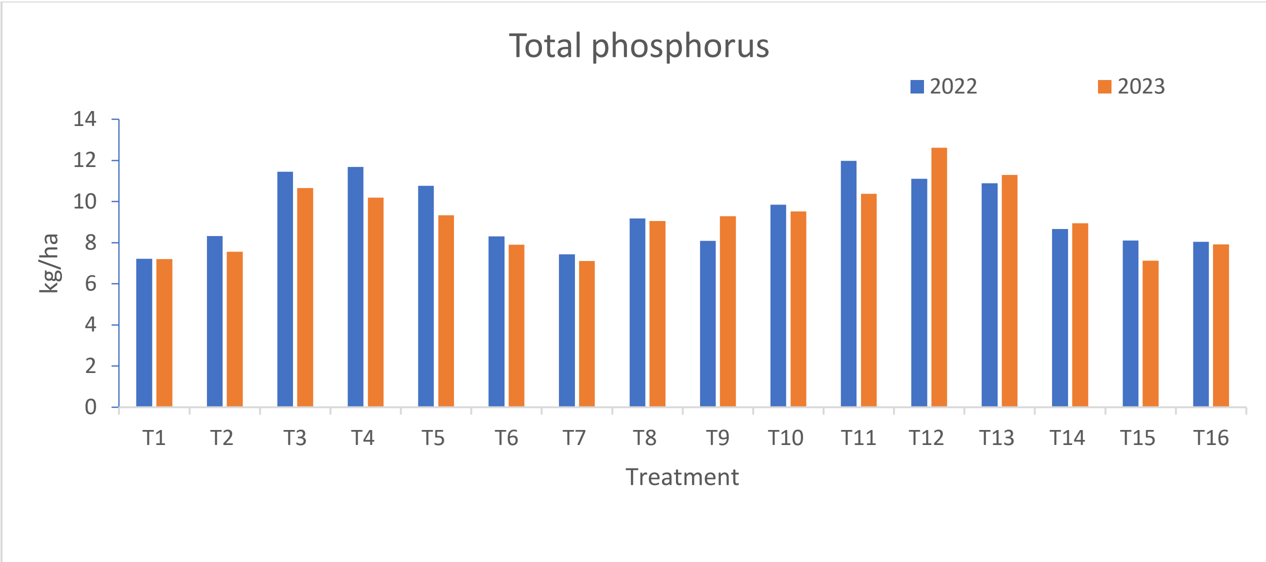

Figure 4.12 Total phosphorus uptake in maize grain

For two years, data on the total phosphorus in maize grain plants were recorded. Same are presented in table 4.12 and figure 4.12. Total phosphorus in maize grain in different treatments ranged from 7.21 kg ha^{-1} to 11.98 kg ha^{-1} in 2022 and it varied between 7.10 kg ha^{-1} to 12.62 kg/ha in 2023, total phosphorus in maize grain average of 2022 and 2023 varied from 8.31 to 9.85. It was highest T_{11} treatment and lowest T_7 treatments. An examination of data indicates that total phosphorus in maize grain was maximum in T_{11} (11.98) in 2022; where it was maximum in T_{12} (12.62) in 2023. Total phosphorus in maize grain was minimum in T_1 (7.21) in 2022; where it was minimum in T_7 (7.10) in 2023. In 2022 T_{11} treatments significantly higher T_3, T_4, T_{12} treatments and in 2023 T_{12} treatments significantly higher in T_{11} and T_{13} treatments, depending on the year of the experiment, there was a greater variation in the proportion of phosphorus in the maize grain; also, the grain had accumulated phosphorus in 2022 and 2023. The overall phosphorus level in the T_{12} treatment fertilizer dose was the greatest. Grain phosphorus content was highly impacted by the year of the experiment and the type of fertilizer used. Although the values varied within very narrow range (Nenova *et al.*, 2019).

4.1.2.6 Total potassium uptake in maize grain

After harvesting grain samples had analyzed in laboratory and total potassium data were recorded for 2022 and 2023. The data of the same are presented in table 4.13 and figure 4.13

Table 4.13 Total potassium uptake in maize grain (kg ha^{-1})

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	15.80	16.20	16.00
2	T_2 = 75% RDF (Recommended dose of fertilizer)	18.12	16.00	17.60
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	20.21	26.65	23.43
4	T_4 = 75% RDF+ Vermi-compost 2.5 t ha^{-1}	19.98	20.19	20.09
5	T_5 = 75% RDF + Nano urea	18.67	18.33	18.50
6	T_6 = 75% RDF (3 Application timings)	16.31	18.9	17.61
7	T_7 = 75% RDF (2 Application timings)	16.43	16.10	16.27
8	T_8 = 75% RDF (4 Application timings)	16.17	16.06	16.12
9	T_9 = 75% RDF (Basal application timings)	16.08	16.28	16.18
10	T_{10} = 100% RDF (3 Applications)	16.43	16.43	16.43
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	21.98	28.38	25.18
12	T_{12} = 100% RDF+ Vermi-compost 2.5 t ha^{-1}	25.10	29.62	27.36
13	T_{13} = 100 % RDF + Nano urea	25.89	28.30	27.10
14	T_{14} = 100% RDF (4 Application timings)	20.67	18.94	19.81
15	T_{15} = 100% RDF (2 Application timings)	16.10	16.12	16.11
16	T_{16} = 100% RDF (Basal application timings)	16.04	15.91	15.98
C.D.(P=0.05)		1.04	1.18	1.09
S.E.m. (±)		0.49	0.56	0.52

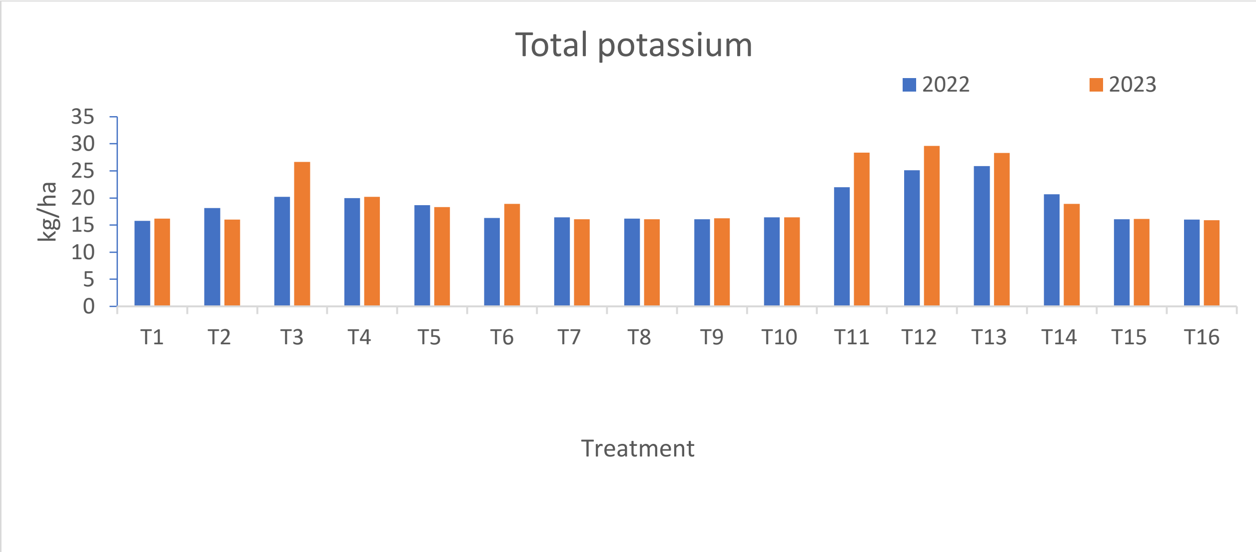

Figure 4.13 Total potassium uptake in maize grain

For two years, data on the total potassium in maize grain plants were recorded. Same are presented in table 4.13 and figure 4.13. Total potassium in maize grain in different treatments ranged from 15.80 kg ha^{-1} to 25.89 kg ha^{-1} in 2022 and it varied between 16.00 kg ha^{-1} to 29.62 kg ha^{-1} in 2023, total potassium in maize grain average of 2022 and 2023 varied from 16.43 to 18.90. It was highest T_{11} treatment and lowest T_1 treatments. An examination of data indicates that total potassium in maize grain was maximum in T_{13} (25.89) in 2022; where it was maximum in T_{12} (29.62) in 2023. Total phosphorus in maize grain was minimum in T_1 (15.80) in 2022; where it was minimum in T_2 (16.00) in 2023. In 2022 T_{13} treatments significantly higher T_{12} treatments and in 2023 T_{12} treatments significantly higher in T_{11} and T_{13} treatments, A larger yield is finally achieved when there is adequate supply of potassium, which keeps the plant almost normal even during drought conditions. Potassium helps the plant absorb more water to reach turgidity, which improves the water relations under water stress (Subbarao *et al.*, 2000). Amanullah *et al.*, (2016) reported that under drought stress circumstances, potassium applied topically and topically in the soil enhanced maize growth, yield, and yield components.

.4.1.3 Soil characteristics before sowing and after harvesting of the maize crop

For experiments 1. Soil characteristics of the soil samples collected before sowing and after the crop's harvest, the same data is presented in tables 4.14 to 4.27 and figure no 4.14 to 4.27. Same are discussed in the succeeding paragraphs.

4.1.3.1. Soil pH before sowing and after harvest in 2022

Soil pH data of samples collected before sowing and after harvesting of maize crop for 2022 are presented in table 4.14 and figure 4.14. Same are discussed below

Table 4.14 Before sowing and after harvest soil pH

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T1 = Absolute control	7.5	7.6	7.55
2	T2 = 75% RDF (Recommended dose of fertilizer)	7.6	7.5	7.50
3	T3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	7.6	7.6	7.60
4	T4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	7.6	7.6	7.60
5	T5 = 75% RDF + Nano urea	7.7	7.6	7.60
6	T6 = 75% RDF (3 Application timings)	7.6	7.5	7.55
7	T7 = 75% RDF (2 Application timings)	7.5	7.6	7.50
8	T8 = 75% RDF (4 Application timings)	7.5	7.5	7.50
9	T9 = 75% RDF (Basal application timings)	7.5	7.5	7.50
10	T10 = 100% RDF (3 Applications)	7.6	7.5	7.55
11	T11 = 100% RDF + FYM 5 t ha^{-1}	7.5	7.6	7.65
12	T12 = 100% RDF+ vermi-compost 2.5 t ha^{-1}	7.6	7.5	7.50
13	T13 = 100 % RDF + Nano urea	7.5	7.5	7.55
14	T14 = 100% RDF (4 Application timings)	7.6	7.6	7.60
15	T15 = 100% RDF (2 Application timings)	7.5	7.5	7.55
16	T16 = 100% RDF (Basal application timings)	7.5	7.6	7.50

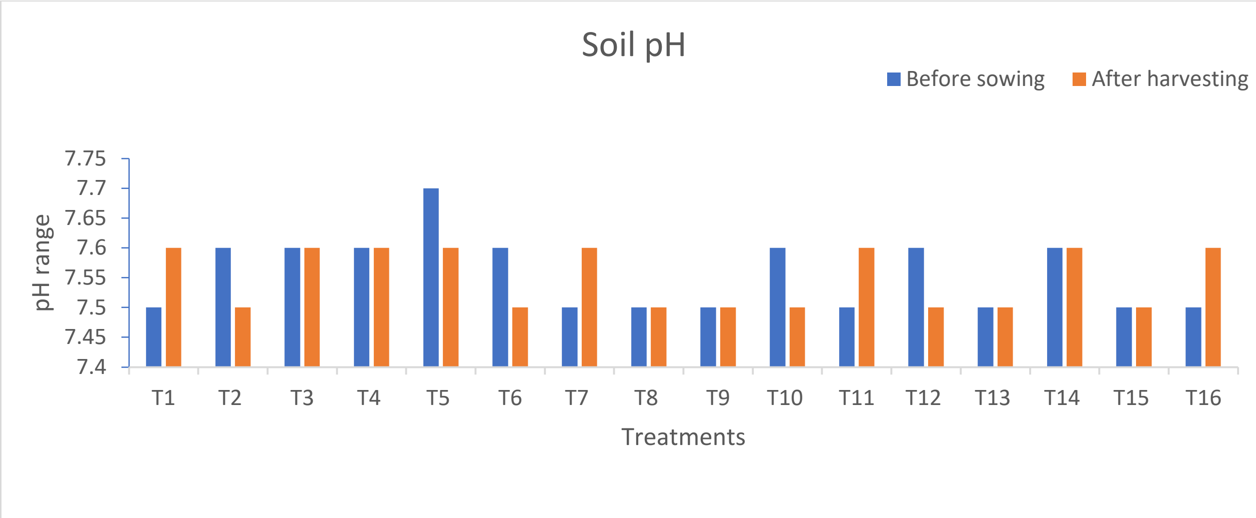

Figure 4.14 Soil pH in 2022

Before sowing and after harvest soil collected in an experimental field and it analyzed in laboratory, data are presented table 4.14 and figure 4.14 in the year 2022. Before sowing soil pH was found highest in treatments T_5 (7.7) and lowest in treatments T_1, T_7, T_8, T_9, T_{11}, T_{13}, T_{15}, T_{16} treatments (7.5). In after harvest soil pH was highest in treatments $T_{1,}$ T_3, $T_{4,}$ T_5, $T_{7,}$ $T_{11,}$ $T_{14,}$ T_{16} (7.7) and lowest in treatments T_2, T_6, T_8, T_9, T_{10}, T_{12}, T_{13}, T_{15} (7.5). However, there is not much change the soil pH before and after the harvest of soil crop, the soils in Punjab are mostly alkaline in nature. The pH of most soils range between 7.0-8.2 (Makkar *et al.*, 2018).

4.1.3.2. Soil pH before sowing and after harvest in 2023

Soil pH data of samples collected before sowing and after harvesting of maize crop for 2023 are presented in table 4.15 and figure 4.15. Same are discussed below

Table 4.15 Before sowing and after harvest soil pH

Sr.no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	7.6	7.6	7.60
2	T_2 = 75% RDF (Recommended dose of fertilizer)	7.7	7.6	7.60
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	7.6	7.6	7.65
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	7.7	7.6	7.65
5	T_5 = 75% RDF + Nano urea	7.7	7.6	7.65
6	T_6 = 75% RDF (3 Application timings)	7.7	7.7	7.70
7	T_7 = 75% RDF (2 Application timings)	7.6	7.6	7.65
8	T_8 = 75% RDF (4 Application timings)	7.7	7.7	7.70
9	T_9 = 75% RDF (Basal application timings)	7.5	7.5	7.50
10	T_{10} = 100% RDF (3 Applications)	7.8	7.6	7.65
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	7.6	7.7	7.75
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	7.6	7.7	7.70
13	T_{13} = 100 % RDF + Nano urea	7.7	7.6	7.65
14	T_{14} = 100% RDF (4 Application timings)	7.7	7.8	7.75
15	T_{15} = 100% RDF (2 Application timings)	7.8	7.7	7.75
16	T_{16} = 100% RDF (Basal application timings)	7.7	7.6	7.55

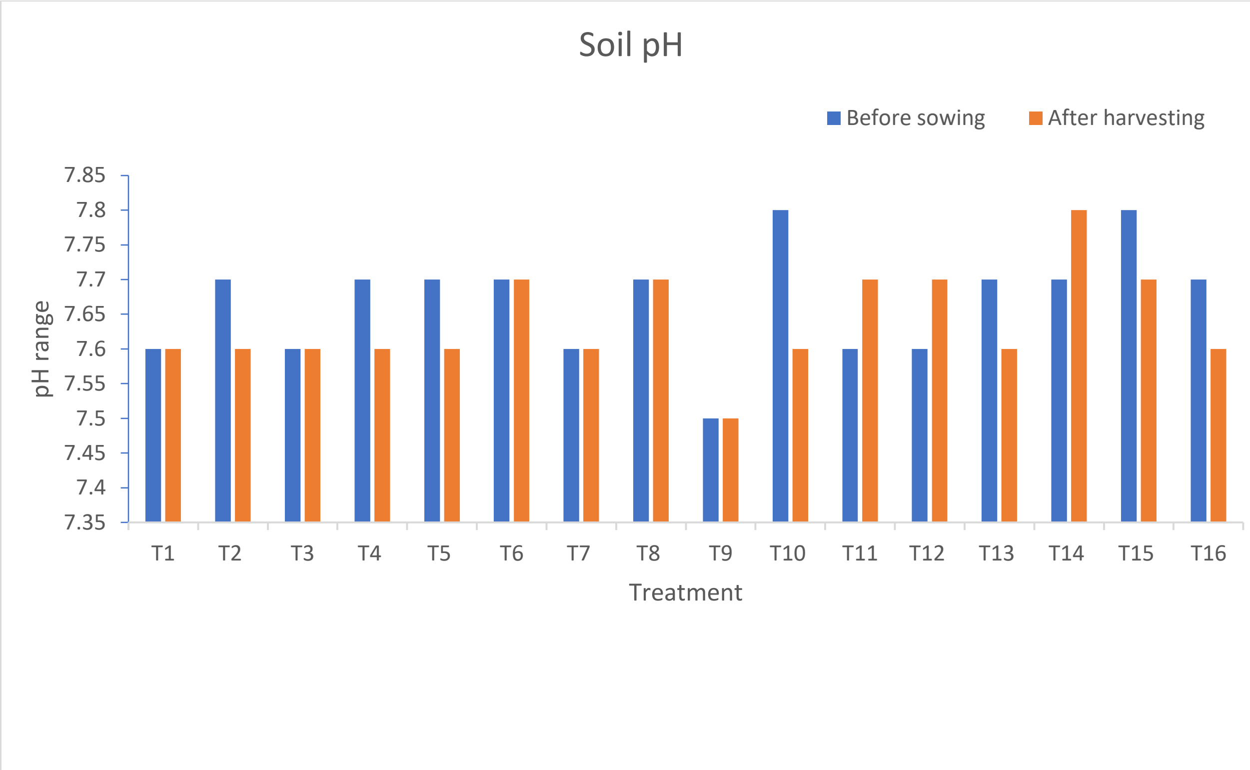

Figure 4.15 Soil pH in 2023

Before sowing and after harvest soil collected in an experimental field and it analyzed in laboratory, data are presented table 4.15 and figure 4.15 in the year 2023. Before sowing soil pH was highest in treatments $T_{10,}$ T_{15} (7.8) and lowest in treatments T_9, (7.5). In after harvest soil pH highest in T_{14} treatments (7.8) and lowest in treatments $T_{9,}$ (7.5). The pH range in Punjab's cultivated soils is 6.5 to 8.5, according to Sharma *et al.*, (2016). The pH range of the soil in Punjab's southwest is 7.68 to 7.98. Mandal *et al.*,2018

4.1.3.3. Soil EC before sowing and after harvest in 2022

Soil EC data of samples collected before sowing and after harvesting of maize crop for 2022 are presented in table 4.16 and figure 4.16. Same are discussed below

Table 4.16 Soil EC (dSm^{-1}) before sowing and after harvesting in 2022

Sr.no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	0.28	0.28	0.28
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.30	0.27	0.29
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	0.28	0.29	0.29
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	0.27	0.34	0.31
5	T_5 = 75% RDF + Nano urea	0.29	0.28	0.29
6	T_6 = 75% RDF (3 Application timings)	0.29	0.28	0.29
7	T_7 = 75% RDF (2 Application timings)	0.30	0.29	0.30
8	T_8 = 75% RDF (4 Application timings)	0.29	0.28	0.29
9	T_9 = 75% RDF (Basal application timings)	0.28	0.29	0.29
10	T_{10} = 100% RDF (3 Applications)	0.29	0.28	0.29
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.28	0.28	0.28
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	0.28	0.27	0.28
13	T_{13} = 100 % RDF + Nano urea	0.29	0.26	0.28
14	T_{14} = 100% RDF (4 Application timings)	0.31	0.28	0.30
15	T_{15} = 100% RDF (2 Application timings)	0.29	0.27	0.28
16	T_{16} = 100% RDF (Basal application timings)	0.29	0.29	0.29
C.D.(P=0.05)		0.12	0.14	0.10
S.E.m. (±)		0.05	0.07	0.04

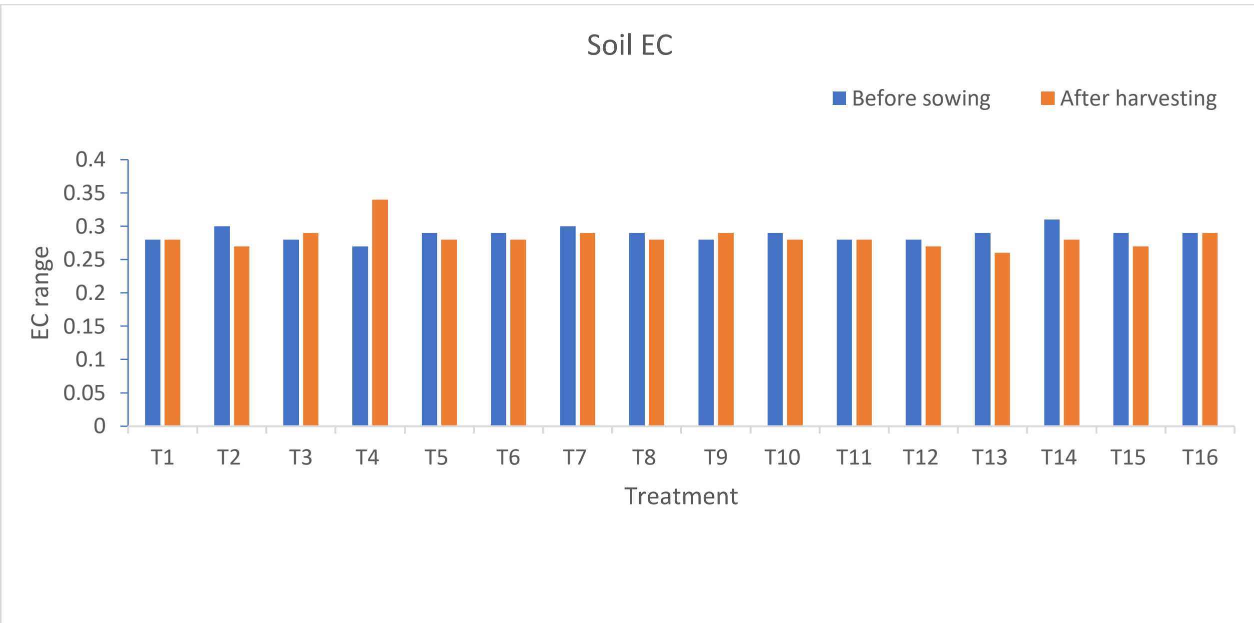

Figure 4.16 Soil EC (dSm^{-1})

Before sowing and after harvest soil collected in an experimental field and it analyzed in laboratory, data are presented table 4.16 and figure 4.16 in the year 2022. Before sowing soil EC (dSm^{-1}) was highest in treatments T_{14} (0.31) and lowest in treatments T_4, (0.27). Harvesting soil EC (dSm^{-1}) was highest in T_4 treatments (0.34) and lowest in treatments T_{13} (0.26). Determining the overall concentration of ions present in the soil is one of its crucial characteristics. Soil quality is determined using it. It is a quick, simple, and affordable way to assess the condition of the soil. The ions in the soil control the salt and nutrient availability for the crops. (Kekane 2015)

4.1.3.4. Soil EC before sowing and after harvest in 2023

Soil EC data of samples collected before sowing and after harvesting of maize crop for 2023 are presented in table 4.17 and figure 4.17. Same are discussed below

Table 4.17 Before sowing and after harvesting soil EC (dSm^{-1})

Sr.no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	0.29	0.29	0.29
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.27	0.31	0.29
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	0.29	0.28	0.29
4	T_4 = 75% RDF+ Vermi-compost 2.5 t ha^{-1}	0.29	0.30	0.30
5	T_5 = 75% RDF + Nano urea	0.28	0.32	0.30
6	T_6 = 75% RDF (3 Application timings)	0.30	0.29	0.30
7	T_7 = 75% RDF (2 Application timings)	0.31	0.28	0.30
8	T_8 = 75% RDF (4 Application timings)	0.30	0.25	0.28
9	T_9 = 75% RDF (Basal application timings)	0.29	0.28	0.29
10	T_{10} = 100% RDF (3 Applications)	0.28	0.30	0.29
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.29	0.35	0.32
12	T_{12} = 100% RDF+ Vermi-compost 2.5 t ha^{-1}	0.30	0.29	0.30
13	T_{13} = 100 % RDF + Nano urea	0.28	0.28	0.28
14	T_{14} = 100% RDF (4 Application timings)	0.33	0.29	0.31
15	T_{15} = 100% RDF (2 Application timings)	0.32	0.29	0.31
16	T_{16} = 100% RDF (Basal application timings)	0.28	0.32	0.30
C.D.(P=0.05)		0.13	0.15	0.17
S.E.m. (±)		0.05	0.07	0.08

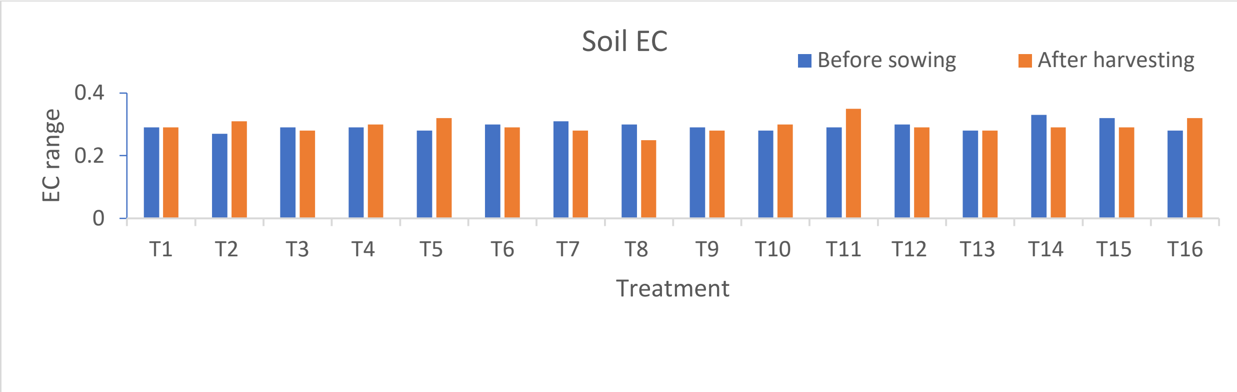

Figure 4.17 Soil EC (dSm^{-1})

EC, data for 2023 presented table 4.17 and figure 4.17. Before sowing soil EC (dSm^{-1}) was highest in treatments T_{14} (0.33) and lowest in treatments T_2, (0.27). After harvesting soil EC (dSm^{-1}) was highest in T_{11} treatments (0.35) and lowest in treatments T_8 (0.25). A rise in salinity is indicated by an increase in soil ions. In addition to causing soil erosion, the high salinity prevents healthy plant growth. Electrical conductivity rises with weathering, salts in natural rocks, coastal areas that flood, and fertilizer use. Shakha *et al.*, (2016). However, the low EC value in both years indicates that these soils have less salinity, reduced erosion, and less weathering.

4.1.3.5. Soil organic carbon before sowing and after harvesting in 2022

Soil organic carbon data of samples collected before sowing and after harvesting of maize crop for 2022 are presented in table 4.18 and figure 4.18. Same are discussed below

Table 4.18 Before sowing and after harvesting in soil organic carbon (g/kg)

Sr.no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	3.19	3.24	3.22
2	T_2 = 75% RDF (Recommended dose of fertilizer)	3.38	3.27	3.33
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	3.29	3.43	3.36
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	3.29	3.41	3.35
5	T_5 = 75% RDF + Nano urea	3.78	3.71	3.75
6	T_6 = 75% RDF (3 Application timings)	3.42	3.56	3.49
7	T_7 = 75% RDF (2 Application timings)	3.46	3.58	3.52
8	T_8 = 75% RDF (4 Application timings)	3.66	3.36	3.51
9	T_9 = 75% RDF (Basal application timings)	3.18	3.49	3.34
10	T_{10} = 100% RDF (3 Applications)	3.56	3.40	3.48
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	3.78	3.60	3.69
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	3.81	3.85	3.83
13	T_{13} = 100 % RDF + Nano urea	3.37	3.49	3.43
14	T_{14} = 100% RDF (4 Application timings)	3.89	3.79	3.84
15	T_{15} = 100% RDF (2 Application timings)	3.81	3.90	3.86
16	T_{16} = 100% RDF (Basal application timings)	3.65	3.96	3.81
C.D.(P=0.05)		0.74	0.80	0.85
S.E.m. (±)		0.56	0.58	0.61

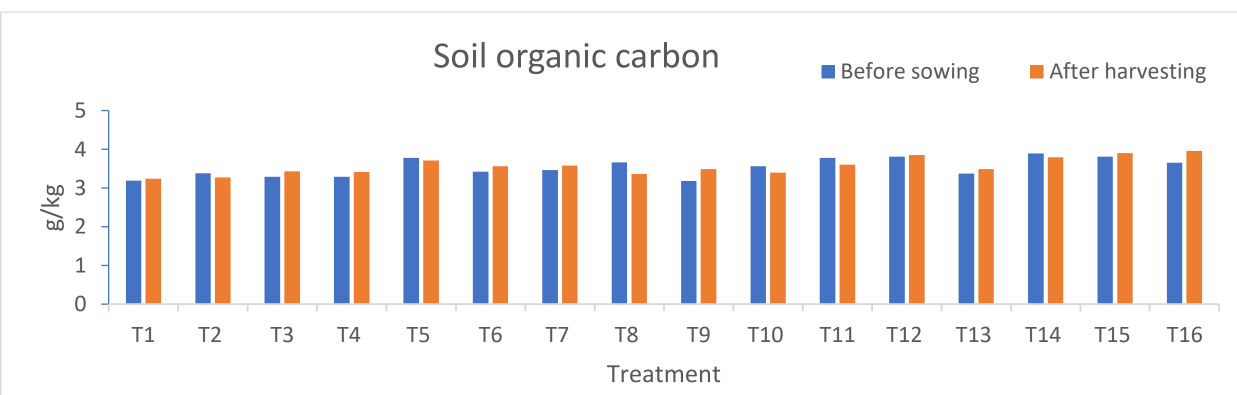

Figure 4.18 Soil organic carbon (g/kg)

Data for soil organic carbon in Various treatments are presented table 4.18 and figure 4.18 in the year 2022. Before sowing soil organic carbon (g/kg) was found highest in treatments T_{14} (3.89) and lowest in treatments T_9, (3.18). In after harvest soil organic carbon (g/kg) highest in T_{16} treatments (3.96) and lowest in treatments T_1 (3.24). Organic carbon contains of the most plots was low and there was not much change before and after harvesting of the crop, the difference between various treatment is non-significant. Organic matter is the soil's most valuable component. In some ways, it ties the soil and stops soil erosion. Nutrients are stored in organic materials. It preserves the microbial population, fertility, and quality of the soil. (Kekane 2015)

4.1.3.6. Soil organic carbon (g/kg) in before sowing and after harvest in 2023

Soil organic carbon data of samples collected before sowing and after harvesting of maize crop for 2023 are presented in table 4.19 and figure 4.19. Same are discussed below

Table 4.19 Soil organic carbon (g/kg) before sowing and after harvesting in 2023

Sr.no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	3.16	3.14	3.15
2	T_2 = 75% RDF (Recommended dose of fertilizer)	3.81	3.82	3.82
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	3.44	3.30	3.37
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	3.53	3.73	3.63
5	T_5 = 75% RDF + Nano urea	3.83	3.97	3.90
6	T_6 = 75% RDF (3 Application timings)	3.75	3.88	3.82
7	T_7 = 75% RDF (2 Application timings)	3.45	3.05	3.25
8	T_8 = 75% RDF (4 Application timings)	4.02	3.89	3.96
9	T_9 = 75% RDF (Basal application timings)	3.43	3.29	3.36
10	T_{10} = 100% RDF (3 Applications)	3.48	3.61	3.55
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	3.29	3.25	3.27
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	3.37	3.92	3.65
13	T_{13} = 100 % RDF + Nano urea	3.56	3.57	3.57
14	T_{14} = 100% RDF (4 Application timings)	3.42	3.68	3.55
15	T_{15} = 100% RDF (2 Application timings)	3.70	3.36	3.53
16	T_{16} = 100% RDF (Basal application timings)	3.59	3.80	3.70
C.D.(P=0.05)		0.83	0.81	0.79
S.E.m. (±)		0.61	0.59	0.56

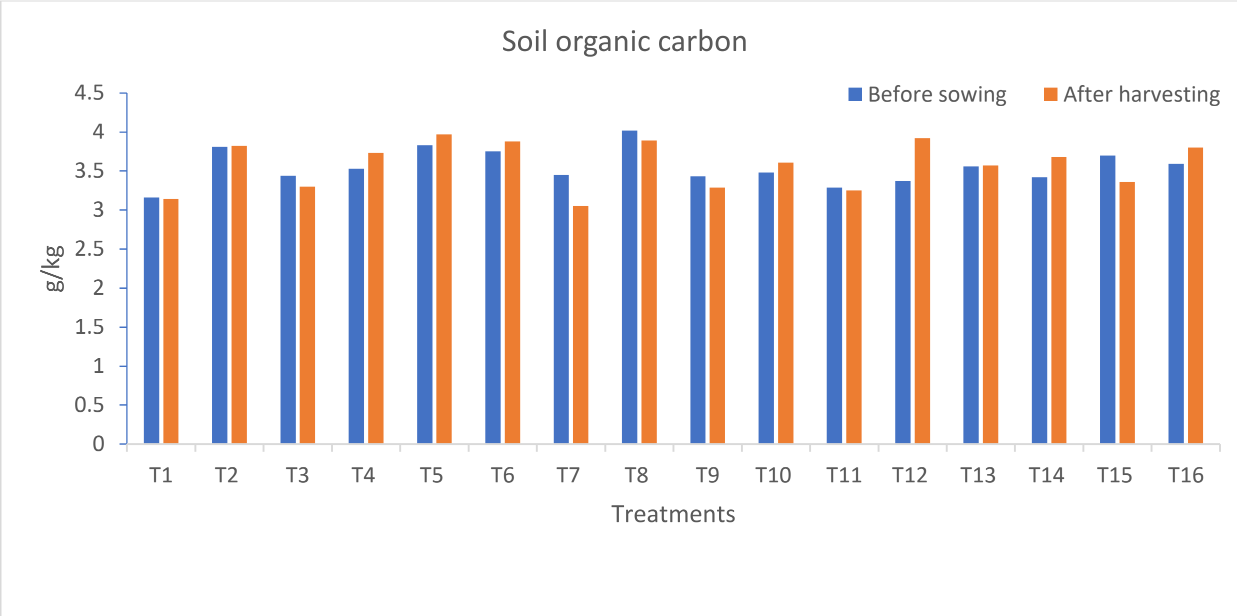

Figure 4.19 Soil organic carbon

Data for soil organic carbon in different treatments presented table 4.19 and figure 4.19 for the year 2023. Before sowing soil organic carbon (g/kg) was highest in treatments T_8 (4.02) and lowest in treatments T_1, (3.16). In after harvest soil organic carbon (g/kg) highest in T_5 treatments (3.97) and lowest in treatments T_1 (3.14). Organic carbon contains of the most plots was low and there was not much change before and after harvesting of the crop, the difference between various treatment is non-significant. Organic carbon is the main constituent of organic matter. The soil's organic carbon serves as the basis for the estimate of organic matter. The organic matter value is obtained by multiplying the organic carbon value by the Van Bemmlen factor, which is 1.724. This is predicated on the idea that 58% of organic matter is organic carbon on average (Shakha *et al.*, 2016).

4.1.3.7. Soil cation exchange capacity in before sowing and after harvesting in 2022

Soil cation exchange capacity data of samples collected before sowing and after harvesting of maize crop for 2022 are presented in table 4.20 and figure 4.20. Same are discussed below

Table 4.20 Soil cation exchange capacity (meq 100g^{-1}) before sowing and after harvest

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	4.09	4.15	4.12
2	T_2 = 75% RDF (Recommended dose of fertilizer)	4.17	4.13	4.15
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	4.28	4.21	4.25
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	4.10	4.15	4.13
5	T_5 = 75% RDF + Nano urea	4.21	4.10	4.16
6	T_6 = 75% RDF (3 Application timings)	4.13	4.14	4.14
7	T_7 = 75% RDF (2 Application timings)	4.10	4.17	4.14
8	T_8 = 75% RDF (4 Application timings)	4.14	4.28	4.21
9	T_9 = 75% RDF (Basal application timings)	4.38	4.14	4.26
10	T_{10} = 100% RDF (3 Applications)	4.14	4.00	4.07
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	4.11	4.09	4.10
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	4.14	4.21	4.18
13	T_{13} = 100 % RDF + Nano urea	4.10	4.14	4.12
14	T_{14} = 100% RDF (4 Application timings)	4.13	4.17	4.15
15	T_{15} = 100% RDF (2 Application timings)	4.19	4.21	4.20
16	T_{16} = 100% RDF (Basal application timings)	4.23	4.45	4.34
C.D.(P=0.05)		0.85	0.89	0.91
S.E.m. (±)		0.67	0.73	0.75

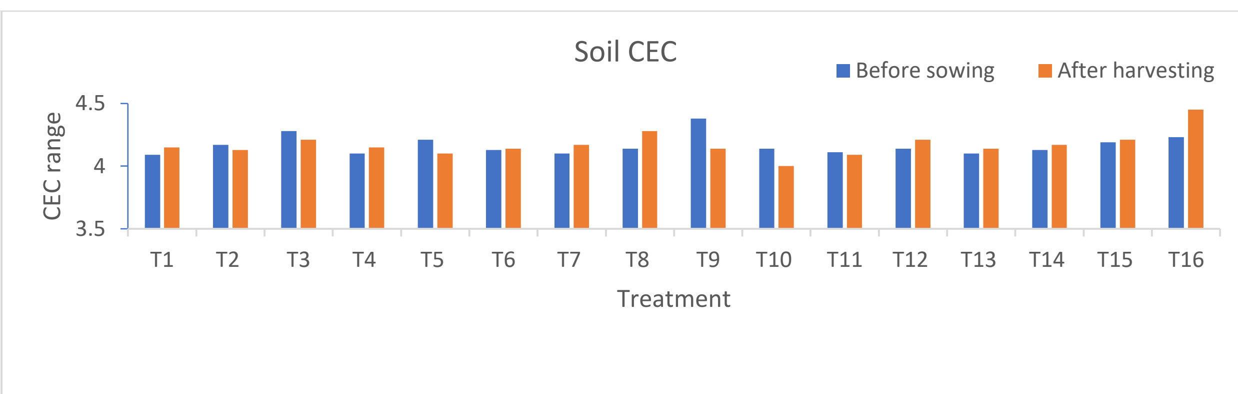

Figure 4.20 Soil cation exchange capacity (meq 100g^{-1})

Data for soil cation exchange capacity in different treatments are presented table 4.20 and figure 4.20 for the year 2022. Before sowing soil cation exchange capacity (meq $100g^{-1}$) was highest in treatments T_9 (4.38) and lowest in treatments T_1, (4.09). In after harvest cation exchange capacity (meq $100g^{-1}$) highest in T_{16} treatments (4.45) and lowest in treatments T_{10} (4.0). Soil cation exchange capacity contain of the most plots was low and there was not much change before and after harvesting of the crop, the difference between various treatment is non-significant, where 1N sodium acetate was used to achieve equilibrium and saturation of the soil with sodium. According to the process outlined in the Practical Soil Science and Agricultural Chemistry Manual, the exchangeable cations were identified. Tolanur (2018)

4.1.3.8. Soil cation exchange capacity before sowing and after harvesting in 2023

Soil cation exchange capacity data of samples collected before sowing and after harvesting of maize crop for 2023 are presented in table 4.21 and figure 4.21. Same are discussed below

Table 4.21 Soil cation exchange capacity (meq $100g^{-1}$) before sowing and after harvesting

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	4.07	4.01	4.04
2	T_2 = 75% RDF (Recommended dose of fertilizer)	4.38	4.22	4.30
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	4.14	4.32	4.23
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	4.05	4.17	4.11
5	T_5 = 75% RDF + Nano urea	4.17	4.26	4.22
6	T_6 = 75% RDF (3 Application timings)	4.14	4.41	4.28
7	T_7 = 75% RDF (2 Application timings)	4.21	4.30	4.26
8	T_8 = 75% RDF (4 Application timings)	4.24	4.21	4.23
9	T_9 = 75% RDF (Basal application timings)	4.30	4.14	4.22
10	T_{10} = 100% RDF (3 Applications)	4.47	4.25	4.36
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	4.57	4.19	4.38
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	4.28	4.16	4.22
13	T_{13} = 100 % RDF + Nano urea	4.17	4.25	4.21
14	T_{14} = 100% RDF (4 Application timings)	4.11	4.29	4.20
15	T_{15} = 100% RDF (2 Application timings)	4.28	4.20	4.24
16	T_{16} = 100% RDF (Basal application timings)	4.38	4.17	4.28
C.D.(P=0.05)		0.91	0.87	0.93
S.E.m. (±)		0.78	0.77	0.79

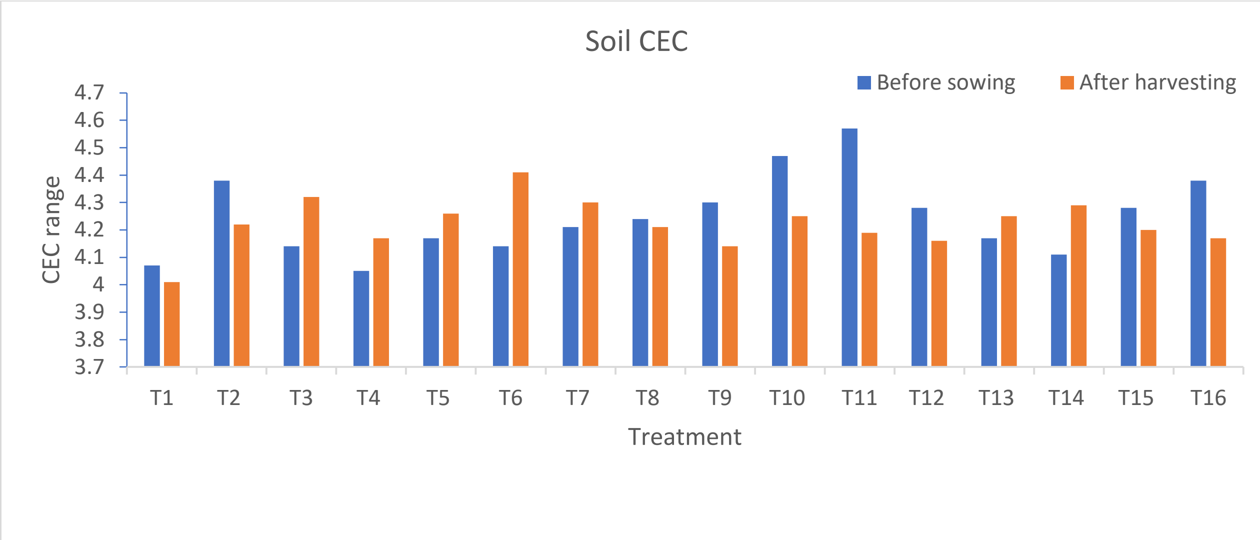

Figure 4.21 Soil cation exchange capacity (meq 100g^{-1})

Data for soil cation exchange capacity in a table with different treatments is presented. 4.21 and figure 4.21 for the year 2023. Before sowing soil cation exchange capacity (meq 100g^{-1}) was highest in treatments T_{11} (4.57) and lowest in treatments T_1, (4.07). In after harvest cation exchange capacity (meq 100g^{-1}) was highest in T_6 treatments (4.41) and lowest in treatments T_1 (4.01). Soil cation exchange capacity contain of the most plots was low and there was not much change before and after harvesting of the crop, the differences between various treatment are non-significant

4.1.3.9. Available nitrogen of soil before sowing and after harvest in 2022

Available nitrogen data of samples collected before sowing and after harvesting of maize crop for 2022 are presented in table 4.22 and figure 4.22. Same are discussed below

Table 4.22 Before sowing and after harvesting in available nitrogen of soil (kg ha^{-1})

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	154.34	151.78	153.06
2	T_2 = 75% RDF (Recommended dose of fertilizer)	154.71	150.12	252.42
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	200.7	185.32	193.01
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	179.8	164.43	172.12
5	T_5 = 75% RDF + Nano urea	179.8	165.39	172.60
6	T_6 = 75% RDF (3 Application timings)	163.07	159.88	161.48
7	T_7 = 75% RDF (2 Application timings)	171.43	163.16	167.30
8	T_8 = 75% RDF (4 Application timings)	209.07	189.34	199.21
9	T_9 = 75% RDF (Basal application timings)	156.35	136.65	146.50
10	T_{10} = 100% RDF (3 Applications)	163.07	157.19	160.13
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	150.53	143.28	146.91
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	225.79	209.54	217.67
13	T_{13} = 100 % RDF + Nano urea	167.25	152.3	159.78
14	T_{14} = 100% RDF (4 Application timings)	192.34	170.45	181.40
15	T_{15} = 100% RDF (2 Application timings)	163.07	159.46	161.27
16	T_{16} = 100% RDF (Basal application timings)	229.97	207.38	218.68
C.D.(P=0.05)		9.20	8.38	8.69
S.E.m. (±)		4.38	3.99	4.16

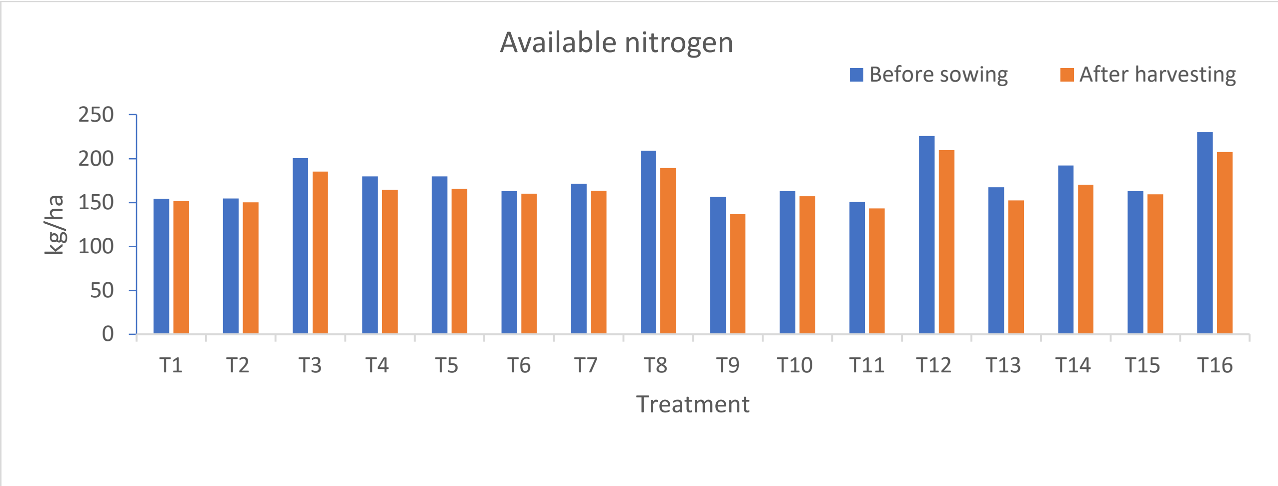

Figure 4.22 Available nitrogen of soil (kg ha^{-1})

Data for soil available nitrogen in treatment plots are presented table 4.22 and figure 4.22 in the year 2022. Before sowing available nitrogen of soil was highest in treatments T_{16} (229.97) and lowest in treatments T_{11}, (150.53). In after harvest soil available nitrogen of soil (kg ha^{-1}) was highest in T_{12} treatments (209.54) and lowest in treatments T_9 (136.65). Nitrates and ammonium forms are the forms of nitrogen that are readily available in the soil. That is less than 1 percent of the total nitrogen in the soil. The nitrogen that is available to plants in the soil is higher because of the ongoing release of nitrogen from organic to inorganic forms. Shakha *et al.*, (2016)

4.1.3.10. Available nitrogen of soil before sowing and after harvesting in 2023

Available nitrogen data of samples collected before sowing and after harvesting of maize crop for 2023 are presented in table 4.23 and figure 4.23. Same are discussed below

Table 4.23 Available nitrogen of soil (kg ha^{-1}) before sowing and after harvesting in 2023

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	153.25	149.21	151.23
2	T_2 = 75% RDF (Recommended dose of fertilizer)	163.07	152.43	157.75
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	200.7	179.51	190.11
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	179.8	168.45	174.13
5	T_5 = 75% RDF + Nano urea	180.7	187.32	184.01
6	T_6 = 75% RDF (3 Application timings)	163.07	159.48	161.28
7	T_7 = 75% RDF (2 Application timings)	171.43	155.57	163.50
8	T_8 = 75% RDF (4 Application timings)	209.07	189.21	199.14
9	T_9 = 75% RDF (Basal application timings)	158.89	149.54	154.22
10	T_{10} = 100% RDF (3 Applications)	163.07	158.87	160.97
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	149.53	148.76	149.15
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	185.79	175.34	180.57
13	T_{13} = 100 % RDF + Nano urea	175.62	169.87	172.75
14	T_{14} = 100% RDF (4 Application timings)	196.52	181.67	189.10
15	T_{15} = 100% RDF (2 Application timings)	163.07	149.85	156.46
16	T_{16} = 100% RDF (Basal application timings)	205.7	193.94	199.82
C.D.(P=0.05)		8.23	7.76	7.54
S.E.m. (±)		3.92	3.69	3.51

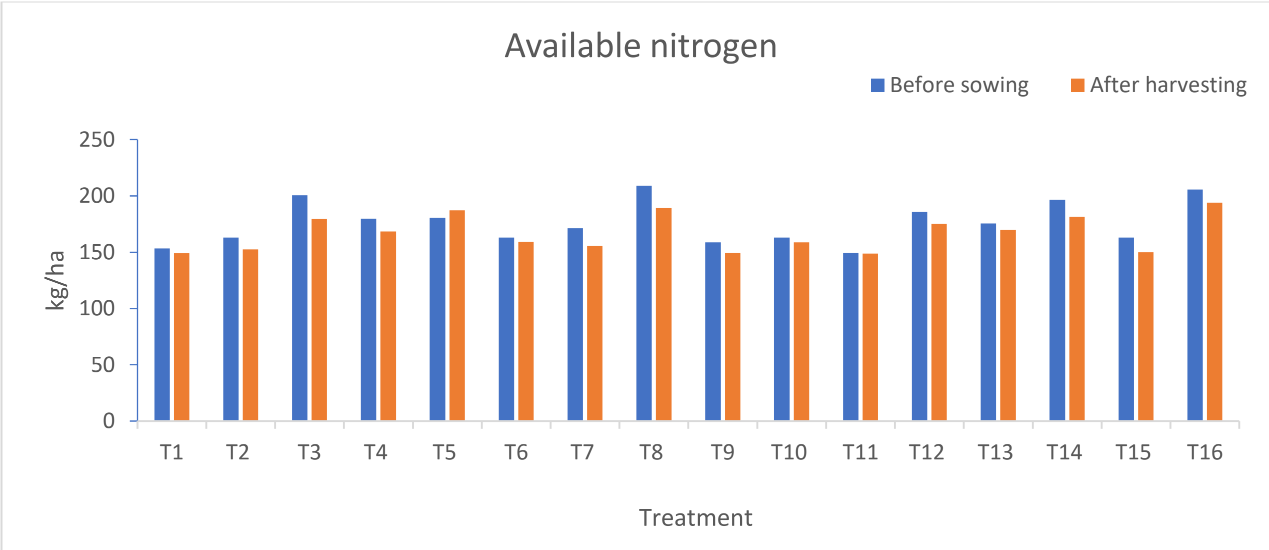

Figure 4.23 Available nitrogen of soil (kg ha^{-1})

Data on available nitrogen content of different treatment plots for 2023 are presented table 4.23 and figure 4.23. Before sowing available nitrogen of soil (kg ha^{-1}) was found highest in treatments T_8 (209.07) and lowest in treatments T_{11}, (149.53). After harvest soil available nitrogen of soil (kg ha^{-1}) was highest in T_{16} treatments (193.94) and lowest in treatments T_1 (149.21). Since nitrogen makes up around 5 percent of organic matter, the amount of nitrogen in the soil is correlated with the amount of organic matter present. (Shakha *et al.*, 2016)

4.1.3.11. Available phosphorus of soil before sowing and after harvesting in 2022

Available phosphorus data of samples collected before sowing and after harvesting of maize crop for 2022 are presented in table 4.24 and figure 4.24. Same are discussed below

Table 4.24 Available phosphorus of soil (kg ha^{-1}) before sowing and after harvesting in 2022

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	5.02	4.98	5.00
2	T_2 = 75% RDF (Recommended dose of fertilizer)	5.49	5.13	5.31
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	5.21	4.78	5.00
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	5.95	5.23	5.59
5	T_5 = 75% RDF + Nano urea	7.25	6.69	6.97
6	T_6 = 75% RDF (3 Application timings)	7.46	7.12	7.29
7	T_7 = 75% RDF (2 Application timings)	7.14	6.54	6.84
8	T_8 = 75% RDF (4 Application timings)	7.72	7.23	7.48
9	T_9 = 75% RDF (Basal application timings)	8.08	7.76	7.92
10	T_{10} = 100% RDF (3 Applications)	7.00	6.43	6.72
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	7.33	6.54	6.94
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	7.62	7.19	7.41
13	T_{13} = 100 % RDF + Nano urea	7.82	6.68	7.25
14	T_{14} = 100% RDF (4 Application timings)	8.09	7.96	8.03
15	T_{15} = 100% RDF (2 Application timings)	8.54	7.29	7.92
16	T_{16} = 100% RDF (Basal application timings)	7.26	7.75	7.51
C.D.(P=0.05)		2.34	2.27	2.46
S.E.m. (±)		1.16	1.10	1.19

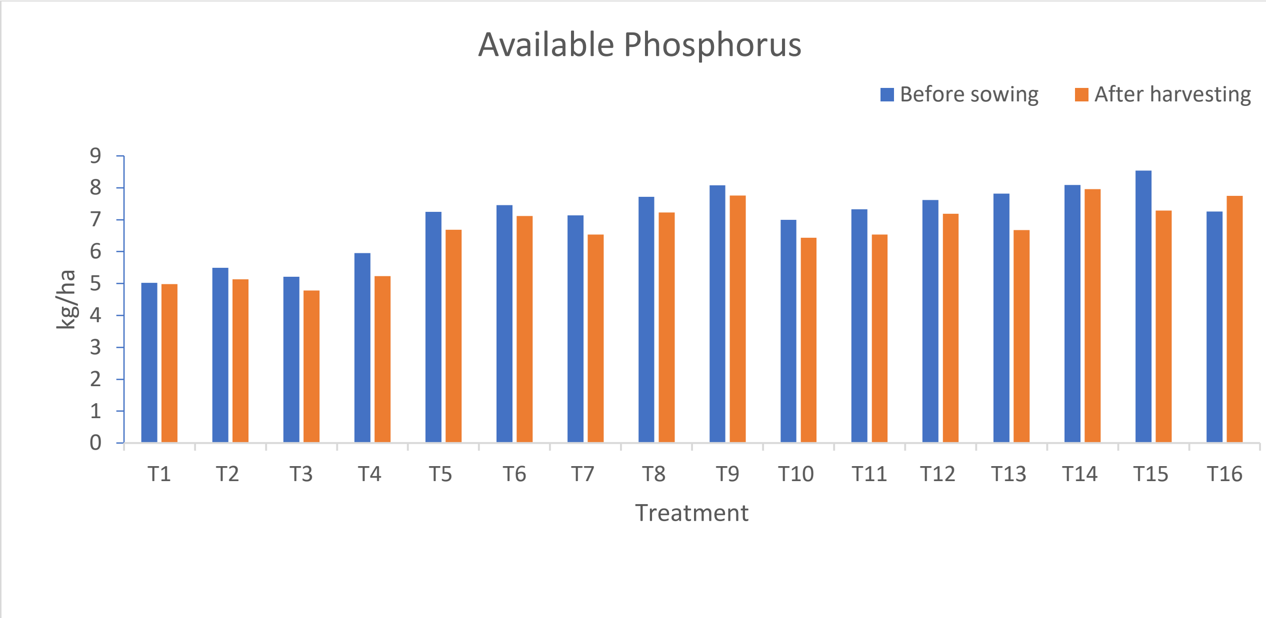

Figure 4.24 Available phosphorus of soil (kg ha^{-1}) 2022

Data on available phosphorus content for different treatment plot for 2023 are presented table 4.24 and figure 4.24 in the year 2022. Before sowing available phosphorous of soil (kg ha^{-1}) was highest in treatments T_{15} (8.54) and lowest in treatments T_1, (5.02). After harvesting soil available phosphorous of soil (kg ha^{-1}) was highest in T_{15} treatments (7.96) and lowest in treatments T_3 (4.78). The district of Punjab has soils with 20 parts per million of accessible phosphorus, which is extremely low and requires phosphorus application. Jatav *et al.,* (2013)

4.1.3.12. Available phosphorus of soil before sowing and after harvesting in 2023

Available phosphorus data of samples collected before sowing and after harvesting of maize crop for 2023 are presented in table 4.25 and figure 4.25. Same are discussed below

Table 4.25 Available phosphorus of soil (kg ha^{-1}) before sowing and after harvesting in 2023

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	5.18	4.06	4.62
2	T_2 = 75% RDF (Recommended dose of fertilizer)	5.28	5.16	5.22
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	5.39	5.01	5.20
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	5.11	5.05	5.08
5	T_5 = 75% RDF + Nano urea	6.82	6.72	6.77
6	T_6 = 75% RDF (3 Application timings)	8.75	6.72	7.74
7	T_7 = 75% RDF (2 Application timings)	7.02	6.89	6.96
8	T_8 = 75% RDF (4 Application timings)	8.09	7.10	7.60
9	T_9 = 75% RDF (Basal application timings)	6.97	6.85	7.91
10	T_{10} = 100% RDF (3 Applications)	6.55	6.34	6.45
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	6.89	6.04	6.47
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	7.98	6.42	7.20
13	T_{13} = 100 % RDF + Nano urea	7.94	6.81	7.38
14	T_{14} = 100% RDF (4 Application timings)	7.42	6.45	6.94
15	T_{15} = 100% RDF (2 Application timings)	7.53	6.93	7.23
16	T_{16} = 100% RDF (Basal application timings)	7.45	6.87	7.16
C.D.(P=0.05)		2.45	2.08	2.28
S.E.m. (±)		1.21	1.01	1.13

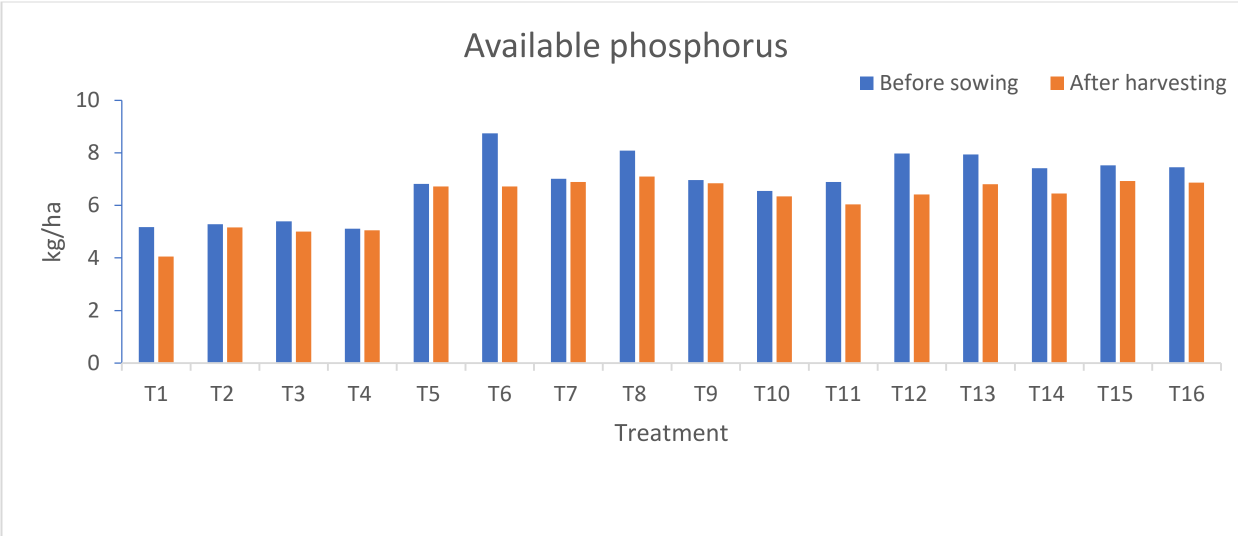

Figure 4.25 Available phosphorus of soil

Data on available phosphorus content for different treatment plots for 2023 are presented table 4.25 and figure 4.25. Before sowing available phosphorous of soil (kg ha^{-1}) was highest in treatments T_6 (8.75) and lowest in treatments T_1 (5.18). After harvest soil available phosphorous of soil (kg ha^{-1}) was highest in T_8 treatments (7.1) and lowest in treatments T_1 (4.06). Due to its role in energy storage, it is one of the most significant macronutrients for both plants and animals. Additionally, it keeps track of how many nutrients are found in the plant nucleus (Kekane *et al.*, 2015)

4.1.3.13. Available potassium of soil (kg ha^{-1}) before sowing and after harvesting in 2022

Available potassium data of samples collected before sowing and after harvesting of maize crop for 2022 are presented in table 4.26 and figure 4.26. Same are discussed below

Table 4.26 Available potassium of soil (kg ha^{-1}) before sowing and after harvesting in 2022

Sr. no	Treatments	Before sowing	After harvesting	Mean
1	T_1 = Absolute control	104.13	102.24	103.19
2	T_2 = 75% RDF (Recommended dose of fertilizer)	112.00	109.16	110.58
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	109.67	104.32	107.00
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	110.67	102.11	106.39
5	T_5 = 75% RDF + Nano urea	111.33	109.95	110.64
6	T_6 = 75% RDF (3 Application timings)	115.20	100.16	107.68
7	T_7 = 75% RDF (2 Application timings)	112.00	103.64	107.82
8	T_8 = 75% RDF (4 Application timings)	116.56	108.47	112.52
9	T_9 = 75% RDF (Basal application timings)	110.33	104.21	107.27
10	T_{10} = 100% RDF (3 Applications)	113.10	103.45	108.28
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	109.33	105.56	107.45
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	115.33	106.65	110.99
13	T_{13} = 100 % RDF + Nano urea	109.62	101.90	105.76
14	T_{14} = 100% RDF (4 Application timings)	112.18	107.34	109.76
15	T_{15} = 100% RDF (2 Application timings)	113.33	112.18	112.74
16	T_{16} = 100% RDF (Basal application timings)	111.43	107.29	109.36
C.D.(P=0.05)		4.66	4.49	4.31
S.E.m. (±)		2.22	2.14	2.05

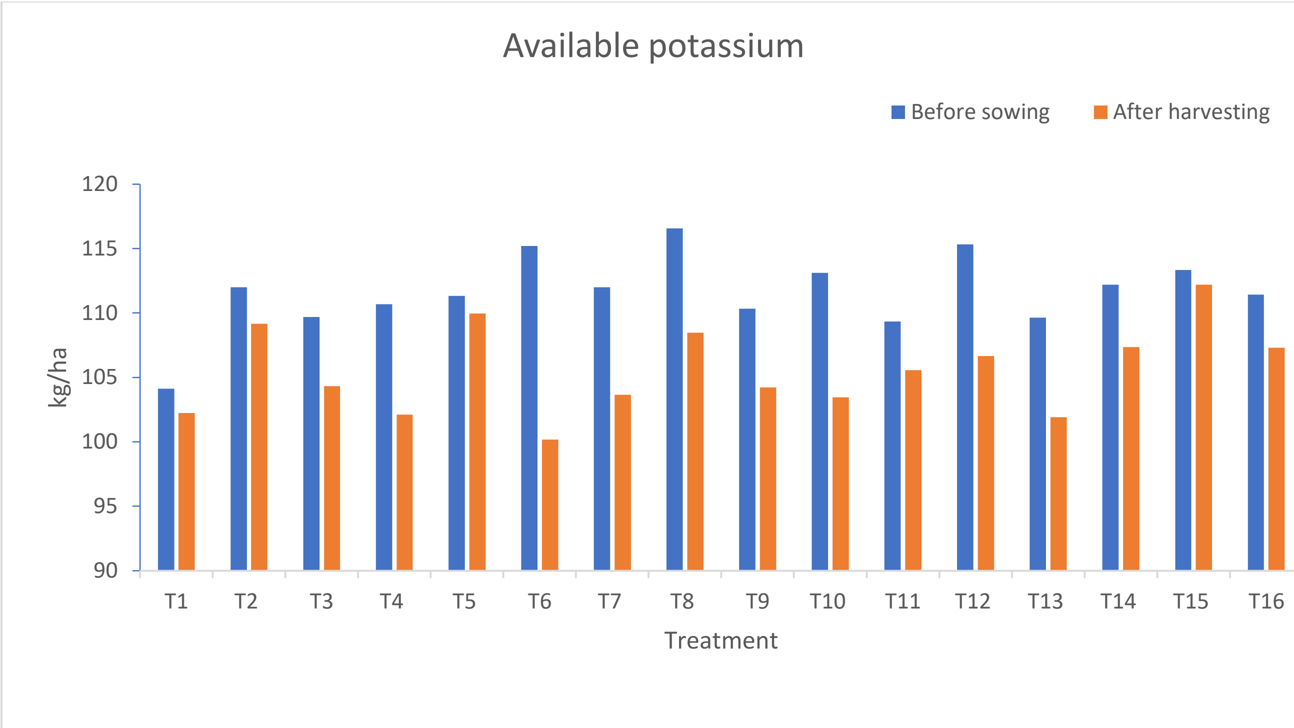

Figure 4.26 Available potassium of soil (kg ha^{-1})

Data on available potassium content for different treatment plot for 2022 are presented table 4.26 and figure 4.26. Before sowing available potassium of soil (kg ha^{-1}) was highest in treatments T_8 (116.56) and lowest in treatments T_1 (104.13). After harvest soil available phosphorous of soil (kg ha^{-1}) was highest in T_{15} treatments (112.18) and lowest in treatments T_6 (100.16). Potassium is essential to the physiological functions of plants. Vasanthapu M (2022)

4.1.3.14. Before sowing and after harvesting available potassium of soil in 2023

Available potassium data of samples collected before sowing and after harvesting of maize crop for 2023 are presented in table 4.27 and figure 4.27. Same are discussed below

Table 4.27 Before sowing and after harvesting available potassium of soil (kg ha^{-1}) in 2023

Sr. no	Treatments	Before sowing	After harvest	Mean
1	T_1 = Absolute control	107.23	102.15	104.69
2	T_2 = 75% RDF (Recommended dose of fertilizer)	111.00	108.13	109.57
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	111.35	103.54	107.45
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	110.67	105.66	108.17
5	T_5 = 75% RDF + Nano urea	114.33	105.98	110.16
6	T_6 = 75% RDF (3 Application timings)	110.33	108.76	109.55
7	T_7 = 75% RDF (2 Application timings)	108.00	105.33	106.67
8	T_8 = 75% RDF (4 Application timings)	112.33	110.24	111.29
9	T_9 = 75% RDF (Basal application timings)	109.00	108.12	108.56
10	T_{10} = 100% RDF (3 Applications)	108.33	108.98	108.66
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	109.67	106.71	108.19
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	114.00	104.98	109.49
13	T_{13} = 100 % RDF + Nano urea	109.00	100.45	104.73
14	T_{14} = 100% RDF (4 Application timings)	112.67	110.34	111.51
15	T_{15} = 100% RDF (2 Application timings)	106.67	105.43	106.05
16	T_{16} = 100% RDF (Basal application timings)	110.33	102.29	106.31
C.D.(P=0.05)		4.57	4.41	4.27
S.E.m. (±)		2.18	2.13	2.03

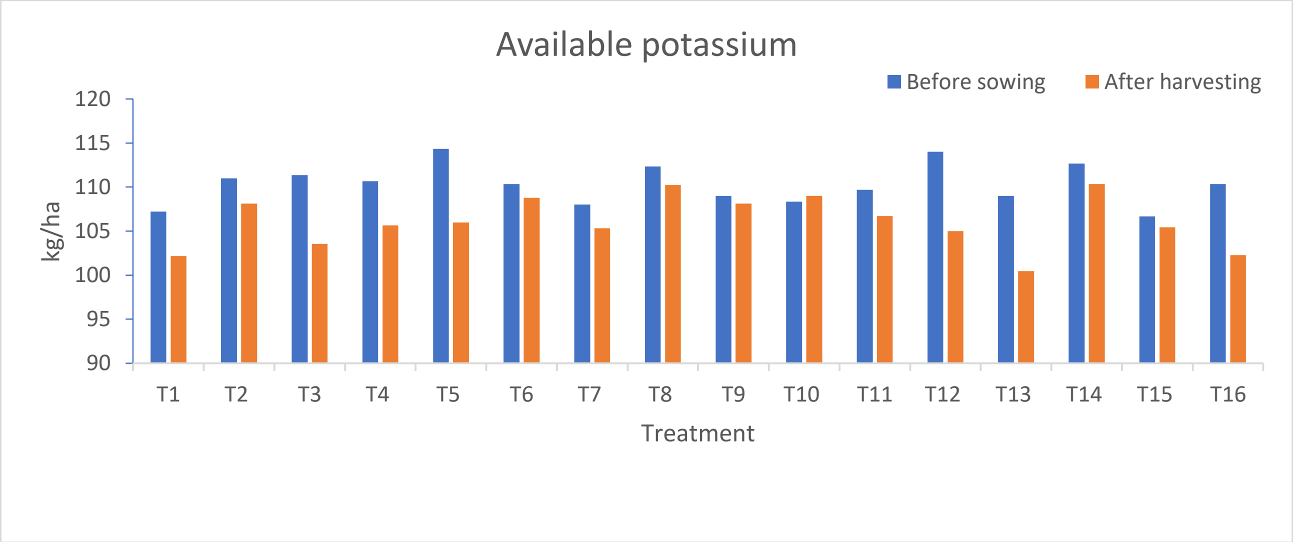

Figure 4.27 Available potassium of soil (kg ha^{-1})

Data on available potassium content for different treatment plots for 2023 are presented table 4.27 and figure 4.27. Before sowing available potassium of soil (kg ha^{-1}) was highest in treatments T_5 (114.33) and lowest in treatments T_{15} (106.67). After harvest soil available phosphorous of soil (kg ha^{-1}) was highest in T_{14} treatments (110.34) and lowest in treatments T_{13} (100.45). There's a lot of potassium available in the soils of Punjab. The amount of potassium that is available is larger than 113 kg/ha in 92% of the state's total geographical area, with the remaining 8% falling into the category of less than 113 kg/ha. (Sharma *et al.*, 2016).

4.1.4 Economics of treatments

4.1.4.1 Gross returns

The data pertaining to gross returns during the year 2022, 2023 have been shown in table 4.28, 4.29 A gradual increase in the gross return was observed with increased treatment vermi-compost, farm yard manure, urea and nano urea. The application of vermi-compost, Farm yard manure, urea and nano urea recorded the maximum gross returns under the treatment T_{12} in the year 2023 (Rs 102694/ha) as compared to gross return obtained in year 2022 (Rs 101849/ha)

4.1.4.2 Net returns

Statistics in table 4.28 and 4.29 indicated that maximum net return was obtained under treatment T_{12} (Rs 44012/ha) during the year 2023 and the year 2022 where maximum net return was (Rs 45266/ha).

4.1.4.3 Benefit cost ratio

Benefit: Cost ratio improved significantly upon increased application of vermi-compost, recommended dose fertilizer and its combination. B-C ratio was found to be significantly highest under treatment T_{12} in year 2023 (1.78) as compared to 2022 (1.76). Higher profitability under T_{12} could be explained in the light of higher cob productivity obtained.

Table 4.28 Effect of different treatment on Net Return-Benefit Cost ratio during 2022

Sr. no	Treatments	Yield(q/ha)		Gross return (Rs/ha)	Cost of cultivation (Rs/ha)			Net return (Rs /ha)	BCR
		Grain	Dry matter		Fixed cost	Variable	Total cost		
1	T_1	22.89	34.106	48508	25000	7125	32125	16384	1.51
2	T_2	41.56	61.924	88074	25000	25328	50328	37746	1.75
3	T_3	36.92	55.011	78241	25000	25478	50478	27763	1.55
4	T_4	39.89	59.436	84535	25000	24148	49148	35387	1.72
5	T_5	37.14	55.339	78707	25000	23886	48886	29821	1.61
6	T_6	37.00	55.130	78410	25000	22521	47521	30889	1.65
7	T_7	42.75	63.698	90596	25000	31978	56978	33617	1.59
8	T_8	44.17	65.813	93605	25000	29107	54107	39498	1.73
9	T_9	40.33	60.092	85467	25000	30861	55861	29606	1.53
10	T_{10}	47.85	71.297	101404	25000	31650	56650	44754	1.79
11	T_{11}	45.00	67.050	95364	25000	33867	58867	36497	1.62
12	T_{12}	48.06	71.609	101849	25000	31583	56583	45266	1.76
13	T_{13}	42.92	63.951	90956	25000	28191	53191	37765	1.71
14	T_{14}	43.67	65.068	92545	25000	30087	55087	37459	1.68
15	T_{15}	42.17	62.833	89367	25000	29162	54162	35205	1.65
16	T_{16}	40.36	60.136	85531	25000	31270	56270	29261	1.52

Table 4.29 Effect of different treatment on Net Return-Benefit Cost ratio during 2023

Sr. no	Treatments	Yield(q/ha)		Gross return (Rs/ha)	Cost of cultivation (Rs/ha)			Net return (Rs /ha)	BCR
		Grain	Dry matter		Fixed cost	Variable	Total cost		
1	T_1	20.33	30.292	47149	25000	6433	31433	15716	1.50
2	T_2	36.08	53.759	83677	25000	22815	47815	35861	1.75
3	T_3	31.33	46.682	72661	25000	22491	47491	25170	1.53
4	T_4	33.39	49.751	77438	25000	20022	45022	32416	1.72
5	T_5	30.33	45.192	70341	25000	18421	43421	26921	1.62
6	T_6	28.86	43.001	66932	25000	15079	40079	26853	1.67
7	T_7	35.33	52.642	81937	25000	26211	51211	30727	1.6
8	T_8	38.00	56.620	88130	25000	26538	51538	36592	1.71
9	T_9	34.94	52.061	81033	25000	27619	52619	28414	1.54
10	T_{10}	40.39	66.181	93672	25000	29146	54146	39527	1.73
11	T_{11}	42.33	63.072	98172	25000	34498	59498	38674	1.65
12	T_{12}	44.28	65977	102694	25000	33682	58682	44012	1.78
13	T_{13}	37.83	56.367	87735	25000	26009	51009	36726	1.72
14	T_{14}	40.83	60.837	94693	25000	31031	56031	38662	1.69
15	T_{15}	35.00	52.150	81172	25000	24495	49495	31677	1.64
16	T_{16}	38.17	56.873	88524	25000	32859	57859	30665	1.53

4.2 Experiment 2

It was conducted with the following objective:

(a) To study the uptake of nitrogen in maize plants under different fertilizer treatments.

Experiment was conducted in field on a coarse loamy mixed hyper thermic family of Typic Haplustept soil in *kharif* season for two years. Results obtained from various field and laboratory analysis are presented and discussed here. There were only two treatments i.e. T_1 = Control T_2 = 100%RDF (3applications)

4.2.1 Growth attributes studies:

Under these studies growth attributes data were collected at every 3 days from 23 days of sowing onwards, up to harvest. The plant parameters recorded were plant height, dry weight, cob length, cobs weight and grain weight. Data for the same are presented in table 4.30 to 4.35; figure 4.28 to 4.33 are discussed below

4.2.1.1 Plant height (2022)

Plant height data were collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2022, the treatment wise details of data are presented in table 4.30 and figure 4.28

Table 4.30 Plant height at every three days from 23 days of sowing to harvesting during 2022

Days after sowing	Height (cm)		
	T_1	T_2	Mean
23	25.67	24.00	24.84
26	29.67	34.67	32.17
29	30.33	34.00	32.19
32	41.33	40.33	40.83
35	45.67	44.00	44.84
38	51.00	52.67	51.84
41	64.33	54.67	59.50
44	70.33	62.67	66.50
47	82.33	77.00	79.67
50	77.67	74.33	76.00
53	86.33	85.00	85.67
56	104.67	99.67	102.17
59	108.33	102.33	105.33
62	125.67	131.67	128.67
65	142.33	137.67	140.00
68	136.00	144.33	140.17
71	137.00	142.67	139.84
74	153.00	160.67	156.84
77	140.67	149.67	145.17
80	140.00	154.67	147.34
83	143.00	161.33	152.17
85	143.67	159.67	151.67

89	154.00	151.33	152.67
92	170.00	168.00	169.00
95	171.33	173.00	172.17
98	170.67	184.00	177.34
101	171.21	180.36	175.79
104	170.19	176.43	173.31
107	169.08	174.56	171.82
C.D.(P=0.05)	6.85	7.36	7.09
S.E.m. (±)	3.26	3.50	3.38

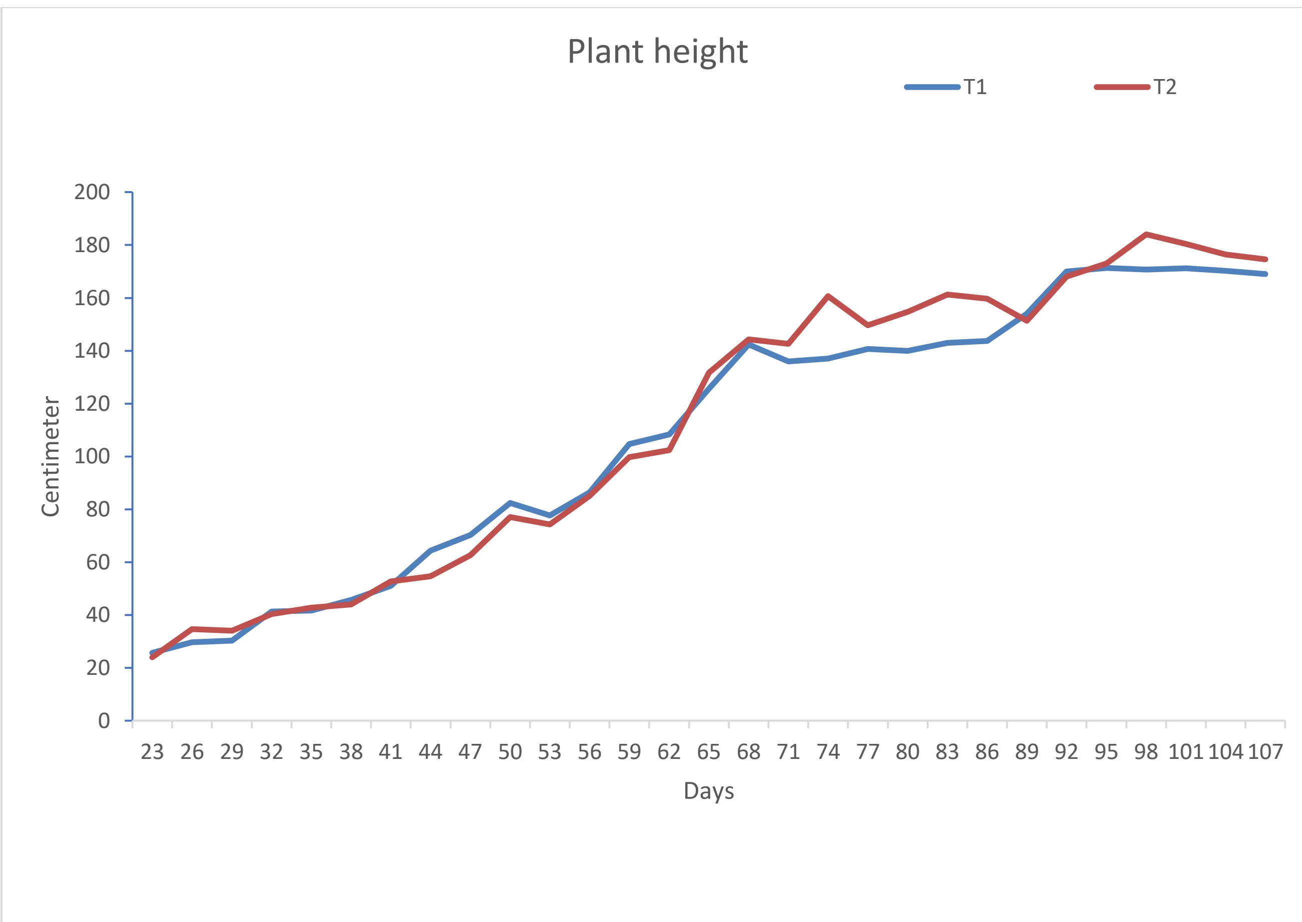

Figure 4.28 Plant heights 2022

Plant height data were collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2022, the treatment wise details of data are presented in table no 4.30 and figure 4.28. In 2022 highest plant height was recorded in treatment T_1 (171.33 cm) i.e. 95 days after plant height and lowest plant height was recorded in treatment T_1 (25.67 cm) i.e. 23 days after plant height. In 2022 highest plant height was recorded in treatment T_2 (184.00) i.e. 98 days after plant height and lowest plant height was recorded in treatment T_2 (24.00) i.e. 23 days after plant height. In experimental site observed that plant height gradually increases in both treatments. The findings indicated that the height of the plants rose when more nitrogen fertilizer was applied. The current results were consistent with those of Haseebur *et al*., (2010), who reported that whereas maize grown without fertilizer exhibited the lowest plant height, maize grown with a complete dose of nitrogen showed the largest plant height. The early sowing dates of the plants' rapid growth were mostly caused by the high maximum and minimum temperatures that prevailed at that time. Crop development, both physiologically and morphologically, is greatly influenced by temperature. Comparable outcomes had been reported by Panahi *et al.*, (2010) and Azadbakht *et al.*, (2012)

4.2.1.2. Plant height (2023)

Plant height data were collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2023, the treatment wise details of data are presented in table 4.31 and figure 4.29

Table 4.31 Plant height at every three days from 23 days of sowing to harvesting during 2023

Days after sowing	Height(cm)		
	T_1	T_2	Mean
23	25	27	26.00
26	32	33	32.50
29	32	34	33.00

32	42	40	41.00
35	47	49	48.00
38	51	54	52.50
41	63	62	62.50
44	67	72	69.50
47	80	78	79.00
50	77	82	79.50
53	86	89	87.50
56	98	99	98.50
59	110	117	113.50
62	125	125	125.00
65	138	134	136.00
68	146	148	147.00
71	143	144	143.50
74	141	145	143.00
77	139	151	145.00
80	145	149	147.00
83	153	153	153.00
85	153	154	153.50
89	157	154	155.50
92	160	159	159.50
95	170	171	170.50

98	168	172	170.00
101	171.45	173.27	172.36
104	169.22	170.33	169.78
C.D.(P=0.05)	6.86	6.93	6.89
S.E.m. (±)	3.27	3.30	3.28

Figure 4.29 Plant height

Plant height data were collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2023, the treatment wise details of data are presented in table no 4.31 and figure 4.29. In 2023 highest plant height was recorded in treatment T_1 (171.45 cm) i.e. 101 days after plant height and highest plant height was recorded in treatment T_2 (173.27 cm) i.e. 101 days after plant height. In 2023 lowest plant height was recorded in treatment T_1 (25) i.e. 23 days after plant height and lowest plant height was recorded in treatment T_1 (25) i.e. 23 days after plant height. Dawadi *et al.*, (2012) also observed that increasing nitrogen level plant height of maize also increased. Interregional variations in maize height morphological features are caused by a variety of factors, including planting density and genotype Subedi and Ma (2005); Ma *et al.*, (2014). Gou *et al.*, (2017)

4.2.1.3. Dry weight of plants at every three days from seeding to harvesting in 2022

Dry weight plant data were collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2022, the treatment wise details of data are presented in table 4.32 and figure 4.30

Table 4.32 Dry weight of plants at every three days from 23 days of sowing to harvesting

Days after sowing	Weight (gm) 2022		
	T_1	T_2	Mean
23	6	5	5.50
26	8	10	9.00
29	8	7	7.50
32	11	14	12.50
35	10	12	11.00
38	10	13	11.50
41	19	19	19.00
44	21	21	21.00
47	20	18	19.00
50	22	23	22.50
53	27	22	24.50
56	18	27	22.50

59	29	32	30.50
62	36	38	37.00
65	39	43	41.00
68	42	39	40.50
71	43	45	44.00
74	49	49	49.00
77	48	53	50.50
80	55	60	57.50
83	57	63	60.00
85	96	79	87.50
89	91	92	91.50
92	95	95	95.00
95	94	92	93.00
98	112	117	114.50
101	123	129	126.00
104	127	132	129.50
107	133	139	272.00
C.D.(P=0.05)	5.32	5.56	5.44
S.E.m. (±)	2.53	2.65	2.59

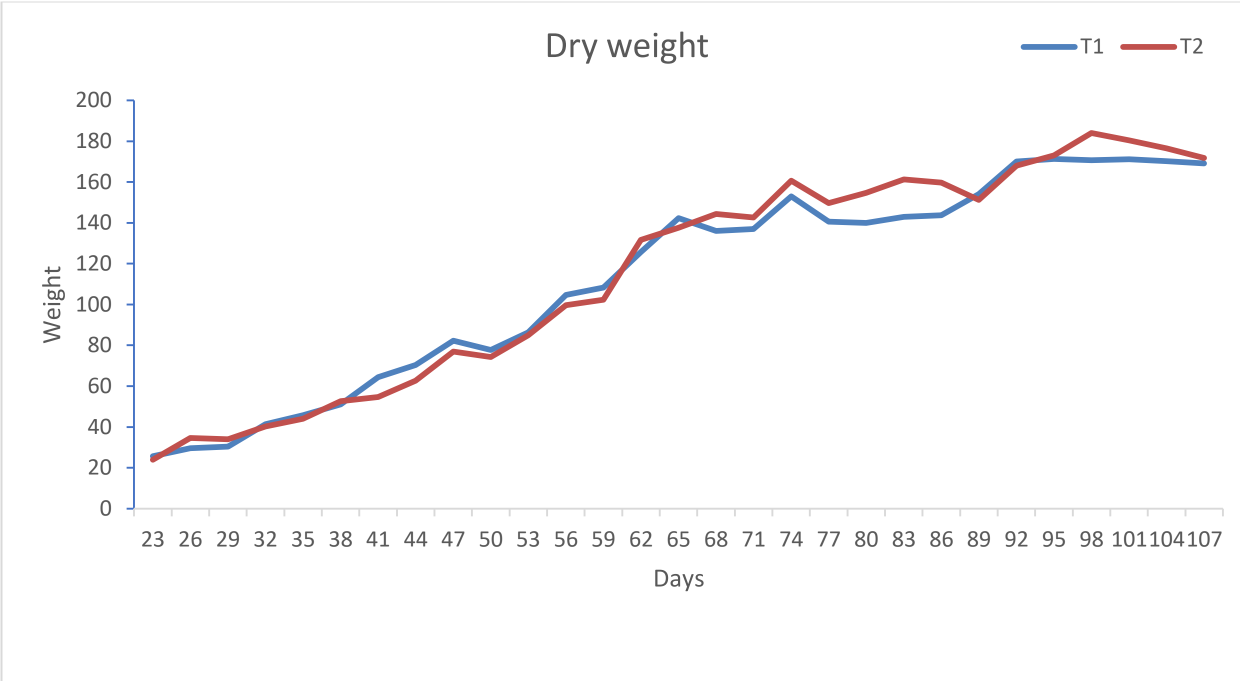

Figure 4.30 Dry weight of plant

Dry weight of plant data was collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2022, the treatment wise details of data are presented in table no 4.32 and figure 4.30. In 2022 highest dry weight of plant data was recorded in treatment T_1 (133 gm) i.e. 107 days after plant and highest dry weight of plant data was recorded in treatment T_2 (139 gm) i.e. 101 days after plant. In 2022 lowest dry weight of plant was recorded in treatment T_1 (6 gm) i.e. 23 days after plant and lowest plant height was recorded in treatment T_2 (5 gm) i.e. 23 days after plant in 2022. Weight measurements of entire plants and ears alone were made throughout the maize harvest in order to calculate the yield structure and total dry matter yield. To compute the dry matter yield of straw, ears, and entire plants, the percentage of dry matter in the maize aerial parts was also ascertained (Szulc P *et al.*, 2021).

4.2.1.4. Dry weight of plants at every three days from 23 days of sowing to harvesting in 2023

Dry weight plant data were collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2023, the treatment wise details of data are presented in table no 4.33 and figure 4.31

Table 4.33 Dry weight of plants at every three days from 23 days of sowing to harvesting

Days after sowing	Weight (gm) 2023		
	T_1	T_2	Mean
23	4	5	4.50
26	6	8	7.00
29	10	7	8.50
32	9	14	11.50
35	12	17	14.50
38	10	15	12.50
41	20	19	19.50
44	17	17	17.00
47	18	18	18.00
50	21	23	22.00
53	27	29	28.00
56	24	24	24.00
59	22	27	24.50
62	37	39	38.00
65	36	37	36.50
68	40	43	41.50
71	43	43	43.00
74	50	54	52.00
77	48	49	48.50

80	58	54	56.00
83	60	63	61.50
85	95	79	87.00
89	90	85	87.50
92	98	96	97.00
95	95	101	98.00
98	106	96	101.00
101	119	125	122.00
104	135	137	136.00
C.D.(P=0.05)	5.40	5.48	5.44
S.E.m. (±)	2.57	2.61	2.59

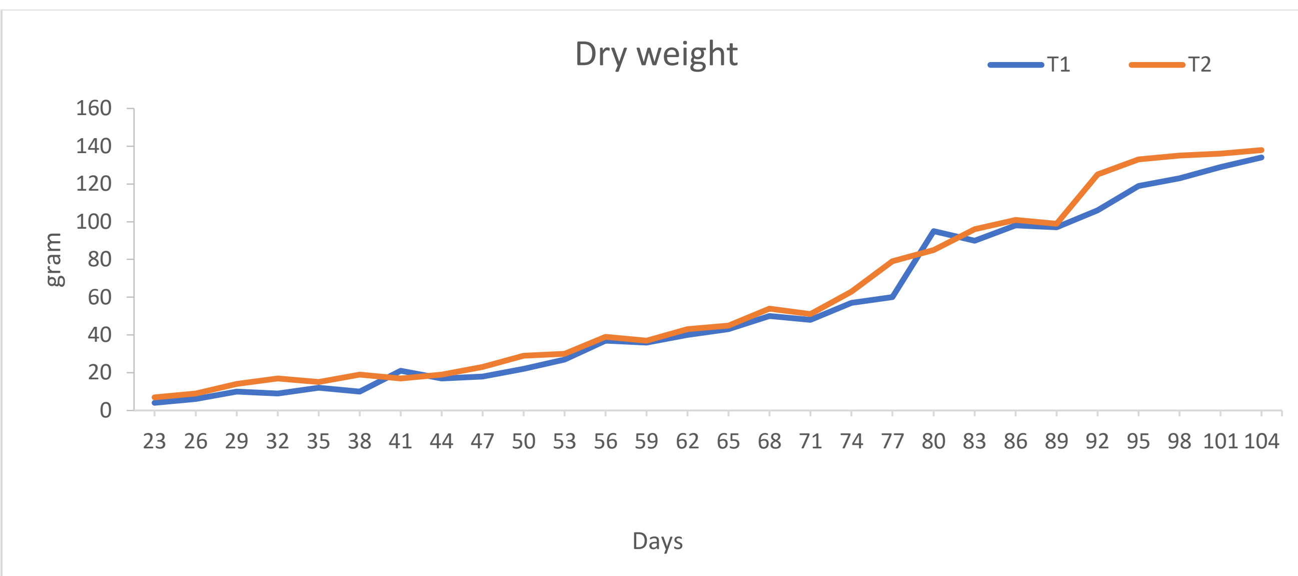

Figure 4.31 Dry weight of plant

Dry weight of plant data was collected at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2023, the treatment wise details of data are presented in table no 4.33 and figure 4.31. In 2023 highest dry weight of plant data was recorded in treatment T_1 (135 gm) i.e. 104 days after plant and highest dry weight of plant data was recorded in treatment T_2 (137 gm) i.e. 104 days after plant. In 2023 lowest dry weight of plant was recorded in treatment T_1 (4 gm) i.e. 23 days after plant and lowest plant height was recorded in treatment T_1 (5 gm) i.e. 23 days after plant. The depth of fertilizer treatment has a substantial impact on the production of dry matter of entire plants and ears (Kruczek, 2005).

4.2.1.5 Length (cm) of cobs at maize harvest

After harvesting maize cobs length data were recorded. During *kharif* growing season 2022 and 2023, the treatment wise details of data are presented in table no 4.34 and figure 4.32

Table 4.34 Length (cm) of cobs at maize harvest in experimental field

Sr. no	Treatments	2022	2023	Mean
1	T1 = Absolute control	17.3	17.93	17.62
2	T2 100%RDF (3applications)	21.23	20.9	21.07
C.D.(P=0.05)		0.86	0.84	0.82
S.E.m. (±)		0.38	0.36	0.35

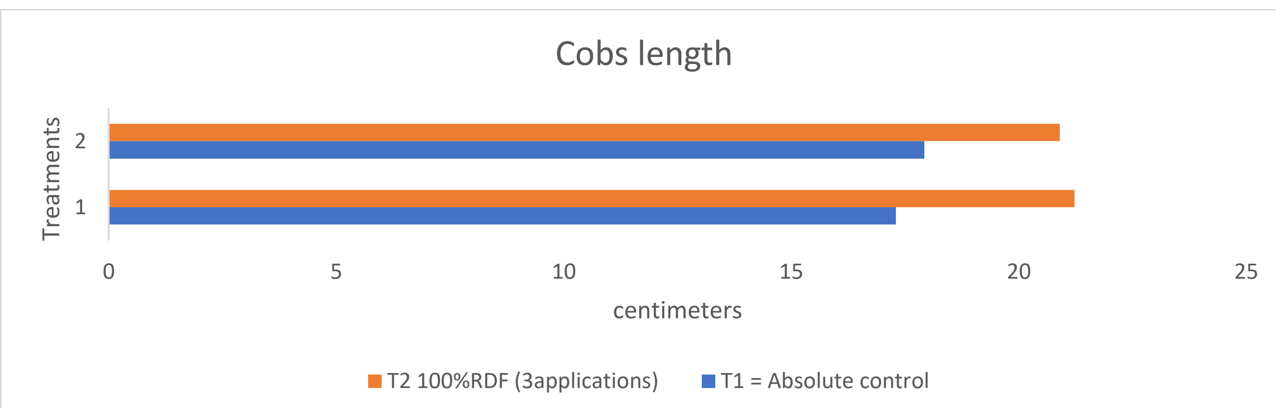

Figure 4.32 Length of maize cobs

After harvest maize cobs length data were recorded. During *kharif* growing season 2022 and 2023, the treatment wise details of data are presented in table no 4.34 and figure 4.32, In 2022 the highest length was observed T_2 treatments in 2023 the highest length was observed in T_2

treatments, and in 2022 the lowest length was observed T_1 treatments in 2023 the lowest length was observed in T_1 treatments. Because of intense competition for nutrients, cob length dropped as plant population rose. Additionally, the shadowing impact of more plants resulted in smaller cobs (Gaire R *et al*., 2020).

4.2.1.6 Weight of maize cobs after harvest

After harvest maize cobs weight data were recorded. During *kharif* growing season 2022 and 2023, the treatment wise details of data are presented in table no 4.35 and figure 4.33

Table 4.35 Weight of maize cobs after harvest (q/ha) in experimental field

Sr. no	Treatments	2022	2023	Mean
1	T1 = Absolute control	69.7	70.6	70.15
2	T2 100%RDF (3applications)	75.9	78.63	77.27
C.D.(P=0.05)		3.04	3.15	3.09
S.E.m. (±)		1.45	1.50	1.47

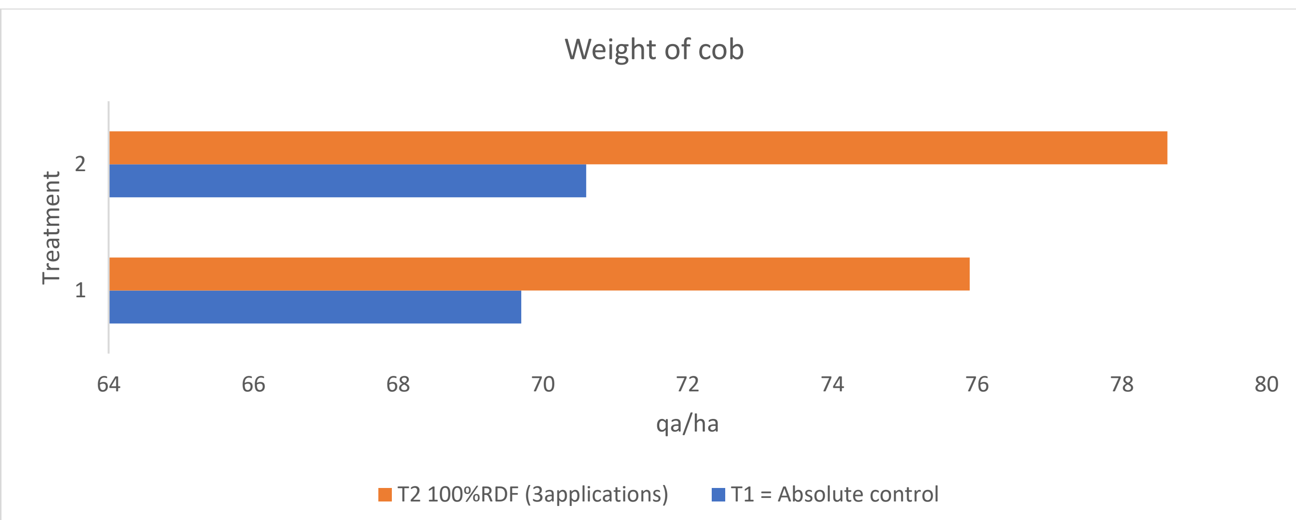

Figure 4.33 Weight of maize cobs (q/ha)

After harvest maize cobs weight data were recorded. During *kharif* growing season 2022 and 2023. the treatment wise details of data are presented in table no 4.35 and figure 4.33, in 2022 the highest weight of maize cobs was observed T_2 treatments in 2023 the highest weight of maize cobs was observed in T_2 treatments, and in 2022 the lowest weight of maize cobs was observed T_1 treatments in 2023 the lowest weight of maize cobs was observed in T_1 treatments the weight of a cob covered in cornhusk demonstrates how much photosynthetic output is transferred to cobs. Wibowo A S *et al.,* (2017)

4.2.2 Laboratory analysis of plant samples

Under these studies experiments were conducted in laboratory to understand nutrient content in different attributes. Total nitrogen, total phosphorous, total potassium, were estimated and are discussed in table 4.36, 4.37, 4.38, 4.39, 4.40, 4.41 and figure 4.34, 4.35, 4.36, 4.37, 4.39, 4.40.

4.2.2.1 Total nitrogen uptake in plant sample (kg ha^{-1}) in 2022

Data on total nitrogen content of plant sample at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2022, are presented in table 4.36 and figure 4.34

Table 4.36 Total nitrogen (kg ha^{-1}) uptake of plant samples during 2022

Days after sowing	Total nitrogen (kg ha^{-1}) 2022		
	T_1	T_2	Mean
23	5.8	5.0	5.40
26	8.2	8.7	8.45
29	9.4	9.7	9.55
32	10.8	10.5	10.65
35	14.2	14.6	14.40
38	14.8	14.9	14.85
41	15.9	15.0	15.45
44	16.3	16.7	16.50

47	17.0	17.5	17.25
50	17.8	18.3	18.05
53	19.6	19.7	19.65
56	21.0	21.5	21.25
59	23.1	22.7	22.90
62	23.9	24.7	24.30
65	24.9	25.5	25.20
68	27.1	28.6	27.85
71	27.6	29.7	28.65
74	28.1	29.5	28.80
77	28.9	30.6	29.75
80	29.6	31.7	30.65
83	30.4	32.5	31.45
85	32.6	34.6	33.60
89	33.2	34.8	34.00
92	35.5	36.6	36.05
95	35.7	35.9	35.80
98	36.1	36.7	36.40
101	36.9	36.9	36.90
104	37.5	37.5	37.50
107	38.0	38.10	38.05

C.D.(P=0.05)	1.52	1.69	1.73
S.E.m. (±)	0.71	0.83	0.85

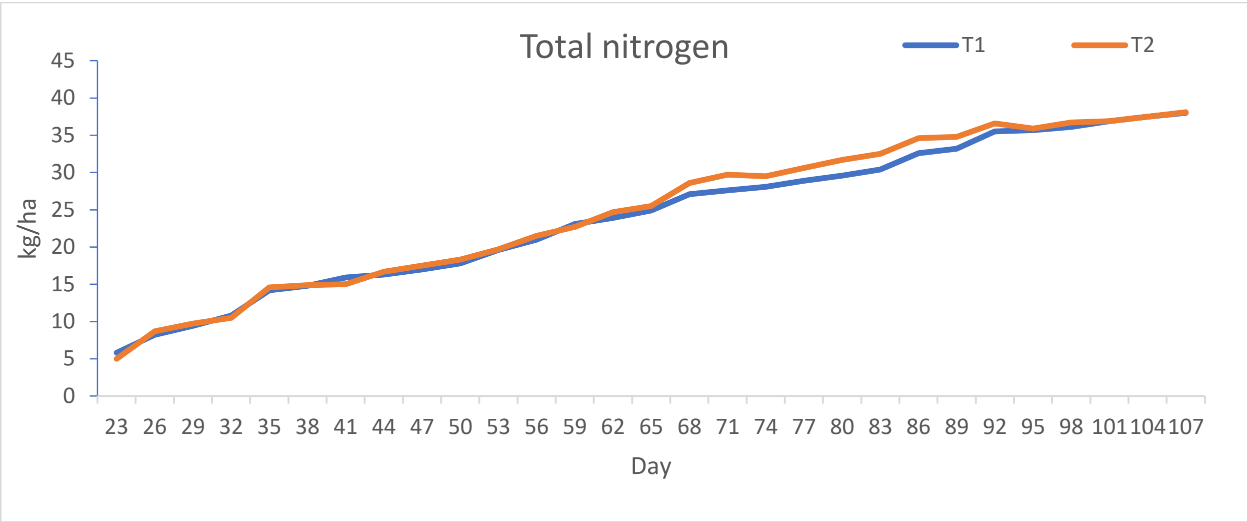

Figure 4.34 Total nitrogen (kg ha^{-1}) in plant samples

Total nitrogen data had analyzed in experiment at every 3 days from 23 days of sowing onwards, up to harvest. during *kharif* growing season 2022. The treatment wise details of data are presented in table 4.36 and figure 4.34, In 2022 highest total nitrogen (kg ha^{-1}) uptake of plant samples was recorded in treatment T_1 (38.0 gm) i.e. 107 days after plant sowing samples and highest total nitrogen (kg ha^{-1}) uptake of plant samples was recorded in treatment T_2 (38.10 gm) i.e. 107 days after plant sowing samples. In 2022 lowest total nitrogen (kg ha^{-1}) content of plant samples was recorded in treatment T_1 (22.89 gm) i.e. 23 days after plant sample and lowest total nitrogen (kg ha^{-1}) content of plant samples was recorded in treatment T_2 (20.33 gm) i.e. 29 days after plant sowing samples. The nitrogen content of maize biomass was significantly affected by mineral fertilization (Nenova *et al.*, 2019).

4.2.2.2 Total nitrogen content in plant sample (kg ha^{-1}) in 2023

Data on total nitrogen content of plant sample at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2023, are presented in table 4.37 and figure 4.35

Table 4.37 Total nitrogen (kg ha^{-1}) content of plant samples during 2023

Days after sowing	Total nitrogen (kg ha^{-1}) 2023		
	T_1	T_2	Mean
23	5.9	5.1	5.50
26	5.5	5.0	5.25
29	7.3	7.5	7.40
32	7.6	7.4	7.50
35	8.7	8.9	8.80
38	9.7	9.1	9.40
41	11.9	11.4	11.65
44	13.1	13.2	13.15
47	14.7	14.5	14.60
50	15.3	15.9	15.60
53	15.8	15.3	15.55
56	17.3	17.5	17.40
59	19.3	19.5	19.40
62	20.8	20.3	20.55
65	21.4	21.6	21.50
68	22.3	22.5	22.40
71	24.8	24.3	24.55
74	25.4	25.1	25.25
77	26.1	27.5	26.80

80	28.8	29.3	29.05
83	30.7	30.4	30.55
85	32.0	31.5	31.75
89	33.8	33.9	33.85
92	35.9	36.2	36.05
95	36.6	36.3	36.45
98	37.8	38.90	38.35
101	38.1	38.46	38.28
104	39.4	37.9	38.65
C.D.(P=0.05)	1.57	1.55	1.54
S.E.m. (±)	0.75	0.74	0.73

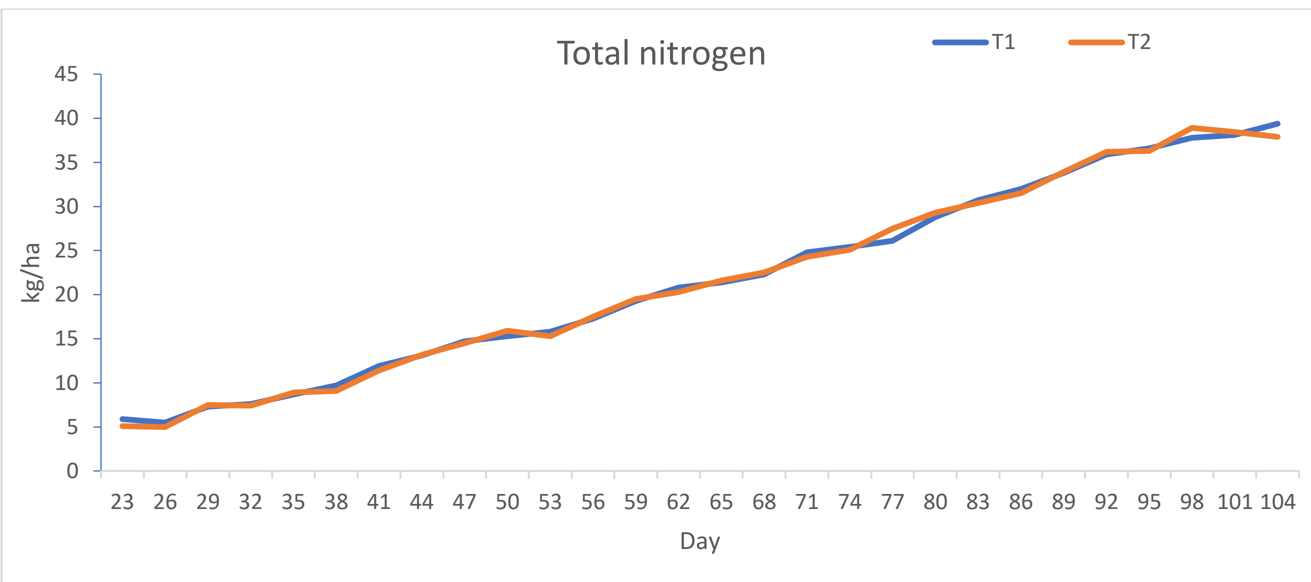

Figure 4.35 Total nitrogen (kg ha^{-1}) in plant samples

In 2023 highest total nitrogen (kg ha^{-1}) content of plant samples was recorded in treatment T_1 (39.4 gm) i.e. 104 days after plant sowing samples and highest total nitrogen (kg ha^{-1}) uptake of plant samples was recorded in treatment T_2 (38.90 gm) i.e. 98 days after plant sowing samples. In 2023 lowest total nitrogen (kg ha^{-1}) content of plant samples was recorded in treatment T_1 (5.9 gm) i.e. 23 days after plant sample and lowest total nitrogen (kg ha^{-1}) content of plant samples was recorded in treatment T_2 (5.0 gm) i.e. 26 days after plant sowing samples. This was explained by the fact that N, P, and K were continuously supplied to the crop during the crop's growth periods; in the early stages, the crop had access to nutrients from chemical sources, but in the latter stages, this slowed down gradually (Vidyavathi *et al.*, 2012).

4.2.2.3 Total Phosphorus uptake in plant sample in 2022

Data on total phosphorus content of plant sample at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2022, are presented in table 4.38 and figure 4.36

Table 4.38 Total Phosphorus (kg ha^{-1}) uptake of plant samples

Days after sowing	Total Phosphorus (kg ha^{-1})		
	T_1	T_2	Mean
23	1.13	1.15	1.14
26	1.15	1.21	1.18
29	2.20	2.29	2.25
32	2.53	2.68	2.61
35	2.89	2.85	2.87
38	2.92	2.95	2.94
41	3.1	3.3	3.20
44	3.5	3.7	3.60

47	3.7	3.9	3.80
50	4.9	4.1	4.50
53	5.0	4.5	4.75
56	4.8	4.9	4.85
59	4.7	5.1	4.90
62	5.0	5.3	5.15
65	5.9	6.4	6.15
68	6.0	6.7	6.35
71	7.2	7.9	7.55
74	7.1	7.4	7.25
77	7.2	7.7	7.45
80	9.2	9.3	9.25
83	9.3	10.7	10.00
85	12.1	11.3	11.70
89	12.5	11.9	12.20
92	13.4	12.8	13.10
95	14.3	14.1	14.20
98	14.8	15.7	15.25
101	14.3	15.9	15.10
104	14.9	15.1	15.00
107	15.8	16.3	16.05

C.D.(P=0.05)	0.63	0.65	0.67
S.E.m. (±)	0.30	0.31	0.33

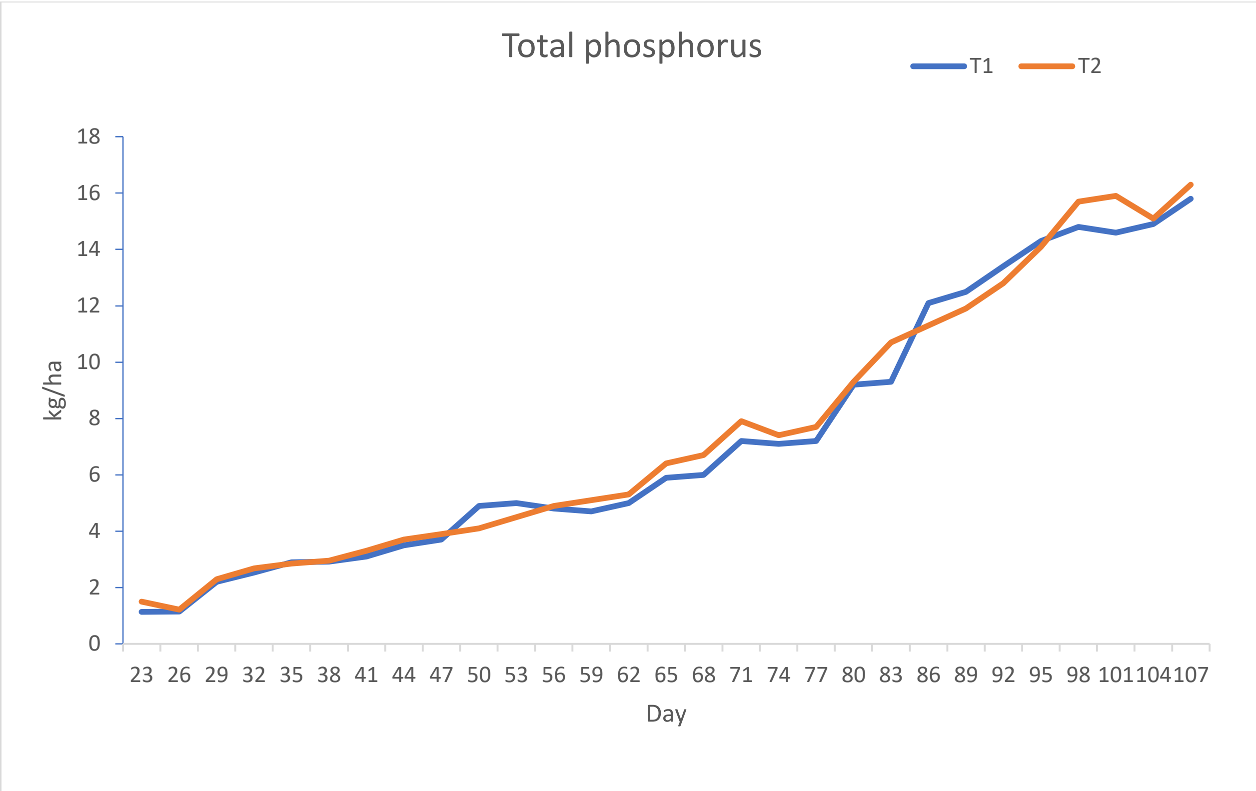

Figure 4.36 Total Phosphorus (kg ha^{-1}) plant samples

In 2022 highest total phosphorus (kg ha^{-1}) uptake of plant samples was recorded in treatment T_1 (15.8 gm) i.e. 107 days after plant sowing samples and highest total phosphorus (kg ha^{-1}) uptake of plant samples was recorded in treatment T_2 (16.3 gm) i.e. 107 days after plant sowing samples. In 2022 lowest total phosphorus (kg ha^{-1}) content of plant samples was recorded in treatment T_1 (1.31gm) i.e. 23 days after plant sample and lowest total phosphorus (kg ha^{-1}) content of plant samples was recorded in treatment T_2 (1.15gm) i.e. 23 days after plant sowing samples. It was discovered that because of its stronger fixation and involvement in a particular absorption reaction, the extractability of available phosphorus reduced as soil temperature increased (Shep-pard and Racz, 1984).

4.2.2.4 Total Phosphorus uptake in plant sample (kg ha^{-1})

Data on total phosphorus content of plant sample at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2023, are presented in table 4.39 and figure 4.37

Table 4.39 Total Phosphorus (kg ha^{-1}) uptake of plant samples

Total Phosphorus (kg ha^{-1})			
Days after sowing	**T_1**	**T_2**	**Mean**
23	1.13	1.5	1.32
26	1.17	1.19	1.18
29	2.4	2.39	2.40
32	2.35	2.8	2.58
35	2.9	2.79	2.85
38	2.69	2.99	2.84
41	3.34	3.78	3.56
44	3.6	3.8	3.70
47	3.9	4	3.95
50	4.8	4.3	4.55
53	5.5	4.9	5.20
56	5.1	5.3	5.20
59	5.7	5.9	5.80
62	5.4	5.7	5.55

65	6	6.7	6.35
68	6.9	7	6.95
71	7.5	7.8	7.65
74	7.7	7.6	7.66
77	7.9	7.8	7.85
80	9.4	9.5	9.45
83	9.7	10.9	10.30
86	12.4	11.7	12.05
89	12.7	12.1	12.40
92	13.8	12.8	13.30
95	14.8	14.1	14.45
98	14.9	15.7	15.30
101	15	16.12	15.56
104	15.9	15.1	15.50
C.D.(P=0.05)	0.63	0.65	0.61
S.E.m. (±)	0.30	0.31	0.29

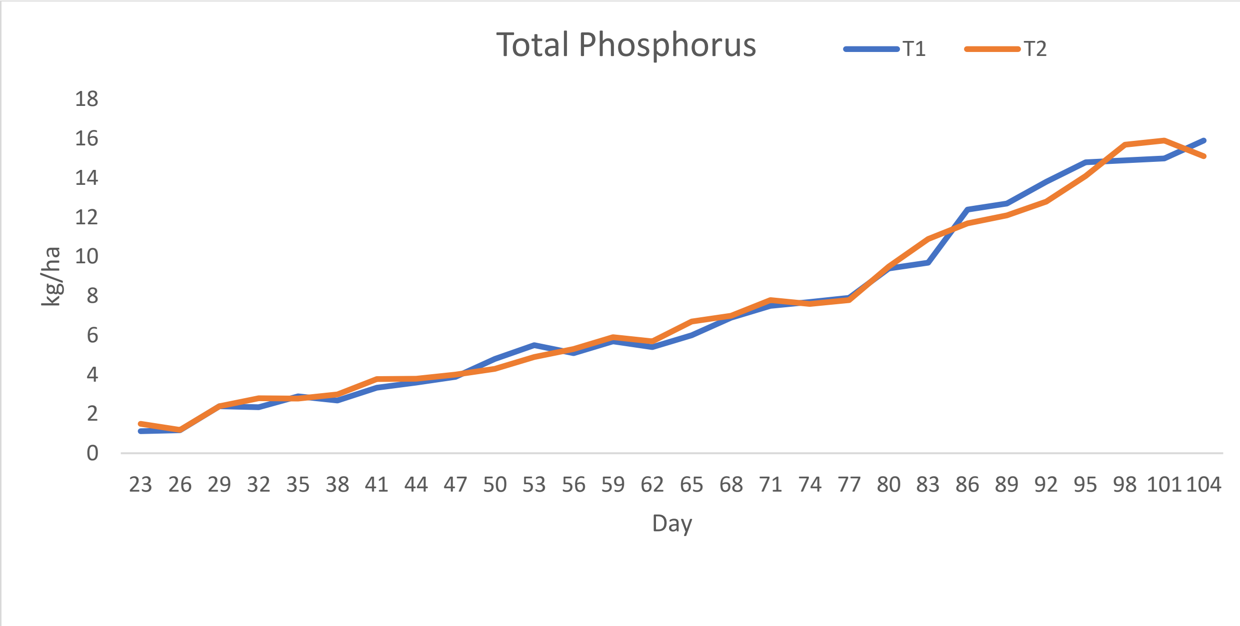

Figure 4.37 Total Phosphorus (kg ha^{-1}) in plant samples

In 2023 highest total phosphorus (kg ha^{-1}) uptake of plant samples was recorded in treatment T_1 (15.9 gm) i.e. 104 days after plant sowing samples and highest total phosphorus (kg ha^{-1}) uptake of plant samples was recorded in treatment T_2 (16.12 gm) i.e. 101 days after plant sowing samples. In 2023 lowest total phosphorus (kg ha^{-1}) content of plant samples was recorded in treatment T_1 (1.13 gm) i.e. 23 days after plant sample and lowest total phosphorus content of samples of plants were noted after treatment T_2 (1.5gm) i.e. 23 days after plant sowing samples. The second nutrient that maize plants require the most is phosphorus, which has a direct impact on crop development and yield (Dhillon *et al.*, 2017). One of the elements that limit agricultural cropping systems the most is phosphorus (Roberts and Johnston, 2015).

4.2.2.5 Total Potassium of dry matter in plant sample (kg ha^{-1})

Data on total potassium uptake of plant sample at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2022, are presented in table 4.40 and figure 4.38

Table 4.40 Total potassium (kg ha^{-1}) uptake of plant samples

Days after sowing	Total potassium (kg ha^{-1})		
	T_1	T_2	Mean
23	2.59	2.61	2.60
26	2.62	2.67	2.65
29	3.71	3.73	3.72
32	4.15	4.23	4.19
35	5.28	5.30	5.29
38	5.30	5.33	5.32
41	6.6	6.8	6.70
44	7.0	7.4	7.20
47	8.1	8.5	8.30
50	9.1	9.6	9.35
53	10.0	10.4	10.20
56	10.9	10.6	10.75
59	11.7	11.9	11.80
62	12.5	11.9	12.20
65	13.6	13.8	13.70
68	13.1	13.7	13.40
71	14.9	14.9	14.90
74	15.6	15.6	15.60

77	16.8	16.7	16.75
80	17.0	17.8	17.40
83	17.2	17.9	17.55
85	18.9	18.6	18.75
89	20.8	20.3	20.55
92	21.5	24.1	22.80
95	23.5	24.7	24.10
98	24.2	25.8	25.00
101	27.8	26.4	27.10
104	29.4	28.4	28.90
107	29.1	29.0	29.05
C.D.(P=0.05)	1.18	1.16	1.20
S.E.m. (±)	0.56	0.55	0.58

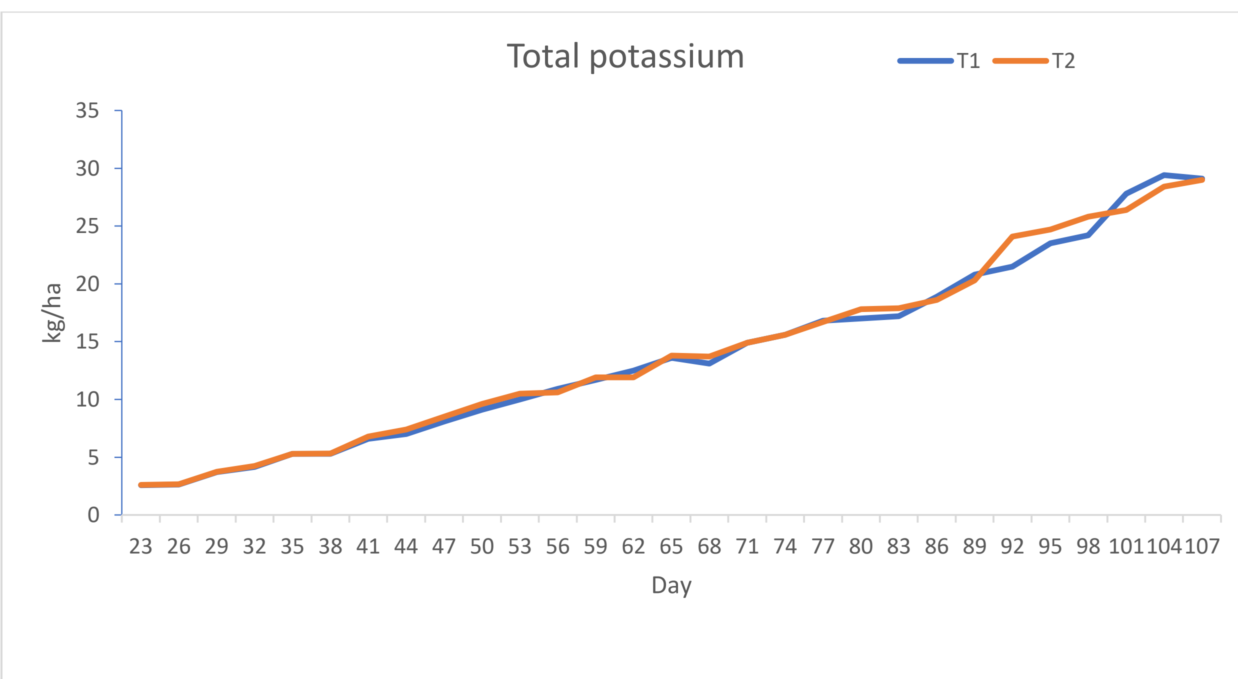

Figure 4.38 Total Potassium (kg ha^{-1}) in plant samples

In 2022 highest total potassium (kg ha^{-1}) uptake of plant samples was recorded in treatment T_1 (29.4gm) i.e. 104 days after plant sowing samples and highest total potassium (kg ha^{-1}) uptake of plant samples was recorded in treatment T_2 (29gm) i.e. 107 days after plant sowing samples. In 2022 lowest total potassium (kg ha^{-1}) content of plant samples was recorded in treatment T_1 (2.59gm) i.e. 23 days after plant sample and lowest total potassium content of plant samples was recorded in treatment T_2 (2.61gm) i.e. 23 days after plant sowing samples. Potassium affects the quantity and quality of agricultural crops and is a necessary macronutrient for plant growth and development (Clarkson D T *et al.*, 1980)

4.2.2.6 Total Potassium dry matter in plant sample (kg ha^{-1}) 2023

Data on total potassium uptake of plant sample at every 3 days from 23 days of sowing onwards, up to harvest. During *kharif* growing season 2023, are presented in table 4.41 and figure 4.39

Table 4.41 Total potassium (kg ha^{-1}) uptake of plant samples

Days after sowing	**Total potassium (kg ha^{-1})**		
	T_1	T_2	Mean
23	2.98	2.88	2.93
26	2.73	2.75	2.74
29	3.88	3.75	3.82
32	4.29	4.30	4.30
35	5.35	5.45	5.40
38	5.48	5.39	5.44
41	6.9	6.6	6.75
44	7.3	7.5	7.40

47	8.9	8.8	8.85
50	9.7	10.6	10.15
53	10.7	10.9	10.80
56	10.45	10.63	10.54
59	12.7	11.88	12.29
62	12.73	11.45	12.09
65	13.8	13.9	13.85
68	14.1	14.7	14.40
71	15.91	15.7	15.81
74	15.9	15.4	15.65
77	16.4	16.9	16.65
80	17.3	17.1	17.20
83	17.7	17.6	17.65
85	18.6	18.5	18.55
89	20.6	20.7	20.65
92	22.5	23.1	22.80
95	24.5	24.9	24.70
98	25.2	25.6	25.40
101	28.8	26.9	27.85
104	30.4	29.8	30.10
C.D.(P=0.05)	1.22	1.19	1.20

S.E.m. (±)	0.58	0.55	0.57

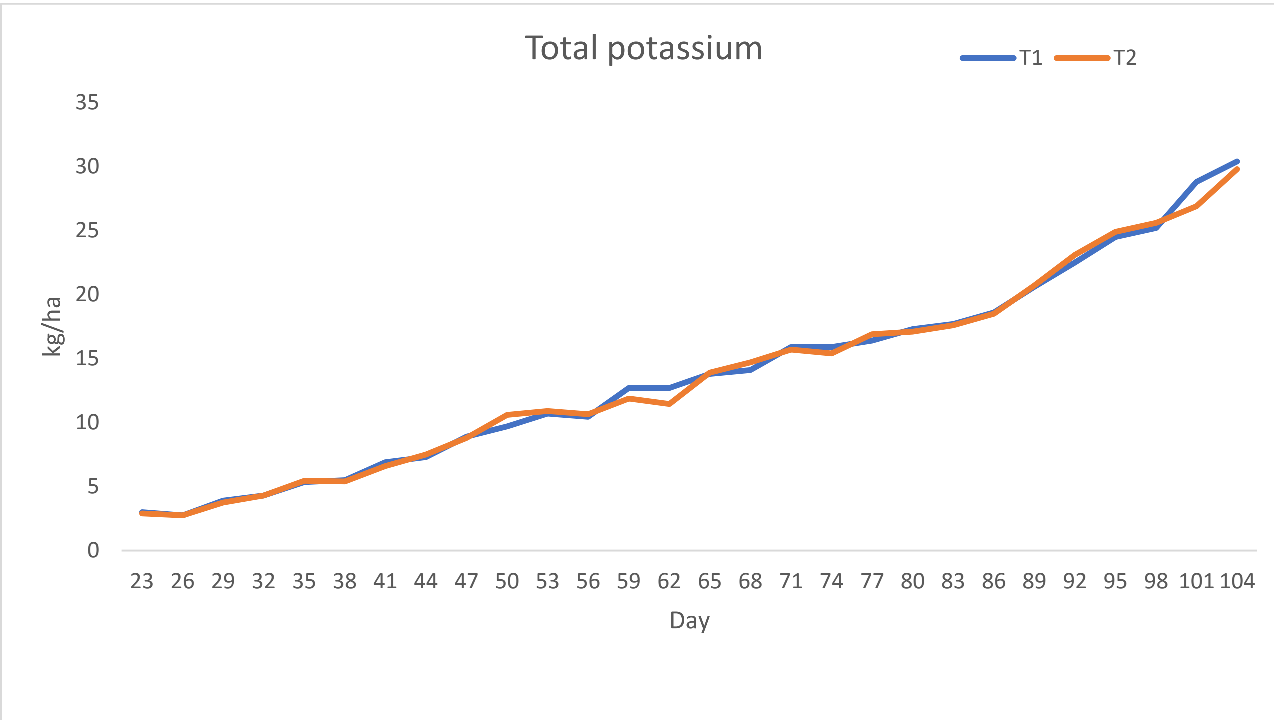

Figure 4.39 Total Potassium (kg ha^{-1}) in plant samples

In 2023 highest total potassium (kg ha^{-1}) uptake of plant samples was recorded in treatment T_1 (30.40 gm) i.e. 104 days after plant sowing samples and highest total potassium (kg ha^{-1}) uptake of plant samples was recorded in treatment T_2 (29.8 gm) i.e. 104 days after plant sowing samples. In 2023 lowest total potassium (kg ha^{-1}) content of plant samples was recorded in treatment T_1 (2.73gm) i.e. 26 days after plant sample and lowest total potassium content of plant samples was recorded in treatment T_2 (2.75gm) i.e. 26 days after plant sowing samples. Potassium concentrations in plant organs varied significantly as a result of the experimental factor. The stems and leaves of maize showed an especially robust reaction to both no potassium fertilizations and varying rates of potassium application. Bak *et al.*, (2016)

4.2.3 Soil characteristics of the experiment number II field

In the soil science department of Lovely Professional University, Punjab's School of Agriculture, a field experiment was carried out. Table 4.42 displays the soil properties of the soil sample taken both prior to and following the harvest of the maize crop.

Table 4.42 Soil characteristics of the experimental field

Sr.no	Parameter	Range
1	Soil pH	7.8
2	Soil EC (dSm^{-1})	0.34
3	Organic carbon (g/kg)	3.97
4	Soil cation Exchange capacity (meq $100g^{-1}$)	4.45
5	Available nitrogen (kg ha^{-1})	209.54
6	Available phosphorus (kg ha^{-1})	7.19
7	Available potassium (kg ha^{-1})	112.67

Soil collected was alkaline in reaction having pH of 7.8. Electrical conductivity of soil was slightly saline, sandy loam is texture. The cation exchange of capacity of the soil was 4.45meq $100g^{-1}$ and organic carbon of was 3.97g/kg. The soil had a medium level of available potassium and phosphorus and a low level of organic carbon and available nitrogen.

CHAPTER - V

SUMMARY AND CONCLUSIONS

Summary and conclusions

The results of the investigation entitled, 'Evaluation of timing of nitrogen application in maize (*Zea mays* L.) grown on coarse loamy Typic Haplustept soil of Punjab' are summarized below along with the concluding remarks:

Experiment -1

The field investigation was conducted in RBD design that contained sixteen treatments in experiment 1 to meet the second, third and fourth objectives of the approved study. This experiment was conducted with three replications in semi-arid semi-tropical monsoon type climate that are generally favorable for maize cultivation. The experimental site received in 681.7 mm rainfall in 2022 and 636.3 mm rainfall in 2023. The experimental site is classified as coarse loamy fixed hyper Thermic family of Typic Haplustept soil as per Soil Taxonomy. Recommended dose of fertilizer was N @ 125 kg ha^{-1}, P_2O_5 @ 60 kg ha^{-1}, K_2O @ 30 kg ha^{-1}, only neem-coated urea was used in all recommended dosage fertilizer applications. In the field experiment phosphorous, potassium, vermi-compost and farm yard manure were applied as basal. The significant outcomes of this investigation are summarized below:

1. Application of vermi-compost, neem coated urea, nano urea, farm yard manure or their combination did not depict any significant difference at the emergence stage of maize,

2. The maximum height of maize crop was found 60 days after sowing under the T_{16} 100% RDF (basal application timings) treatment in 2022 and T_3 75% RDF + FYM 5 t ha^{-1} (Farm yard manure) treatments in 2023

3. Highest maize cob length was recorded in 100% RDF (2 Application timings) in 2022 and in 100% RDF (Basal application timings) in 2023

4. Application of 75% RDF+ vermi-compost @2.5 t ha^{-1} recorded highest dry matter yield of maize crop after harvest in 2022 and Application of 100% RDF (4 Application timings) the recorded highest dry matter yield in 2023

5. Application of 100% RDF+ vermi-compost @2.5 t ha^{-1} produced the recorded highest maize grain yield in 2022 and Application of 100% RDF (3 applications) is the recorded highest maize grain yield in 2023

6. The highest content of total nitrogen was recorded in the application 100% RDF (basal application timings) in 2022 and under the application 100% RDF + FYM 5 t ha^{-1} in 2023

7. Highest content of total nitrogen in maize grain was recorded under the treatment 100% RDF (2 application timings) in 2022 and the highest content of total nitrogen in maize grain was recorded under the treatment 100% RDF (4 application timings) in 2023

8. Application of nano-urea did not show any significant advantages as compared to recommended dose of fertilizer nitrogen application in maize

9. Integrated use of vermi-compost @2.5tha^{-1} along with the recommended dose of fertilizer application has an added advantage or all other treatments

10. In respect of economic, application of 100% RDF+ vermi-compost 2.5 t ha^{-1} recorded maximum gross returns, net returns and Benefit-Cost ratio (1.78) as compared to other combination of treatments

Experiment-2

Field experiment was performed at the Lovely Professional University's research farm in Phagwara, Punjab, during the 2022 and 2023 *kharif* season This experiment primary goal was to understand, biomass and nitrogen uptake pattern of maize (Zea mays L.) grown in coarse loamy Typic Haplustept soil. The experiment farm is located at latitude at 31°14’30.5’’N and longitude 75°41'52.1” E. The field trial was conducted in randomized block design with three replications in non-saline alkaline soil. Their wore two treatments: the rdf N @ 125 kg ha^{-1}, P2O5 @ 60 kg ha^{-1}, K2O @ 30 kg ha^{-1} was tested against the no fertilizer control. The PAU maize variety PMH-13 was sown in kharif season of 2022 and 2023.The plant attribute data was collected at 3 days of interval starting after 23 days of sowing till maturity. Data on plant height, dry matter weight and total nitrogen was recorded for the plant sample after the plant achieved 3 leaves stage. The results of these experiments are summarized below:

1)The perusal of plant height data indicated for clear cut stages of maize growth at 42, 56, 65 and 89 days of sowing. However, the differences in growth stages are not clearly decipherable in dry weight in total nitrogen data.

2)Plant growth stage at 42 days is almost near to the knee-high stage and 65 days stage is near to the tasseling stage of the maize. These two stages match with the already recommended dose of nitrogen fertilizer.

3) Plant height data indicated two more growth stages of maize at 56 and 89 days.

4)Therefore, for improving maize productivity and increasing fertilizer urea efficiency it is suggested that nitrogen fertilizer dose should be further split to four top dressing applications.

5) However, further field trials in different agro-climatic regions are necessary for any final recommendation to the farmers.

Conclusions

Application of nano-urea did not show any significant advantages as compared to RDF nitrogen application in maize**.** Integrated use of vermi-compost @2.5t ha^{-1} along with the RDF application has an added advantage or all other treatments. Plant height data indicated two more growth stages of maize at 56 and 89 days. Therefore, for improving maize productivity and increasing fertilizer urea efficiency it is suggested that nitrogen fertilizer dose should be further split to four top dressing applications. However, further field trials in different agro-climatic reigns are necessary for any final recommendation to the farmers.

CHAPTER - VI

BIBLIOGRAPHY

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Abendroth LJ, Elmore RW, Boyer MJ and Marlay SK (2011) Corn growth and development. PMR **1009**. Iowa State Univ. Ext., Ames.

Abdelsalam N R, Kandil E E and Al-Msari M A F (2019) Effect of foliar application of NPK nanoparticle fertilization on yield and genotoxicity in crop, Te Science of the Total Environment **653**: pp.1128–1139.

Ajithkumar K, Kumar Y, Savitha AS, Ajayakumar MY, Narayanaswamy C, Raliya R, Krupashankar MR and Bhat SN (2021) Effect of IFFCO nano fertilizer on growth, grain yield and managing turcicum leaf blight disease in maize. International Journal of Plant and Soil Science.2021; v**33:** pp16-19.

Ali M, Khalil S K, Ayaz S and Marwat M I (1998) Phenological stages, flag leaf areas, plant height and leaves per plant of corn influenced by phosphorus levels and plant spacings. Sarhad J. Agric., **4** (6):pp515-517.

Alexander RJ (1987) Corn dry milling: processes, products, and applications. In: Watson SA, Ramstad PE, editors. Corn: chemistry and technology. St. Paul, Minn.: Am Assoc Cereal Chem. pp351–76.

All India Coordination Research Project (2007) on Maize 50th Annual Report by Directorate of Maize Research, Indian Council of Agriculture Research (ICAR). Pusa, New Delhi.

Almaz Meseret Gezahegn (2021) Review Article role of integrated nutrient management for sustainable maize production, International journal of agronomy, vol **20**.

Almaz M G, Halim R A and Martini M Y (2017) Effect of combined application of poultry manure and inorganic fertiliser on yield and yield components of maize intercropped with soybean, Pertanika Journal of Tropical Agricultural Science, vol.**40**, no. 1, pp. 173–183.

Amanullah I, Irfanullah A and Hidayat Z (2016) Potassium management for improving growth and grain yield of maize (*Zea mays* L.) under moisture stress condition. *Sci. Rep,* ***6*:** pp27-34

Anonymous (2012) Annual Kharif-Maize Progress Report 2012, Directorate of Maize Research, IARI, New Delhi.

Anonymous (2015) Annual Progress Report of Kharif maize. All India Coordinated research Project on Maize. Pusa Campus, New Delhi.

Arancon N Q, Edwards C A, Bierman P, Metzger J D and Lucht C (2005) Effects of vermi-composts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. Pedobiol **49**: pp297–306.

Ariraman R, Chelvi R and Karthikeyan M (2020) Integrated Nutrient Management Practices on Maize Growth Parameters, Yield Parameters and Yield of Maize, Tnau journal,(**8**): pp4-8

Arnon D I and Stout P R (1939) The Essentiality of Certain Elements in Minute Quantity forPlants with Special Reference to Copper. Plant Physiology, **14**: pp371-375.

Asibi A E, Chai Q, and Coulter J (2019) Mechanisms of Nitrogen Use in Maize. Agronomy, **9**(12): pp 7-16.

Atiyeh R M, Lee S S, Edwards C A, Arancon N Q and Metzger J (2002) The influence of humic acid derived from earthworm-processed organic waste on plant growth. Bioresour Technol **84**:pp7–14.

Awasthi A and Pandey KK (2014) Integrated nutrient management in the maize (Zea mays L.) yield and soil properties. International Journal of Agricultural Sciences,**10**: pp244-246.

Awika J (2011) Major cereal grains production and use around the world. In Advances in cereal science: implications to food processing and health promotion. American Chemical Society Atlantic City, NJ, Washington DC, pp.1–13.

Azadbakht A, Azadbakht G, Nasrollahi H and Bitarafan Z (2012) Evaluation of different planting dates effect on three maize hybrids in Koohdasht region of Iran. Int. J. Sci. Adv. Technol, **2**: pp34-38.

Baboo P (2021) Nano urea the philosophy of future. Available online on Research Gate

Babu C, Praveen BR, Singh M (2022a) Nano Urea: A step towards India's self-reliance in Nitrogen fertilizer production. Food Sci Rep v**3**: pp10–15.

Bak K, Gaj R and Budka A (2016). Accumulation of nitrogen, phosphorus and potassium in mature maize under variable rates of mineral fertilization. Fragmenta Agronomica,**33**: pp7-19

Beiragi M A, Khorasani K, Shojaei S H, Dadresan M, Mostafavi K, Golbashy M (2011) A study on effects of planting dates on growth and yield of 18 corn hybrids (Zea mays L.). American J. Experimental Agri., 1(3): pp110-120.

Bellon M R, Hodson D, Bergvinson D, Beck D, Martinez Romero E and Montoya Y (2005) Targeting agricultural research to benefit poor farmers: Relating poverty mapping to maize environments in Mexico. Food Policy, **30**: pp476–492.

Boone L V, Vasilas B L and F. Welch (1984) The nitrogen content of corn grain as affected by hybrid, population, and location, Communications in Soil Science and Plant Analysis, **15**pp:639-650

Brar B S, Singh J, Singh G and Kaur G (2015) Effect of long-term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize wheat rotation. Agronomy vol-**5**: pp 220–238.

Briggs G E, Kidd F and West C A (1920) quantitative analysis of plant growth. Part I. Anni. Appl. Biol. **7**: pp103-123.

Brown WL, Bressani R, Glover DV, Hallauer AR, Johnson VA and Qualset CO (1988) Quality-protein maize: report of an ad hoc panel of the advisory committee on technology innovation, Board on Science and Technology for International Development, National Research Council, in cooperation with the Board on Agriculture, National Research Council. Washington D.C: National Academy Press.

Clarkson D T and Hanson J B (1980) The mineral nutrition of higher plants Annu. Rev. Plant Physiol, **31**: pp. 239-298

Cartwright B, Tiller KG, Zarcinas BA and Spouncer LA (1983) The Chemical Assessment of the Boron Status of Soils. Aust. J. Soil Res., V**21**: pp321-332.

Chagwiza C, Muradian R and Ruben R (2016) Cooperative membership and dairy performance among smallholders in Ethiopia. Food Policy **59**:pp165–173.

Chahal S S and Kataria P (2005) Technology adoption and cost return aspects of maize cultivation in Punjab. Agricultural Situation in India **62** (4):241-247.

Chaoui H I, Zibilske L M and Ohno T (2003) Effects of earthworm casts and compost on soil microbial activity and plant nutrient availability. Soil Biol Biochem v**35**: pp295–302.

Chaudhary D P, Kumar S, and Yadav O P (2013) Nutritive Value of Maize*:* Improvements, Applications and Constraints. Maize: Nutrition Dynamics and Novel Uses, v**3**:17.

Chen C, Westcott M, Neill K, Wichman D and Knox M (2004) Row configuration and nitrogen applicationfor barley-pea intercropping in Montana. Agronomy Journal.2004; **96**(**6**):pp1730– 1738.

Chomba S K, Okalebo J R, Moses I, Mutuo P K and Markus W G (2013) Predicting maize response to fertilizer application using growth curves in western Kenya, Global Science Research Journals; Vol. **1** (**1**), pp. 078-085, November.

Davies B, Coulter JA and Pagliari PH (2020) Timing and rate of nitrogen fertilization influence maize yield and nitrogen use efficiency. PLoS One.;**15**(5): e0233674.

Dawadi D R. and Sah S K (2012) Growth and Yield of Hybrid Maize (Zea mays L.) in Relation to Planting Density and Nitrogen Levels during Winter Season in Nepal tropical Agricultural Research Journal, **23**:pp220-224

Department of Agriculture and obtainable from Resource Centre Directorate Agricultural Information Services (2003) Book Maize production Private Bag X144, Pretoria, 0001 South Africa.

Dhaliwal S S, Sharma S, Sharma V, Shukla A K, Walia S S, Alhomrani M, Gaber A, Toor A S, Verma V and Randhawa M K (2021) Long-Term Integrated Nutrient Management in the

Maize–Wheat Cropping System in Alluvial Soils of North-Western India: Influence on Soil Organic Carbon, Microbial Activity and Nutrient Status. Agronomy, V (**11**): pp22-58.

Dhillon J, Torres G, Driver E, Figueiredo B and Raun W R (2017) World phosphorus use efficiency in cereal crops. Agron. J. **109**: pp1670–1677

Dwyer L M and Stewart D W (1986) Leaf Area Development in Field Grown Maize. Agronomy Journal **78**: pp334-343.

Edwards C A and Burrows I (1988) The potential of earthworm compost as plant growth media. In: Edwards CA, Nauhauser A (eds) Earthworm in environmental and waste management.Springer, Netherlands, pp 211–220.

Eisele H F (1938) The influence of environmental factors on the growth of the corn plant under field conditions. Iowa Agri. Exp. Sta. Res. Bull. v**229**: pp259-287.

El-Fouly M M, Fawzi A F A, Mobarak Z M, Aly E A and Abdalla F E (1990) Micronutrient foliar intake by different crop plants, as affected by accompanying urea. In: van Beusichem, M.L. (eds) Plant Nutrition Physiology and Applications. Developments in Plant and Soil Sciences, vol **41**: pp1129-1134.

Erenstein O, Chamberlin J and Sonder K (2021) Estimating the global number and distribution of maize and wheat farms. Global Food Security **30**: pp100-108.

Erenstein O, Jaleta M and Sonder K (2022) Global maize production, consumption and trade: trends and R&D implications. Food Sec. **14**: pp1295–1319.

Fageria N K (1992) Maximizing crop yields. Marcel Dekker, New York.

Fageria N K and Baligar V C (2003) Fertility management of tropical acid soil for sustainable crop production, In Handbook of soil acidity pp 373–400.

Fageria N K, Santos A B and Cutrim V A (2007) Yield and nitrogen use efficiency of lowland rice genotypes as influenced by nitrogen fertilization. Pesq. Agropec. Bras. **42**: pp1029-1034.

Fanzo J, Haddad L, Schneider K R, Béné C, Covic N M, Guarin A, Herforth A W, Herrero M, Sumaila U R, Aburto N J, Amuyunzu-Nyamongo M, Barquera S, Battersby J, Beal T, Bizzotto Molina P, Brusset E, Cafero C, Campeau C, Caron P and Rosero Moncayo J (2021) Viewpoint: Rigorous monitoring is necessary to guide food system transformation in the countdown to the 2030 global goals. Food Policy,**104**, 102163.

FAO (1998) Guide to Efficient Plant Nutrient Management, Rome: Land and Water Development Division, Food and Agricultural Organization of the United Nation, Quebec City, Canada.

FAO, UNICEF, WFP and WHO (2021) The State of Food Security and Nutrition in the World 2021: Transforming food systems for food security, improved nutrition and affordable healthy diets for all. FAO, Rome.

Ferdu, AK Demissew and A Birhane (2002) Major Insect Pests of Maize and their Management: A Review in: Nigussie M., D. Tanner and A.S. Twumasi (Eds.) Enhancing the Contribution of Maize to Food Security in Ethiopia. Proc. 2nd Nat. Maize Workshop, Addis Ababa Ethiopia, pp12-16.

Frank M and Husted S (2023) Is India's largest fertilizer manufacturer misleading farmers and society using dubious plant and soil science? Plant Soil (2023)

Gaire R, Pant C, Sapkota N, Dhamaniya R and Bhusal T N (2020) Effect of Spacing and Nitrogen Level on Growth and Yield of Maize (Zea mays L.) in Mid hill of Nepal, Malaysian Journal of Halal Research Journal,**3**: pp50-55.

George J, Holthman L, Sabermanesh K, Heuer S, Tester M, Plett D and Garnett T (2016). Small amounts of ammonium (NH_4+) can increase growth of maize (Zea mays). Journal of Plant Nutrition and SoilScience,**1**: pp1-9.

Gittenger J P (1982) Economic Analysis of Agric. Project. The Johns Hopkins Univ. Press, Baltimore, Maryland.

Goldbach H E (1997) A critical review on current hypothesis concerning the role of nutrients in higher plants: Suggestions for further research and methodological requirements. J. Trace Microprobe Tech. v**15**: pp51–91.

Goldsworthy P R, A F E Palmer and D W Sperling (1974) Growth and yield of lowland tropical maize in Mexico. J. Agric. Sci. Cambridge **83**: pp223–230.

Golla B, Mintesnot A and Getachew M (2018) Impact of Nitrogen Rate and Intra Row Spacing on Growth parameters and Yield of Maize at Bako, Western Ethiopia", *Open Journal of Plant Science,* **3**: pp30-40.

Gompertz B (1825) On the nature of the function expressive of the law of human mortality, and on a new mode of determining the value of life contingencies. Philosophical Transactions of the Royal Society of London B: Biological Sciences.**182**:pp513–535.

Govind Prasad, Mehar Chand, Pawan Kumar and Ran Singh Rinwa. 2017. Performance of Maize (Zea mays L.) Hybrids with Respect to Growth Parameters and Phenological Stages under Different Sowing Dates in Kharif Season. Int.J.Curr.Microbiol.App.Sci. **6**(7): pp5079-5087.

Graham GG, Lembake J and Morales E (1990) Quality-Proteinmaize as the sole source of dietary protein and fat in rapidly growing young children. Pediatrics. V,**85**: pp85- 91.

Gruhn P, Goletti F and Yudelman M (2000) Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges, International Food Policy Research Institute, Washington, DC, USA.

Guignard M S, Leitch A R, Acquisti C, Eizaguirre C, Elser J J and Hessen D O (2017). Impacts of nitrogen and phosphorus: from genomes to natural ecosystems and agriculture. Front. Ecol. Evol. 5:70.

Gulati A, Roy R and Hussain S (2021) Performance of Agriculture in Punjab. Revitalizing Indian Agriculture and Boosting Farmer Incomes. India Studies in Business and Economics. Springer, Singapore.V**5**: pp2-4.

Guo L, Wu G, Li C, Liu W, Yu X, Cheng D and Jiang G (2015) Vermi-composting with maize increases agricultural benefits by 304 %. Agronomy for Sustainable Development, **35**(3):pp1149–1155.

Gou L, Xue J, Qi B, Ma B and Zhang W (2017) Morphological variation of maize cultivars in response to elevated plant densities. Agron. J. **109**: pp1443–1453

Hammad H M, Ahmad A, Azhar F, Khaliq T, Wajid A, Nasim W and Farhad W (2011) Optimizing water and nitrogen requirement in maize (Zea mays L.) under semiarid conditions of Pakistan. Pak. J.Bot.,43(6): pp2919-2923.

Hammad H M, Chawla M S and Jawad R (2022) Evaluating the impact of nitrogen application on growth and productivity of maize under control conditions, Frontiers of Plant Science, vol.**13**: pp 13-18.

Hammad H M, Farhad W, Abbas F, Fahad S, Saeed S, Nasim W and Bakhat H F (2017) Maize plant nitrogen uptake dynamics at limited irrigation water and nitrogen. Environ. Sci. Pollut.Res v24: pp2549–2557.

Haseebur R, Asghar M A, Waseem A, Muhammad T, Muhammad A and Muhammad S Z (2010) Impact of Nitrogen Application on Growth and Yield of Maize (Zea mays L.) Grown alone and in Combination with Cowpea (Vigna un-guiculata L.).American-Eurasian Journal of Agricultural and EnvironmentalSci-ence,**7**:43-47

Hashim M, Dhar S, Vyas A K and Singh C B (2017) Yield trends and changes in physico-chemical properties of soil in maize-wheat cropping system under integrated nutrient management. *J. Environ. Biol,* **38**: pp727–734

Hefer P (2009) Assessment of fertilizer use by crop at the global level 2006, Vol. **8**: pp.1–10.

Hsiao T C, Acevedo E AND Henderson D W (1970) Maize leaf elongation: continuous measurement and close dependence on plant water status. Science v**168**: pp590-591.

Hugar AY and Halikatti SI (2015) Crop weather relationships under different sowing windows and planting geometry in maize, Karnataka J.Agric. Sci **28**(4): pp497- 499.

IFFCO (2022) IFFCO Nano Urea. In: Indian Farmers Fertilizer Cooperative (IFFCO). https://nanourea.in/en/nanourea. Accessed 3 March

Ion V, Dicu G, State D, Fintineru G, Epure L I, Basa A Gh and Toader M (2015) Grain yield and yield components of different hybrids of maize cultivated in south romania under drought condition. Scientific papers,**4**: pp 809-812

Irmak S and Djaman K (2016) Effects of planting date and density on plant growth, yield, evapotranspiration, and irrigation and evapotranspiration-yield production functions of maize (*Zea mays L*.) under subsurface drip irrigation and rainfed conditions. Trans. ASABE, **59**: pp1235-1256.

Jadhav V, Ramappa K B and Manjunatha A V (2020) Comparative economics of Neem coated urea vis-a-vis normal urea: Evidence from a field-based study in the Indian context. Econ. Af. **65**(2): pp 275–284.

Jansen H G P, Walker T S and Barker R (1990) Adoption ceilings and modern coarse cereal cultivars in India. American Journal of Agricultural Economics **72**:pp653-663.

Jaya N, Mc Clure A, Yin X and Tyler DD (2011) Hayes RM. In-Season prediction of corn yield using plant height under major production systems. Agronomy Journal **103** (3).

Jeyabal A and Kuppuswamy G (2001) Recycling of organic wastes for the production of vermi-compost and its response in rice–legume cropping system and soil fertility. EurJ Agron, **15**:pp153-170.

Jaynes D B (2013) Nitrate loss in subsurface drainage and corn yield as affected by timing of side dress nitrogen. Agric. Water Manage v**130**: pp52–60.

Jehanzeb (1999) Economic Efficiency of the Agrarian Structure in the North West Frontier Province of Pakistan: An Econometric Analysis. Ph.D. Thesis, Deptt. of Econ. University of Peshawar.

Jokela W E, Randall G W (1989) Corn yield and residual soil nitrate as affected by time andrate of nitrogen application. *Agron. J*. v-**81**: pp720–726.

Joshi P K, Singh N P and Singh N N (2005) Maize in India: Production system, constraint and research priority, International maize and wheat improvement centre, Maxico.

Jatav M K, Dua V K, Manoj K, Trehan S P and Sushil K (2013) Spatial distribution of soil available Nutrients in the potato growing pockets of Hoshiarpur district of Punjab

Jaynes D B (2013) Nitrate loss in subsurface drainage and corn yield as affected by timing of side dress nitrogen. Agric. Water Manage v**130**: pp 52–60.

Kaiser DE and Rubin JC (2013) Corn nutrient uptake as affected by in-furrow starter fertilizer for three soils. Agron. J **105**: pp1199-1203.

Kannan LR, Dhivya M, Abinaya M, Lekshmi R and Krishnakumar S (2013) Effect of integrated nutrient management on soil fertility and productivity in maize. Bull. Env. Pharmacol. Life Sci., **2 (8)** pp:61- 67.

Karadavut U, Palta C, Kokten K and Bakoglu A (2010) Comparative study on some nonlinear growth models for describing leaf growth of maize. International Journal of Agriculture & Biology, v**2**: pp23-26.

Keerthi P, Prabhakara R G and Sunitha N. (2017). Effect of sowing time on growth and yield of sweet corn cultivars. International. *Journal of Current Microbiology and Applied Sciences*, **6**: pp777-782.

Kekane S (2015). A review on physico-chemical properties of soil,**1**: pp 29-32.

Kennett D J, Prufer K M, Culleton B J, George R J, Robinson M, Trask W R, Buckley G M, Moes E, Kate E J, Harper T K, O Donnell L, Ray E E, Hill E C, Alsgaard A, Merriman C, Meredith C, Edgar H J H, Awe J J and Gutierrez S M (2020) Early isotopic evidence for maize as a staple grain in the Americas. Science Advances, 6, eaba3245.

Khan A, Lu G, Ayaz M, Zhang H, Wang R and Lv F (2018). Phosphorus efficiency, soil phosphorus dynamics and critical phosphorus level under long-term fertilization for single and double cropping systems. Agric. Ecosyst. Environ. **256**: pp1–11.

Kiros Habtegebrial Habtemichial, Bal Ram Singh and Jens Bernt Aune (2007) Crop response to N_2 fixed by faba bean (*Vicia faba* L.) as affected by sulfur fertilization and rhizobial inoculation in semi-arid Northern Ethiopia Volume**170**, Issue3.

Kopsell DA, Armel GR, Mueller TC, Sams CC, Deyton DE, McElroy JS and Kopsell DE (2009) Increase in nutritionally important sweet corn kernel carotenoids following mesotrione and atrazine applications. Journal of Agricultural and Food Chemistry.; v**57**: pp6362–6368.

Kovicak P (2009) Výživa a systémy hnojení rostlin. České Budějovice, Kurent s.r.o. **109**s. ISBN 978-80-87111-16-1

Kruczek A (2005) The effect of method fertilization on the maize yield and Energy value of raw material, in dependence on varieties and term of sowing. Rocz. Akad. Rol. Pozn. **64**: pp 87–96.

Kumar D and Singh V (2019) Bioethanol Production from Corn. In: Serna-Saldivar, S.O. (Ed.),Corn (Third Edition). AACC International Press, Oxford, pp. 615–631.

Kumar R, K Srinivas and N. Sivaramane (2013) Assessment of the maize situation, outlook and investment opportunities in India. Country Report – Regional AssessmentAsia (MAIZE-CRP), National Academy of Agricultural Research Management, Hyderabad, India.

Kumar R, Kumar S, Kaul B, Karjagi J, Jat C G, Parihar S L and Kumar C M A (2012a) Maize research in India–Historical prospective and future challenges. Maize Journal**1**(1):pp1– 6.

Kurilich AC and Juvik JA (1999) Quantification of carotenoid and tocopherol antioxidants in Zea mays. J Agric Food Chem **47**:pp1948–55.

Landsberg, J J (1977) Effects of weather on plant development.p.289-307. Environmental effects on crop physiology. Academic Press, London.

Liu G, Yang Y, Guo X, Liu W, Xie R, Ming B and Hou P (2023) A global analysis of dry matter accumulation and allocation for maize yield breakthrough from 1.0 to 25.0 Mg ha^{-1}. Resources, Conservation and Recycling,188:10.1016/j.resconrec.2022.106656.

Liu L H, Ludewig U, Gassert B, Frommer WB and von Wirén N (2003) Urea transport by nitrogen-regulated tonoplast intrinsic proteins in Arabidopsis. Plant Physiol. **133**(**3**): pp1220-8.

Lohry R D and J S Schepers (1988) Chlorophyll leaf nitrogen and yield relationships of irrigated corn in Nebraska. Agronomy abstracts,241. Madison, WI: American Society of Agronomy.

Lutz W, Sanderson W and Scherbov S (2001) the end of world population growth. Nature **412**: pp543–5.

Ma D, Xie R, Liu X, Niu X, Hou P, Wang K, Lu Y and Li S (2014) Lodging-related stalk characteristics of maize varieties in China since the 1950s. Crop Sci. **54**

Makkar, Arushi, Chatli Anshu (2018) Analysis of Soil Samples from Various Areas of Punjab.

Mangelsdorf P C, MacNeish R S and Willey G R (1964) Origins of Agriculture in Middle AmericaIn Natural Environment and Early Cultures, Handbook of Middle American Indians, Vol. **1**, ed. R.C. West, pp. 427–445. University of Texas Press, Austin.

Mani D, Upadhyay S K, Kumar C, Balak S and Pathak N (2011) Effect of integrated nutrient management system on nutrient uptake and yield of maize (*Zea mays l*). New Agri **22**: pp 5–14.

Martin JP. (1976). Darwin on Earthworms: The Formation of Vegetable Moulds; Bookworm Publishing, ISBN 0-916302-06-7.

Maryam A B, Saied K K, Habib S S, Mandana D, Khodadad M and Golbashy M. A (2011) study on effects of planting dates on growth and yield of 18 corn hybrids (Zea mays L.). Am J Exp Agric2011; **1**(3): pp110-120

Masclaux D C, Daniel V F, Dechorgnat J Chardon F, Gaufichon L and Suzuki A (2010) Nitrogen uptake, assimilation and remobilization in plants: Challenges for sustainable and productive agriculture. Ann. Bot v-**105:** pp 1141–1157.

Mehta D C and Dias F F (1999) Maize: Perspectives and applications in India. Starch - Stärke, **51**: 52–57.

Meisinger J J (1984) Evaluating Plant-Available Nitrogen in Soil-Crop Systems, Book nitrogen in crop production, chapter 26.

Mandal A, Toor A S, Dhaliwal S S (2018) Effect of land-uses on physico-chemical properties and nutrient status of surface (0–15 cm) and sub-surface (15–30 cm) layers in soils of South- Western Punjab, India. Int. J Curr. Microbiol. Appl. Sci,**7**pp: 2659-2671.

Mohapatro S, Shankar T, Maitra S, Pal A, Nanda SP, Ram MS and Panda SK. (2021). Growth and productivity of maize (Zea mays L.) as influenced by nitrogen management options. International Journal of Agriculture, Environment and Biotechnology,**14**: pp207-214.

Mottet A, Haan de, Falcucci C, Tempio A, Opio G and Gerber P (2017) Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. Global Food Security, **14**: pp1–8.

Muhammad A I (2015). Optimizing Nitrogen Level to Improve Growth and Grain Yield of Spring Planted Irrigated Maize (Zea mays L.). J. of Advanced Botany and Zoology, V**2**I3. DOI: 10.15297/JABZ.V2I3.02

Muhammad A, Shaheen N and Mir K S (2007) Benefit Cost Analysis of The Maize Crop Under Mechanized and Traditional Farming Systems in The Nwfp, Sarhad J. Agric. Vol. **23**:170-176.

Murdia LK, Wadhwani R, Wadhawan N, Bajpai P and Shekhawat S (2016) Maize utilization in India: An Overview. American Journal of Food and Nutrition. 2016;**4**(6): pp169-176

Nenova L, Benkova M, Simeonova T S and Atanassova I (2019) Nitrogen, phosphorus and potassium content in maize dry biomass under the effect of different levels of mineral fertilization, Agricultural Science and Technology, **11:** pp 311-316

Nuss E T and Tanumihardjo S A (2010) Maize: A Paramount Staple Crop in the Context of Global Nutrition. Comprehensive Reviews in Food Science and Food Safety, **9**(4): pp417–436.

Ogola J B O, Wheeler T R, Harris P M (2002) Effects of nitrogen and irrigation on water use of maize crops. Field Crop. Res, v-**78: pp**105–117.

Palta C and Karadavut U (2011) Shoot Growth Curve Analysis of Maize Cultivars Under Boron Deficiency, The Journal of Animal & Plant Sciences, **21**(4): pp696-699

Palm C A, Myers R J K and Nandwa S M (1997) "Organic inorganic nutrient interactions in soil fertility replenishment," Replenishing Soil Fertility in Africa,**51**, pp.193–218.

Panahi M, Nsaeri R, Soleimani R (2010) Efficiency of some sweet corn hybrids at two sowing dates in central Iran. Middle- East J. Scientific Res, **6:** pp 51-55.

Patra D D, Anwar M, Chand S, Kiran U, Rajput D K and Kumar S (2002) Nimin and Mentha spicata oil as nitrification inhibitors for optimum yield of Japanese mint. Commun.Soil Sci. Plant Anal, **33**: pp 451–460.

Pearl R, Winsor C P and White F (1928) The form of the growth curve of cantaloupe (Cncumis melo) under field conditions. Proe. Nat. Acad. Sci. **14**: pp885-901.

Peek MS, Estelle RD, Alexander W and Irwin NF (2002) Physiological response curve analysis using nonlinear mixed models. Oecologia **132**: pp175–180.

Pelerin S, and Mollier A (2001) How to include mineral nutrition in crop growth models? The example of phosphorus on maize. Plant nutrition Food security and sustainability of agro-ecosystems. W. J. Horst et al. (Eds.) **12**: pp110–111.

Peter Ranum, Juan Pablo, Pe na-Rosas, Maria Nieves and Garcia-Casal (2014) Global maize production, utilization, and consumption, Ann. N.Y. Acad. Sci. vol **13**: pp12-15.

Prasad R, Sharma S N, Singh S, Devakumar C, Saxena V S and Shivay Y S (2002) Neem coating of urea for environment and agriculture. Fertilizer News **47**: pp63–67.

Purseglove J W (1972) Tropical Crops, Monocotyledons. Longman Group Limited, London, pp52- 54.

Raj K, Singh B, Kaur P and Beri V (2008). Planning for precision farming in different agro-ecological sub-regions of Punjab - role of natural resources in agricultural research, planning, development, & transfer of technology. Department of Soils, Punjab Agricultural University, Ludhiana -141001, India, p 72 + 13 maps.

Raliya R, Kumar Y, Singh T and Tiwari K (2021) Nano fertilizers for sustainable crop production, higher nutrient use efficiency and enhanced profitability. Indian J Fertilisers **17**: pp1206–1214.

Raliya R (2020) A method of manufacturing of nano urea fertiliser using urea for slow release, enhanced utilization by the plants and application thereof (Mumbai, India, Patent no. 400681), office of the comptroller general of patents, designs & trade marks, department of industrial policy and promotion, ministry of commerce and industry, government of India Intellectual Property India. Accessed 22 Mar 2023

Ramamoorthy B, Velayutham M and Mahajan VK (1974) recent trends in making fertilizer recommendations based on soil test under fertilizer resource constraints in India. In: Proceedings of FAI-FAO Seminar, New Delhi, India, pp 335-346

Raman R and Suganya K (2018) Effect of integrated nutrient management on the growth and yield of hybrid maize. J. Agri. Res, **3(2)**: pp15-18.

Ramappa KB, Jadhav V and Manjunatha AV (2022) A benchmark study on economic impact of Neem Coated Urea on Indian agriculture. Sci Rep. May 31;**12**(1):9082.

Ramasamy P K and Suresh S N (2001). Effect of vermi-compost on root numbers and length of sunflower plant (Helianthus annuus L.). J. of pure and applied microbiology,**4**(1): pp297-302.

Randall G W, Vetsch J A and Huffman J R (2003) Corn production on a subsurface-drained mollisol as affected by time of nitrogen application and nitrapyrin. Agron. J. v**95**: pp1213–1219.

Rani P L, Sreenivas G, Reddy D R, Rao V P, Surekha K and Sankar A S (2013) Influence of dates of sowing and nitrogen levels on growth and yield of Kharif maize under irrigated conditions in South Telanagana Agro-climatic Zone of Andhra Pradesh, India. Intern.J. Bio Res. Stress Manag. **4: pp** 34–42.

Ranum P, Rosas J P P and Casal M N G (2014) Global maize production, utilization, and consumption. Annals of the new york academy of sciences.,**13**(12): pp105-112.

Rathier T M, Frink C R (1989) Nitrate in runoff water from container grown juniper and albertam spruce under different irrigation and N fertilization regimes. J Environ Horticul., **7**(1): pp32–35.

Rathore T R, Warsi M Z K, Singh N and Vasal S K (1998) Production of maize under excess soil moisture (waterlogging) conditions. In: Proceedings of the 2nd Asian Regional Maize Workshop PACARD. Laos Banos, Phillipines **1**: pp.23-25.

Reddy V R and Devi MJ (2017) Stomatal closure response to soil drying at different vapor pressure deficit conditions in maize. Plant Physiol. Biochem.v**154**: pp714–722.

Reddy YN, Reddy YP, Ramya V, Suma LS, Reddy AN and Krishna S S (2021) Drought adaptation: Approaches for crop improvement. In Millets and Pseudo Cereals; Woodhead Publishing: Cambridge, v**2**: pp. 143–158.

Reed S and Holland R H (1919) The growth rate of ani annual plant, Helianthus. Proe. Nat. Acad. Sci. v**5**: pp135-144.

Rehman A, Nawaz M, Chattha MU, Khan I, Chattha MB, Hussain F, Ayub MA, Iqbal MM, Ahmed F, Aslam MT, Khan FA, Kharal M and Hassan MU (2021) Neem coated urea improves the productivity, nitrogen use efficiency and economic return of wheat crop. Intl J Agric Biol **26**: pp450–460.

Richards FJ (1959) A flexible growth curve for empirical use, Journal of Experimental Botany **10**: pp290–300.

Richards F S (1969) The quantitative analysis of growth. In: Plant Physiology: A treatise. Ed: Steward, F.S.Academic Pres, New York, Vol**5**: pp3-77.

Rouf Shah T, Prasad K, and Kumar P (2016) Maize a potential source of human nutrition and health: A review. Cogent Food & Agriculture,V **2**:pp1-5.

Sacks W J, Deryng D, Foley JA and Ramankutty N (2010) Crop planting dates: An analysis of global patterns. Global Ecololgy and Biogeography **19**: pp607-620.

Sandhu J S (2013) Status of breeder seed production and its implication, In Golden Jubilee Souvenir: 2012-2013, National Seeds Corporation Ltd, New Delhi.

Sanginga N and Woomer P L (2009) Integrated Soil Fertility Management in Africa: Principles, Practices, and Developmental Process, CIAT, Cali, Colombia

Schmutterer H (1990) Properties and potential of natural pesticides from the neem tree, Azadirachta indica Ann. Rev. Entomol., vol **35**: pp 271-297.

Scott P, Pratt R C, Hoffman N and Montgomery R (2019) Specialty Corns. In: Serna-Saldivar, S.O. (Ed.), Corn (Third Edition). AACC International Press, Oxford, pp. 289–303.

Sehgal J L, Mandal D K, Mandal C and Vadivelu S (1990) Agro-Ecological Regions in India. National Bureau of Soil Survey & Land Use Planning, Nagpur

Seleiman MF, Almutairi KF and Alotaibi M (2021) Nano-fertilization as an emerging fertilization technique: Why can modern agriculture benefit from its use? Plants **10**: pp1–27

Shah T R, Prasad K, Kumar P. (2016). Maize A potential source of human nutrition and health: A review, Cogent Food & Agriculture, **Vol.2**: pp1-9.

Shaheen N, Mir K S and Muhammad A (2007) Benefit Cost Analysis of The Maize Crop Under Mechanized and Traditional Farming Systems in The Nwfp, Sarhad J. Agric. Vol. **23**:170-176.

Shakha S, Gurmeet K and Madhuri R. International journal of engineering sciences & research technology assessment of soil quality in parts of ludhiana district, punjab, india in order to attain agricultural sustainability.

Sharma V, Singh M J and Khokhar A K (2020) Productivity, nutrient uptake and soil properties as influenced by integrated nutrient management in maize-wheat cropping system under rainfed conditions of sub-montane Punjab. Agric. Res. J, **57**: pp 839–847.

Sharma B D, Kumar R, Manchanda J S, Dhaliwal S S, Thind H S and Singh Y (2016) Mapping of chemical characteristics and fertility status of intensively cultivated soils of Punjab, India. Communications in Soil Science and Plant Analysis,**47:** pp1813-1827.

Sheoran S, Raj D, Antil R S, Mor V S and Dahiya D S (2017) Productivity, seed quality, and nutrient use efficiency of wheat (*Triticum aestivum* L.) under organic, inorganic, and INM practices after 20 years of fertilization. Cereal Res. Commun, **45**: pp 315–325.

Sheppard S and Racz G (1984) Effect of soil temperature on phosphorus extractability. I Extraction and plant uptake of soil and fertilizer phosphorus. Canadian Journal of Soil Science,**64**: pp241-254.

Singh A, Jaiswal A and Singh M (2019) Impact of neem coated urea on rice yield and Nutrient Use Efficiency (NUE). Agricultural Reviews. Vol **40**(1): pp70-74.

Singh M V, Kumar N and Mishra BN (2013) Integrated use of nitrogen and FYM on yield, nutrient uptake and economics of maize in eastern Uttar Pradesh. Annals of Plant and Soil Research **15**(2): pp128- 130.

Singh R, Sharma R R, Kumar S, Gupta R K, Patil R T (2008) Vermi-compost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (Fragaria x ananassa Duch.). Bioresour Technol **99**: pp8507–8511.

Singh V K, Bajaj R P, Sisodia R J (1992) Effect of sowing date and plant population on yield of maize. Current. Res., 21(2): pp24-25.

Sivaramane N, Kumar R, and Srinivas K (2013) Assessment of the maize situation, outlook and investment opportunities in India. Country Report – Regional Assessment Asia (MAIZE-CRP), National Academy of Agricultural Research Management, Hyderabad, India.

Senthil K N and Surendran U (2002). Vermi-composts Eco-friendly Evergreen revolution. Kissan World., **29**(9): pp 49-50

Solomon K F, Chauhan Y and Zeppa A (2017) Risks of yield loss due to variation in optimum density for different maize genotypes under variable environmental conditions, *Journal of Agronomy and Crop Science*, **203**:519–527.

Srivastava R K and Beohar PA (2004). Vermi-compost as an organic manure. A good substitute of fertilizers. J. Curr. Sci. **5**: pp141-143.

Subbaiah PV and Ram SA (2019) Effect of integrated use of organic and inorganic sources of nutrients and bio fertilizers on growth and nutrient content of maize (Zea mays L.). International Journal of Current Microbiology and Applied Sciences,**8**:1106-1116.

Subbarao G V, Wheeler R M, Stutte G W and Levine L H (2000) Low potassium enhances sodium uptake in red-beet under moderate saline conditions. *J. Plant Nutr,* **23**: pp1449–1470.

Subedi K D and Ma B L (2005) Ear Position, leaf area, and contribution of individual leaves to grain yield in conventional and leafy maize hybrids. Crop Sci. **45**: pp2246–2256.

Sud U C, Ahmad T, Gupta V K, Chandra H, Sahoo P M, Aditya K, Singh M and Biswas A (2016) "Measuring Crop Area and Yield under Pure Stand, Mixed and Continuous Cropping: Findings from the Field Tests in three countries" under the project "Research on Improving Methods for Estimating Crop Area, Yield and Production under Mixed, Repeatedand Continuous Cropping", *Rome Publication,* Working Paper No.**16**

Szulc P, Ambroży-Deręgowska K, Waligóra H, Mejza I, Grześ S, Zielewicz W, Wróbel B. Dry Matter Yield of Maize (Zea mays L.) as an Indicator of Mineral Fertilizer Efficiency. Plants. 2021; 10(3):535.

Thornley and France (2007) Mathematical Model in Agriculture: quantitative methods for the plant. Animal and Ecological Sciences; Cobi: London.books.google.co.id.

Tolanur S (2018) Second edition practical soil science and agriculture chemistry. CbS publishers and distributors Pvt. Ltd. New Delhi, India

Tripathi KK, Warrier R, Govila OP and Ahuja V (2011) Biology of Zea mays (Maize). Department of Biotechnology, Ministry of Science and Technology and Ministry of Environment and Forests, Government of India.

Trough E (1960) Fifty years of soil testing, Transactions 7th International Congress of Soil Science **3**(4): pp48-53.

Umesh S, Lal P A, Tika B K, Khem R D and Jiban S. (2017). Effect of sowing dates and maize cultivars in growth and yield of maize along with their agroclimatic indices in Nawal parasi Nepal Journal of Agri Search, **3**: pp57-62.

United States Department of Agriculture (2009) World agricultural production: world wheat area down, corn steady, soy up. Foreign Agricultural Service and USDA Office of Global Analysis. pp1–7.

Upadhyay PK, Dey A and Singh VK (2023) conjoint application of nano-urea with conventional fertilizers: An energy efficient and environmentally robust approach for sustainable crop production. PLoS One **18**: e0284009.

Valero J A, Juan M, Maturano A A, Ramírez J M T, Martín B and Alvarez J F O (2005) Growth and nitrogen use efficiency of irrigated maize in a semiarid region as affected by nitrogen fertilization. Spanish J.Agric. Res., **3**: pp134-144.

Vasanthapu M (2023) A review of the evaluation of soil fertility status of Punjab state of India, The pharma innovation, **12**: pp3701-3706

Venterea R T, Coulter J A (2015) Split application of urea does not decrease and may increase nitrous oxide emissions in rainfed corn. Agron J, v**107**: pp 337–348.

Verma K and Bindra AD (2019) Impact of integrated nutrient management on nutrient content, nutrient uptake, protein content and grain yield in maize (Zea mays L.)-wheat (Triticum aestivum L.) cropping system in an acid alfisol. International Journal of Current Microbiology and Applied Sciences,**8**: pp 899-917.

Vidyavathi D, Babalad H B, Hebsur N S, Gali S K, Patil SG and Alagawadi AR (2012) Nutrient status of soil under different nutrient and crop management practices. Karnataka Journal of Agricultural Science, **25** pp:193-198.

Wailare AT and Kesarwani A (2017) Effect of Integrated Nutrient Management on growth and yield parameters of maize (*zea mays l.*) as well as soil physico-chemical properties. Biomed J Sci & Tech Res **1(2):** pp294-297.

Wallington T J, Anderson J E, Mueller S A, Kolinski Morris E, Winkler S L, Ginder J M and Nielsen O J (2012) Corn Ethanol Production, Food Exports, and Indirect Land Use Change. *Environmental Science & Technology*, **46**: pp 6379–6384.

Wibowo A S, Barunawati N, and Magfoer M D. (2017). Respon Hasil Tanaman JagungManis (*Zea mays L.*) terhadap Pemberian KCl dan Pupuk Kotoran Ayam. Jurnal Produksi Tanaman, **5**:1381-1388.

Widstrom N W, Youg J R, Martin W K and Shaver E L (1984) Grain and forage yields of irrigated second crop corn seeded on five planting dates, Agron Journal, **76**: pp883-886.

Wood J A, Dellaporta S L, Chomet P S, Mottinger J P, Yu SM and Hicks JB (1984) Endogenous transposable elements associated with virus infection in maize. Cold Spring Harb Symp Quant Biol. **49**: pp321-8.

Wu F and Guclu H (2012) Aflatoxin Regulations in a Network of Global Maize Trade. PLOS ONE *7*, e45-151.

Yin X, Mc Clure A, Jaya N and Tyler DD (2011) Hayes RM. In-Season prediction of corn yield using plant height under major production systems. Agronomy Journal.**103:** pp3-7.

Zaidi P H and Singh N N (2001) Effect of water-logging on growth, biochemical compositions and reproduction in maize. J. Plant Biol. **28**: pp61–69.

Zhang P, Gu S, Wang Y, Xu C, Zhao Y, Liu X, Huang S (2023) The relationships between maize (*Zea mays L.*) lodging resistance and yield formation depend on dry matter allocation to ear and stem. The Crop Journal. 11(1): pp258-268.

Zhang X, Perez-Rodriguez P, Semagn K, Beyene Y, Babu R and Lopez-Cruz MA (2013) Genomic prediction in biparental tropical maize populations in water-stressed and well-watered environments using low density and GBS SNPs. Heredity. 2015; v114: pp 291–299.

Zhang Q, Li G, Lu W, Lu D (2022) Interactive effects of nitrogen and potassium on grain yield and quality of waxy maize Plants (Basel), **11**: p. 25-28

Appendix-I

Total nitrogen content in dry matter (%)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	0.59	0.71	0.65
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.39	0.38	0.39
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	0.50	0.60	0.55
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	0.49	0.63	0.56
5	T_5 = 75% RDF + Nano urea	0.54	0.66	0.60
6	T_6 = 75% RDF (3 Application timings)	0.46	0.58	0.52
7	T_7 = 75% RDF (2 Application timings)	0.39	0.47	0.43
8	T_8 = 75% RDF (4 Application timings)	0.41	0.50	0.46
9	T_9 = 75% RDF (Basal application timings)	0.37	0.39	0.38
10	T_{10} = 100% RDF (3 Applications)	0.35	0.36	0.35
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.42	0.46	0.44
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	0.45	0.55	0.50
13	T_{13} = 100 % RDF + Nano urea	0.49	0.55	0.52
14	T_{14} = 100% RDF (4 Application timings)	0.43	0.44	0.43
15	T_{15} = 100% RDF (2 Application timings)	0.39	0.48	0.44
16	T_{16} = 100% RDF (Basal application timings)	0.39	0.40	0.40
C.D.(P=0.05)		0.024	0.028	0.026
S.E.m. (±)		0.011	0.013	0.012

Appendix-II

Total phosphorous content in dry matter (%)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	0.18	0.18	0.18
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.12	0.12	0.12
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	0.11	0.10	0.11
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	0.16	0.16	0.16
5	T_5 = 75% RDF + Nano urea	0.18	0.20	0.19
6	T_6 = 75% RDF (3 Application timings)	0.20	0.19	0.20
7	T_7 = 75% RDF (2 Application timings)	0.12	0.11	0.12
8	T_8 = 75% RDF (4 Application timings)	0.10	0.08	0.09
9	T_9 = 75% RDF (Basal application timings)	0.20	0.21	0.20
10	T_{10} = 100% RDF (3 Applications)	0.15	0.12	0.14
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.15	0.14	0.14
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	0.17	0.16	0.17
13	T_{13} = 100 % RDF + Nano urea	0.16	0.18	0.17
14	T_{14} = 100% RDF (4 Application timings)	0.15	0.14	0.14
15	T_{15} = 100% RDF (2 Application timings)	0.18	0.18	0.18
16	T_{16} = 100% RDF (Basal application timings)	0.19	0.17	0.18
C.D.(P=0.05)		0.009	0.008	0.010
S.E.m. (±)		0.004	0.004	0.005

Appendix-III

Total potassium content in dry matter (%)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	0.47	0.53	0.50
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.26	0.33	0.30
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	0.50	0.57	0.54
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	0.46	0.55	0.50
5	T_5 = 75% RDF + Nano urea	0.53	0.61	0.57
6	T_6 = 75% RDF (3 Application timings)	0.35	0.69	0.52
7	T_7 = 75% RDF (2 Application timings)	0.24	0.38	0.31
8	T_8 = 75% RDF (4 Application timings)	0.31	0.32	0.32
9	T_9 = 75% RDF (Basal application timings)	0.27	0.33	0.30
10	T_{10} = 100% RDF (3 Applications)	0.31	0.30	0.31
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.43	0.49	0.46
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	0.28	0.38	0.33
13	T_{13} = 100 % RDF + Nano urea	0.34	0.36	0.35
14	T_{14} = 100% RDF (4 Application timings)	0.30	0.32	0.31
15	T_{15} = 100% RDF (2 Application timings)	0.25	0.31	0.28
16	T_{16} = 100% RDF (Basal application timings)	0.28	0.31	0.29
C.D.(P=0.05)		0.011	0.013	0.021
S.E.m. (±)		0.005	0.006	0.010

Appendix-IV

Total nitrogen content in grain (%)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	1.32	1.39	1.36
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.82	0.92	0.87
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	1.12	1.42	1.27
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	1.12	1.46	1.29
5	T_5 = 75% RDF + Nano urea	1.17	1.58	1.37
6	T_6 = 75% RDF (3 Application timings)	1.32	1.64	1.48
7	T_7 = 75% RDF (2 Application timings)	0.84	1.11	0.97
8	T_8 = 75% RDF (4 Application timings)	1.04	1.28	1.16
9	T_9 = 75% RDF (Basal application timings)	0.91	1.03	0.97
10	T_{10} = 100% RDF (3 Applications)	0.81	0.93	0.87
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.89	1.13	1.01
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	1.02	1.16	1.09
13	T_{13} = 100 % RDF + Nano urea	1.10	1.36	1.23
14	T_{14} = 100% RDF (4 Application timings)	0.91	1.09	1.00
15	T_{15} = 100% RDF (2 Application timings)	0.94	1.12	1.03
16	T_{16} = 100% RDF (Basal application timings)	0.87	0.90	0.89
C.D.(P=0.05)		0.037	0.041	0.059
S.E.m. (±)		0.017	0.020	0.028

Appendix-V

Total phosphorous content in grain (%)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	0.31	0.35	0.33
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.20	0.21	0.20
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	0.31	0.34	0.33
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	0.29	0.31	0.30
5	T_5 = 75% RDF + Nano urea	0.29	0.31	0.30
6	T_6 = 75% RDF (3 Application timings)	0.22	0.27	0.25
7	T_7 = 75% RDF (2 Application timings)	0.17	0.20	0.19
8	T_8 = 75% RDF (4 Application timings)	0.21	0.24	0.22
9	T_9 = 75% RDF (Basal application timings)	0.20	0.27	0.23
10	T_{10} = 100% RDF (3 Applications)	0.21	0.24	0.22
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.27	0.25	0.26
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	0.23	0.29	0.26
13	T_{13} = 100 % RDF + Nano urea	0.25	0.30	0.28
14	T_{14} = 100% RDF (4 Application timings)	0.20	0.22	0.21
15	T_{15} = 100% RDF (2 Application timings)	0.19	0.20	0.20
16	T_{16} = 100% RDF (Basal application timings)	0.20	0.21	0.20
C.D.(P=0.05)		0.008	0.011	0.010
S.E.m. (±)		0.004	0.005	0.005

Appendix-VI

Total potassium content in grain (%)

Sr. no	Treatments	2022	2023	Mean
1	T_1 = Absolute control	0.69	0.80	0.74
2	T_2 = 75% RDF (Recommended dose of fertilizer)	0.44	0.44	0.44
3	T_3 = 75% RDF + FYM 5 t ha^{-1} (Farm yard manure)	0.55	0.85	0.70
4	T_4 = 75% RDF+ vermi-compost 2.5 t ha^{-1}	0.50	0.60	0.55
5	T_5 = 75% RDF + Nano urea	0.50	0.60	0.55
6	T_6 = 75% RDF (3 Application timings)	0.44	0.65	0.55
7	T_7 = 75% RDF (2 Application timings)	0.38	0.46	0.42
8	T_8 = 75% RDF (4 Application timings)	0.37	0.42	0.39
9	T_9 = 75% RDF (Basal application timings)	0.40	0.47	0.43
10	T_{10} = 100% RDF (3 Applications)	0.34	0.41	0.38
11	T_{11} = 100% RDF + FYM 5 t ha^{-1}	0.49	0.67	0.58
12	T_{12} = 100% RDF+ vermi-compost 2.5 t ha^{-1}	0.52	0.67	0.60
13	T_{13} = 100 % RDF + Nano urea	0.60	0.75	0.68
14	T_{14} = 100% RDF (4 Application timings)	0.47	0.46	0.47
15	T_{15} = 100% RDF (2 Application timings)	0.38	0.46	0.42
16	T_{16} = 100% RDF (Basal application timings)	0.40	0.42	0.41
C.D.(P=0.05)		0.016	0.019	0.022
S.E.m. (±)		0.008	0.009	0.010

List of Publications

1. Behera H S and Kumar R (2022) Evaluation of Timing of Nitrogen Application in Maize (Zea mays L.) Grown on Coarse Loamy Typic Haplustepts Soil of Punjab: A Review. International Journal of Plant & Soil Science, **34**: 39–47(Published)-NAAS

2. Behera H S and Kumar R (2023) Evaluation of Timing of Nitrogen Application in Maize (*Zea mays L*.) Grown on Coarse Loamy Typic Haplustepts Soil of Punjab. Journal of Hunan University Natural Sciences, **50:**10-24(Published) (Scopus)

3. Behera H S and Kumar R (2024) Growth attributes of maize sowing to harvesting in a coarse loamy Punjab soil, International Journal of Emerging Technologies and Innovative Research, **11**: 73-78 (Published)-UGC

4. Behera H S and Kumar R (2024) Effect of nitrogen management on the growth attributes of maize (*Zea Mays L*.) in coarse loamy Typic Haplustept soil. Annals of Biology **40** (2): 217-222, 2024 (Published) (Scopus)

5. Behera H S and Kumar R (2024) Characteristics of Punjab's typic haplustept soil for the maize (Zea Mays L.). International Journal of Research in Agronomy 7(11): 07-14(Published)-NAAS

6. Behera H S and Kumar R (2025) Timing of nitrogen treatment in maize (*Zea mays L*.) produced in punjab's coarse loamy typic haplustept soil being evaluated. Asian Journal of Soil Science and Plant Nutrition **11**(1): 314-322(Published)-NAAS

List of Conference

1. Evaluation of timings of major nutrients application in maize (*Zea mays L*.) grown on coarse loamy typic Haplustept soil of Punjab, ICAATAS-2022. On 4 &5 June 2022 conduct on CUTM Paralakhemundi, Gajapati, Odisha. Jointly organized by society of agriculture research and social development &M S Swaminathan School of Agriculture, CUTM Parlakhemundi.

2. Timing of Nitrogen Treatment in Maize (*Zea Mays L*.) Produced in Punjab's Coarse Loamy Typic Haplustept Soil Being Evaluated, abstract present on National conference on Sustainable Development through Agriculture Production, Protection &amp Policy Landscape for Crop Care on 18-19th January, 2023 at MVN University, Palwal (Haryana).

3. Effect of nitrogen management on the growth attributes of maize (Zea Mays L.) in coarse loamy Typic Haplustept soil international conference on Cutting-Edge Solutions in Science- Agriculture, Technology, Engineering and Humanities" (CSATEH-2024) during August 24-26, 2024 at UGC-HRDC Hall, Kumaun University, Nainital, Uttarakhand, India

List of Awards

1. The GIRISDA 2022 & AEEFWS award screening committee, awards for "Best Research Scholar Award" on 6,7,8 june 2022 conduct on Just Agriculture-the magazine, Guru Kashi University, Bathinda (ICAR Accredited) & AEEFWS SOCIETY, Punjab.

2. 6th International Conference on "Cutting-Edge Solutions in Science- Agriculture, Technology, Engineering and Humanities" (CSATEH-2024), award screening committee, awards for "Young Scientists Award-2024." On August 24-26, 2024 at UGC-HRDC Hall, Kumaun University, Nainital, Uttarakhand, India

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Evaluation of Timing of Nitrogen Application in Maize (*Zea mays L.*) Grown on Coarse Loamy Typic Haplustepts Soil of Punjab: A Review

Himanshu Sekhar Behera [a#*] and Raj Kumar [a†]

[a] *Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Punjab, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Maize (*Zea mays* L.) is a species of *Zea mays* plant in the Poaceae family, the origin of maize is Mexico, where many diverse types of maize are found. The discovery of fossil maize pollen with other archaeological evidence in Mexico indicates Mexico to be the native of maize. Maize is widely grown all over the world. In 2014, the total world production was 1.04 billion tonnes. The maize plant can grow up to 3m (10 ft) in heights. Although some natural strains can reach a height of 13meters, the stem is typically made up of 20 internodes of 18 cm (7 in) length. The leaves sprout from the nodes and grow alternately on opposing sides of the stem, with complete edges. The stem's tip is capped with a tassel, which is an inflorescence of male flowers. When the tassel matures and the circumstances are warm and dry enough, the anthers on the tassel dehisce and release pollen. Maize pollen is anemophilous (dispersed by wind), and because of its high settling velocity, the majority of pollen falls within a few metres of the tassel. Every year, maize reproduces sexually. This randomly picks half of the genes from a particular plant to propagate to the next generation, which means that beneficial crop qualities (such as high yield or good nutrition) may be lost in the following generations unless specific strategies are utilised. In genetically modified (GM), maize was one of 26 GM crops produced commercially. Nano-fertilizer technology is meant to distribute nutrients in a controlled manner in response to crop needs, allowing nutrient usage

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 # Ph.D., Scholar,
† Professor,
**Corresponding author: E-mail: himanshubeherars4@gmail.com;*

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EVALUATION OF TIMING OF NITROGEN APPLICATION IN MAIZE (*ZEA MAYS L.*) GROWN ON COARSE LOAMY TYPIC HAPLUSTEPTS SOIL OF PUNJAB

Himanshu Sekhar Behera, Dr. (Prof) Raj Kumar

Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Punjab, India.

Ex-HOD, Professor, Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Punjab, India.

ABSTRACT

The study was a field experiment conducted in the Experimental Farm of the School of Agriculture on the campus of Lovely Professional University in Punjab, at latitudes of 31°24' N and 75°69' E. Analyzing the effects of adding nitrogen to both organic and inorganic fertilizer solutions on maize growth, yield, nutrient absorption, and economics in India during the kharif season of 2022. At the experimental site, the soil texture is coarse loamy Typic Haplustept soil. The trial had sixteen treatments, a randomized block design, and was triple repeated. Following the recommended fertilizer schedule of 50:24:12 N, P_2O_5, and K_2O kg ha^{-1}. To supply the nutrients N, P, and K, respectively, fertilizers containing urea (46% N), single super phosphate (16% P_2O_5), and muriate of potash (60% K_2O) were used. The hybrid PAU variety of maize known as PMH-13, which was utilized in the tests, was the subject of this study and analysis. Both potassium and phosphorus are supplied completely by basal application. Nitrogen was administered at the appropriate amount in a basic manner. Net plot area was used to compute crop yields. Crop observations were conducted at the 20 DAS, 40 DAS, 60 DAS, 80 DAS, and harvest stages. For the purpose of recording biometric observations, samples from each plot were randomly selected. After spraying Nanourea to plant leaves, the plants grow 40, 60, 80 DAS taller and produce yield. After harvest, maizecobs with ears measured 22.9 cm, with 100% RDF+Nanourea treatments having the highest measurement and 75%RDF (3 Application Timings) treatments having the lowest measurement. After 10 days of sowing, the treatments with 100% RDF+ FYM 5t ha^{-1} had 81 plants the most. Fresh weight of seven maize plants is 3215 gm greatest in 100% RDF+FYM 5t ha^{-1} treatments and 2167 gm lowest in 100% RDF+Nano urea treatments. Maizecobs length without ear is 16.4 cm lowest in Absolute control treatments and 18.9 cm highest in 100% RDF (2 Application timings) treatments, Seven maize plants treated with 100% RDF (2 application timings) had the maximum dry weight of 804 gm, whereas seven plants treated with 75% RDF had the lowest dry weight of 518 gm among all the treatments.

Keywords: Maize yield, Maize cob, Maize height, Nanourea.

Introduction

In the family Poaceae, which also includes wheat and rice, maize (Zea mays L.) is the third-most significant cereal crop in the world. Its oldest known ear, dating back to roughly 7000 years ago, was discovered in Mexico, where it first appeared. Maize (Zea mays L.) is the third important cereal crop in India after rice and wheat. It is sensitive to water logging those results in reduced yields of those

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About the authors：Himanshu Sekhar Behera

Corresponding author- Email:

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Growth attributes of maize sowing to harvesting in a coarse loamy Punjab soil

Himanshu Sekhar Behera, Raj Kumar
Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Punjab, India
Professor, Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Punjab, India

Abstract

The experimental farm is located at latitude at 31°14'30.5''N and longitude 75°41'52.1'' E. During the *kharif* season, a field experiment was conducted at the Lovely Professional University's soil science research farm in Jalandhar, Punjab. researching the effect of nitrogen addition on maize growth, yield, nutrient absorption, and economics in India during the 2022 and 2023 *kharif* season using organic and inorganic fertilizer solutions. It was done using a randomized block design and included two treatments, three replications. The PMH-13 hybrid PAU variety of maize was used in the experiments. Phosphorus and potassium are both completely supplied by basal application. Plant height at 30, 60 days of sowing and maturity, cob length, dry matter yield, cobs weight, grains weight were recorded. The plant height at 60 days was maximum in the T_2 treatment and it significantly higher in all treatments because of the 100%RDF (3applications), there was marginal reduction in plant height with the advancement of crop growth. Similar plant height in all the dates of sowing was due to assured germination, manual sowing of seed by dibbling method at proper soil environment and assured irrigation facilities throughout the crop growth period. more growth as a result of application of higher doses of nitrogen. Plant height is an important indicator of plant growth and development and results revealed that different nitrogen levels had a significant effect on the plant height of maize.

Keyword: Cob length, Cob weight, yield, grain

Introduction

Maize (Zea mays L.) is the third important cereal crop in India after rice and wheat. It is sensitive to water-logging that results in reduced yields of those grown in tropical and subtropical regions (Rathore et al., 1998). Total maize production of over 18 per cent is often affected by floods and water-logging problems in South and Southeast Asia (Zaidi et al., 2001) thereby causing substantial production losses. However average yield losses of up to 30 per cent are reported each year in maize production in India. The early growth phase of maize development from second leaf stage to seventh leaf stage is the most susceptible phase during water-logging condition (Zhang et al., 2013). Maize (Zea mays L.) belongs to family poaceae, it originated in Mexico where its oldest known ears could be traced back to about 7000 years ago (Mangeisdorf et al., 1964). The crop has a wider range of uses. These include the following: human food, industrial processed food production of starch and used as forage to feed animals. Maize with its large number of cultivars and different maturity periods has wider range of tolerance to different environmental conditions (Purseglove,1972). Maize is a raw material for a number of products viz., starch, glucose,

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Effect of Nitrogen Management on the Growth Attributes of Maize (*Zea mays* L.) in Coarse Loamy Typic Haplustept Soil

HIMANSHU SEKHAR BEHERA* AND RAJ KUMAR

Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Phagwara-144 411 (Punjab), India
**(e-mail: himanshu.12014367@lpu.in; Mobile: 62807 28359)*

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ABSTRACT

Nitrogen application can play a significant role in improving soil fertility. Fertilization of nitrogen can increase grain yield and biomass in maize. A field experiment was conducted at the Lovely Professional University's soil in Jalandhar, Punjab to calculate the effect of nitrogen addition on maize growth, yield, nutrient absorption and economics during 2022 and 2023 *kharif* season using organic and inorganic fertilizer solutions. It was done using a randomized block design including 16 treatments in three replications. The PMH-13 hybrid variety of maize was used in the experiment. Both phosphorus and potassium were completely supplied as basal application. At harvest, the plant height in T_{12} (100% RDF + vermicompost 2.5 t/ha) treatments gave best performance. Thus, vermicompost was an effective nutrient for maize growth and yield. An important sign of plant growth was plant height in the grain yield of hybrid maize PMH-13 as impacted by the use of nitrogen fertilizer in coarse loamy soils of Punjab, as well as by different nitrogen doses.

Key words: Maize, nitrogen, maize yield

INTRODUCTION

Maize was domesticated more than 9,000 years ago in southern Mexico. Maize, wheat and rice are the world's leading staple cereals, each cultivated on some 200 million ha (Kennett *et al.*, 2020). Maize is a versatile multipurpose crop. At the global level, maize grain is primarily used as feed production (56%) and only 13% for food. Much of the maize grain used as feed is used to derive animal-sourced foods and thereby provides an indirect consumption pathway (Mottet *et al.*, 2017). Maize is a nutritious diet that many Indians prefer because it is relatively light in comparison to other meals and contains minerals and phyto-chemicals. It is consumed for breakfast by 83% of Indian youngsters (in the form of cornflakes, corn powder, etc.). Additionally, doctors encourage patients to use it to strengthen their immune systems as a prophylactic strategy (Shah *et al.*, 2016).

Nitrogen fertilizers have varying effects on maize yield and researchers found that applying nitrogen with splits resulted in high grain production compared to applying nitrogen solely at the base (Abdelsalam *et al.*, 2019). The right nitrogen fertilizer rate and time could increase grain weight by increasing effective grain-filling duration and rate (Hammad *et al.*, 2022). Nitrogen fertilizers are needed to enhance maize production. Maize plays a major role in the livestock industry, biofuels and human nutrition. Globally, less than one-half of applied nitrogen is recovered by maize. Although the application of nitrogen fertilizer can improve maize yield, excess nitrogen application due to low knowledge of the mechanisms of nitrogen use efficiency poses serious threats to environmental sustainability (Asibi *et al.*, 2019). Timing and rate of nitrogen fertilizer application can influence maize (Zea *mays* L.) grain yield, nitrogen uptake and nitrogen use efficiency parameters. Nitrogen fertilizers can be applied many times throughout the year including fall, spring, pre-plant, at planting, side-dress, or through fertigation. Single and split applications of nitrogen rates are beneficial in maize under irrigated conditions on loamy sand soils (Davies *et al.*, 2020).

MATERIALS AND METHODS

During the *kharif* season of the years 2022 and 2023, field experiments were conducted at the Lovely Professional University's soil science research farm in Phagwara, Punjab. The

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Himanshu Sekhar Behera
Ph.D., Student. Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Raj Kumar
Professor, Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Himanshu Sekhar Behera
Ph.D., Student. Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Characteristics of Punjab's typic haplustept soil for the maize (*Zea Mays L.*)

Himanshu Sekhar Behera and Raj Kumar

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Abstract
The experimental site was located at 31°14' N latitude, 75°.41' E longitude. During the kharif season 2022 and 2023, a field experiment was conducted at the Lovely Professional University's soil science research farm in Jalandhar, Punjab. It was done using a randomized block design and included 16 treatments, 3 replications. The nitrogen availability is one of the most significant constraints to crop growth, and the application of nitrogen through mineral and organic fertilizers plays a vital role in sustaining crop production, nitrogen application can play a significant role in improving soil fertility, Fertilization of nitrogen can increase grain yield and biomass in maize. The time of maximum nitrogen accumulation in maize development is dependent on available soil nitrogen when maize begins rapid vegetative growth. About one-half of total nitrogen uptakes by maize occur by the time maize biomass is about one-fourth of the maximum, maize nitrogen use efficiency is estimated globally to be 33 per cent, in part due to loss of fertilizer nitrogen from leaching below the root zone, denitrification, and soil and plant-derived volatilization. Although the application of nitrogen fertilizer can improve maize yield, excess nitrogen application due to low knowledge of the mechanisms of nitrogen use efficiency poses serious threats to environmental sustainability.

Keywords: Soil, grain, nitrogen, maize, environmental sustainability, mechanisms

Introduction

India's third-most important cereal crop is maize (*Zea mays L.*). It is susceptible to flooding. Reduced yields are the effect of water-logging in tropical and subtropical climates. (Rathore *et al.*, 1998) [3]. The yield of maize is influenced by soil, climate, cultivar, and cultural practices. Since maize was first cultivated, researchers have sought to link these processes in order to maximize harvests. The competition from other cereals and marketable crops limits the potential to expand the area planted to maize. So, enhancement of productivity by various management interventions is the only alternative. Insufficient irrigation and low plant population are the yield limiting issues of maize in many areas (Reddy *et al.*, 2017) [4]. Different nitrogen fertilizers affect maize production in different ways. When nitrogen was applied in splits as opposed to basal application, grain output was higher (Abdelsalam *et al.*, 2019) [6]. The rate and timing of nitrogen fertilizer application might affect the grain yield of maize (*Zea mays L.*). Applications of different rates of nitrogen, both single and divided, for maize grown on loamy sand under irrigation were studied by (Davies *et al.*, 2020) [1]. Timing of nitrogen fertilizer application has been shown to have a varied, often site-specific effect on maize grain production. When nitrogen was applied to maize at the two leaf-collar stage or equally divided between the two and six or twelve leaf development phases, there was no discernible difference in grain output in Iowa (Jaynes *et al.*, 2013) [2]. The economic benefit of using fragmented nitrogen use will further assist growers to sustain high maize yields while minimizing the harmful effects of nitrogen fertilizer on the environment (Davies *et al.*, 2020) [1].

Materials and Methods

During the kharif season of the years 2022 and 2023, a field experiments was conducted at the Lovely Professional University's soil science research farm in Phagwara, Punjab, to meet the objectives of investigation entitled, 'Soil characteristics before sowing and after harvesting of

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Timing of Nitrogen Treatment in Maize (*Zea mays L.*) Produced in Punjab's Coarse Loamy Typic Haplustept Soil being Evaluated

Himanshu Sekhar Behera [a++*] and Raj Kumar [a#]

[a] *Department of Soil Science and Agricultural Chemistry, School of Agriculture, Lovely Professional University, Punjab, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Field experiments were performed at the Soil Science research farm of Lovely Professional University, Phagwara, Punjab, during the *kharif* season of 2022 and 2023. This experiment primary goal was to understand, biomass and nitrogen uptake pattern of maize (*Zea mays L.*) grown in coarse loamy Typic Haplustept soil. The experiment farm is located at latitude at 31°14'30.5''N and longitude 75°41'52.1" E. The field trial was conducted in randomized block design with three replications in non-saline alkaline soil. Their wore two treatments: the recommended dose of fertilizer N @ 125 kg ha^{-1}, P_2O_5 @ 60 kg ha^{-1}, K_2O @ 30 kg ha^{-1} was tested against the no fertilizer

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++ *Ph.D., Student;*
\# *Professor;*
**Corresponding author: Email: himanshubeherars4@gmail.com;*

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This is to certify that Prof./Dr./Mr./Mrs./Ms. Himanshu Sekhar Behera. LPU, Punjab

Actively participated/presented a paper (Oral/Poster) entitled Evaluation of timings of nitrogen application in maize grown on coarse loamy Typic Haplustept soil of Punjab.

As Delegate/Scholar/Student in the 5th INTERNATIONAL CONFERENCE ON ADVANCES IN AGRICULTURE TECHNOLOGY AND ALLIED SCIENCES (ICAATAS 2022) on JUNE- 4-5, 2022, held at MS Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Gajapati, Odisha – 761211, India

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