Effect of Nano-Urea on Growth, Yield and Quality of Fodder Maize (*Zea mays* L.)

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2023

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Thesis

Submitted to

The Faculty of Agriculture

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir in partial fulfilment of requirement for award of the degree of

Master of Science in Agriculture

(Agronomy)

2023

Dedicated
To My
Ideal parents
For Building Up My
Educational Career
And
For Excellent Wishes
Throughout My Life
To the challenges,
That made me
stronger….

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
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Certificate–I

This is to certify that the thesis entitled, "**Effect of Nano-Urea on Growth, Yield and Quality of Fodder Maize (*Zea mays* L.)**" submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)**, to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Bisma Nazir (Regd. No. MSA-2021-1401)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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Certificate–III

This is to certify that the thesis entitled, "**Effect of Nano-Urea on Growth, Yield and Quality of Fodder Maize (*Zea mays* L.)**" submitted by **Ms. Bisma Nazir (Regd. No. MSA-2021-1401)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)** was examined and approved by the Advisory Committee and External Examiner on……………...........

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Title of the Thesis	:	**Effect of Nano-Urea on Growth, Yield and Quality of Fodder Maize (*Zea mays* L.)**

ABSTRACT

A field experiment was conducted at Agronomy Research Farm, Faculty of Agriculture, Wadura, SKUAST-K ,during *Kharif* -2022 to study the effect of nano-urea on growth, yield and quality of fodder maize .The experiment comprised of 08 treatments T_1: Absolute Control, T_2:Recommended dose of Nitrogen (RDN) as basal (prilled urea) @ 120 kg ha^{-1}, T_3: 50%RDN +Spray of nano- urea @2ml L^{-1} at (20 and 40) DAS,T_4: 50%RDN+Spray of nano -urea @4ml L^{-1} at (20 and 40DAS),T_5: 50% RDN +Spray of nano urea @6ml L^{-1} at (20 and 40 DAS),T_6: 50%RDN+Spray of nano urea @4ml L^{-1} at (30 DAS),T_7: 50%RDN+Spray of nano urea @8ml L^{-1} at (30DAS),T_8: 50%RDN+Spray of nano urea @12ml L^{-1} at (30DAS).The experiment was laid out in RCBD with 3 replications. The data revealed that treatment T_5 (50%RDN+Spray of nano urea @6ml L^{-1} at 20 and 40 DAS) recorded a significant increase in growth parameters viz., plant height, dry matter accumulation, leaf area index, number of functional leaves and yield viz., green fodder yield (t ha^{-1}) and dry fodder yield (t ha^{-1}) However, T_5 was at PAR with T_4: (50%RDN+Spray of nano -urea @4ml L^{-1} at 20 and 40DAS) as compared to control (T_1) and recommended dose of nitrogen (T_2). The highest green and dry fodder yield of 50.82 t ha^{-1} and 22.76 t ha^{-1} respectively was also recorded in T_5 which was at par with T_4. Furthermore, the economic analysis showed that highest B:C ratio of 1.91 was recorded in treatment T_5 followed by T_4 (1.90). Thus, adoption of foliar application of nano-urea can contribute to reduction of the soil application of prilled urea to half its recommended dose, thereby enhancing growth and yield encouraging sustainability in agriculture.

Keywords: Nano-urea, Growth, Efficiency, Yield attributes, Yield

Signature of Student
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Signature of Major Advisor
Dated: ____________

ACKNOWLEDGEMENT

Alhamdulillah, all praises and thanks be to ALLAH (swt), the most gracious, the most merciful and the best disposer of affairs. Countless blessings be upon our beloved Prophet, his blessed family and all of his noble companions.

I feel proud privilege in expressing my deep sense of gratitude and indebtedness to my major advisor; ***Prof. (Dr.) Amal Saxena*** *(Head of the Division of Agronomy, FoA, SKUAST-K) for his invaluable guidance, constructive and timely suggestions, keen and sustained interest and incessant encouragement bestowed throughout the course of investigation, that led to the successful completion of my research work. The enthusiasm for any work of my guide has been my inspiration and will last with me forever.*

I am highly grateful for constant guidance, encouragement, suggestions and sustained efforts of the worthy members of my advisory committee; ***Prof. (Dr.) Khursheed Ahmad Dar*** *(Professor, Division of Agronomy, FoA, SKUAST-K),* ***Dr. Inayat Mustafa khan,*** *(Assistant Professor, Division of soil science and Agricultural chemistry ,SKUAST-K),* ***Dr. Showkat Maqbool*** *(Associate Professor, Division of Agricultural Economics and Statistics, FoA, SKUAST-K) and* ***Dr. Syed Shafat Kubrevi*** *(Assistant Professor, Division of Agriculture Extension and communication).*

My sincere and heartfelt thanks to my teachers; ***Dr Tauseef Ahmad Bhat****,* ***Dr A. A. Saad****,* ***Dr. Lal Singh****,* ***Dr. Waseem Raja****,* ***Dr. Tahir Ahmad Sheikh****, and* ***Dr. Sheeraz Mahdi****, , for their timely support, scholarly guidance, positive criticism, affection and morale uplift during the whole course of study.*

I am highly thankful to ***Prof. Raihana Habib Kanth****, Dean Faculty of Agriculture, Wadura, for her guidance, support and cooperation.*

With utmost gratitude, I would like to place on record the help extended by the technical office and laboratory staff of Division of Agronomy, FOA Wadura, Mr. Shehzad Ahmed, Mr. Aijaz Ahmad Wani, Mr. Reyaz Ahmad Kalu, Mr. Zahoor Ahmad, Mr. Asif Ah Tantray and Hilal Ahmad Shah for their extended assistance and never denying me of any help.

I am grateful to my batchmates and dearest friends; Shabir A.Bhat, Ms.Barenya Gogoi , Ms. Tabasum Bhat,Ms. Sadaf salam, Ms.Faseeha Aijaz, Ms Saima Nisar ,Rahul Chandel, Sheikh Danish and Waseem Akram for their timely support and very kind help during field, lab and course work.

I'm blessed beyond measure with friends like family; Humaira jan, Insha Amin, Huzaifa Farhein, Yusra Amin, Mohsin Ahad, Imtiyaz Ahmad Mir, Basit

Abrar ,Hazik Hassan Khan,Imran Ramzan ,Jasdev Singh and Bhat Mujeeb who have been my emotional support through thick and thin, always believed in me and never planned any outing without me during my research work.

I wish to accord my cordial thanks to my respected seniors; Ms. Bisma Jan, Ms. Ummaisa, Ms. Moneesa, Ms. Aabiro Rashid, Aadil Akbar, Ms. Bilkuess jamsheed, Ms. Ishrat Murtaza, who helped, directed and upskilled me in the best possible way.

I'm highly thankful to ARIS and Library staff members of SKUAST- K for their timely guidance, support and generous help during preparation of this manuscript.

Words fail to express my gratitude to my dearest and loving parents; ***Nazir Ahmad Tantray and Naseema Begum*** *for their affection, moral support and prayers for my success. I am thankful to my loving siblings;* ***Mujeeba Tabasum, Rehana Tabasum, Saba Tabasum, Shameema Nazir ,Rashida Akhter*** *,my dearest unique brother* ***Owais Tanveer*** *and my brother - in -laws ;* ***Mr Mushtaq Ahmad Dar and Mr Saleem Yousuf Parray*** *for their sincere help, motivation and best wishes that kept me going to achieve my goals.*

Finally, I owe my gratitude to all those who might not have got a mention but directly or indirectly, have cared, prayed and helped me during my research work.

Bisma Nazir

Place: Wadura, Sopore
Dated:

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Chapter-1

INTRODUCTION

Maize is one of the most prominent forage crops not only in India but throughout the world owing to its higher growth rate and yield, wider adaptability, higher digestibility, more palatability and lack of any potential anti-nutritional factor (Hedayetullah and Zaman, 2018). On the dry weight basis, average nutritional content in fodder maize is 20.5-24.7% dry matter (DM), 5.5-8.7% crude protein (CP), 23.1-30.2% crude fibre (CF), 64. 1-72.8% neutral detergent fibre (NDF), 38.3-46.8% acid detergent fibre (ADF) and 6.0-8.0% ash (Chaudhary *et al.*, 2011). However; the optimum quantity and quality of maize fodder production depend upon several factors; among which time of sowing, adequate moisture availability and sufficient supply of all essential macro- and micro-nutrient to the plant comes. It is cultivated in almost all districts in Kashmir. The leading maize producing districts are Kupwara, Baramulla, Budgam and Anantnag. The Nitrogen content is found to vary with respect to different altitudes of the Kashmir valley and ranges from low to medium. Varied results have been obtained with respect to available soil nitrogen, where Pattan recorded an average value of 372.8 kg ha^{-1} and Gurez recorded 251.5 kg ha^{-1} (Dar *et al.*, 2016). From the available nutrients Nitrogen was low to medium with the mean values of 287.99 and 149.69 kg ha^{-1} in Langate block of Kupwara district (Khan *et al.*, 2020).

Sustainable agriculture with a high productivity is crucial to alleviate the perils of hunger and increase food security. Food production and distribution are under an increased and continuous stress at a global scale due to climate change, an increased human population, decreased fertile lands and freshwater resources. This challenge could be addressed with technological advancements coupled with significant modifications to existing global food production systems (Achiri *et al.*, 2017). The nutrient use efficiency (NUE) values of the three most basic macronutrients i.e., nitrogen, phosphorus and potassium are low at 30–35%, 18–20% and 35-40%, respectively (Zhang *et al*., 2015) which shows that more than half of the broadcasted fertilizers in the fields are lost and do not reach their targeted sites due to different factors such as photolysis, hydrolysis, leaching and microbial immobilization and degradation. Due to denitrification, volatilization, leaching, fixing, and immobilisation, nitrogen fertilisation also faces the issue of losses in soil application. To lower the N losses it is advised to maximise the utilisation efficiency of applied fertiliser in order to reduce losses and enhance crop N uptake (Hawkesford, 2014).

Nanoscience coupled with nanotechnology represents a new frontier for the research community that can give a leg up in adopting sustainable agriculture. Nanofertilizer works with the smallest particles, called the nanoparticles, which elevates the hopes for improving agricultural productivity through encountering the problems unsolved conventionally (Manjunatha *et al*., 2016). Nanotechnology has its goal in the realization of novel materials and devices with features on the nanoscale. In the management aspects, efforts are made to increase the efficacy of applied fertilizer with the help of nano clays and zeolites and restoration of soil fertility by releasing the fixed nutrients and making them available for the crops (Khan *et al*., 2021; Syakir *et al*., 2016). It has found potential applications in controlling nutrient release and availability, characterization of soil minerals, weathering of soil minerals and development, nature of soil rhizosphere and nutrient ion transport in soil-plant system (Shang *et al*., 2019).

The study of science and technology at the nanoscale, which is measured in nanometers, is known as nanotechnology. Nanotechnology is a recent development that is being studied in practically all disciplines and could offer better solutions to the issues facing the agricultural industry today. The most crucial agricultural technologies today are nanotechnology and biofertilization, and both are expected to have a major impact on the economy in the near future (Hegab *et al*., 2018). Although it is still in the early stages, there is a big push in agriculture for long-term crop development, with nano-nitrogen playing a significant role. Nano fertilisers are a novel concept in agricultural nutrient management. Because they are environmentally friendly, nano fertilisers are essential for fostering sustainable agricultural development (Shukla *et al*., 2019). This technique has made it possible to manufacture "smart fertiliser," which can increase nutrient effectiveness while lowering environmental protection expenses, using small nanomaterial molecules that convey fertiliser. Numerous benefits of using nano fertilisers include improved crop stress tolerance and increased nutrient use efficiency (Shukla *et al*., 2019), increased agricultural output and less need for chemical fertiliser (Kumar *et al*., 2021).

Nitrogen, a vital component for crop growth and development, can be found in nano urea. The IFFCO Company have recently released Nano Urea, a new product. One Nano Urea particle is approximately 30 nm in size (1 nm is one billionth of a metre), and when compared to ordinary urea, it has about 10,000 times more surface area to volume than granular urea. Additionally, nano urea gets absorbed by plants when sprayed on their leaves because of its extremely small size and surface characteristics (Anonymous, 2021). Nano Urea liquid adequately fulfils the crop's need for nitrogen when sprayed during critical stages of crop growth. It is used in place of traditional urea and other nitrogenous fertilisers to benefit the environment, the health of the soil, and farmer profitability. Nano urea contains 4% nitrogen by weight in its nano form. According to the manufacturer, a half-litre bottle of nano urea may effectively dissolve up to one bag of urea. Nano urea has a substantial advantage in terms of a safe and clean environment due to the fall in the application of conventional bulk urea.

Nano science and Nano-technology represent a new frontier for the research community. Nano fertilizer is working with the smallest possible particles which elevate hopes for improving agricultural productivity through encountering problems unsolved conventionally. Nanotechnology has its goal in realization of novel materials and devices with features on the nano-scale, drawing from fields such as colloidal science and device physics. In the management aspects, efforts are made to increase the efficiency of applied fertilizer with the help of nano clays and zeolites and restoration of soil fertility by releasing fixed nutrients. It has found potential applications in controlling nutrient release and availability, characterization of soil minerals, weathering of soil minerals and development, nature of soil rhizosphere and nutrient ion transport in soil plant system.

Direct application of fertilizers to the soil will results in loss of nutrients in different ways such as photolysis, hydrolysis, leaching and degradation. Hence the applied fertilizer may not be able to reach the targeted sites in the plant system and unable to enhance the optimal growth and productivity of crops. Hence, an attempt was made to increase the efficiency of applied fertilizer in the form of nano-fertilizer through foliar spray to the crop.

Therefore the present study entitled **"Effect of nano-urea on growth, yield and quality of fodder maize (*Zea mays* L.)"** was endeavoured to meet with following objectives:

1. To find out the suitable dose of nano urea for enhanced yield and quality of fodder maize.
2. To estimate the crop growth indices of fodder maize.
3. To work out relative economics.

Chapter-2

REVIEW OF LITERATURE

A brief review related to the research work done on nano-fertilizers / nano-urea and its effect on growth, yield and quality of fodder maize (*Zea mays* L.) is presented hereunder, classified as:

2.1 Effect of nano urea on growth and yield

Azimi *et al*. (2013) performed a field experiment to find out whether bulk and nanosized titanium dioxide particles may improve the wheat grass (*Agropyron desertorum*) seed germination characteristics in Iran at Ferdowsi University of Mashhad's Faculty of Natural Resources and Environment's Range Management Department. The findings demonstrated that nanosized titanium dioxide particles improved the shoot, root, seedling elongation, and root biomass were highest at 40 ppm of nano titanium dioxide.

Raliya and Tarafdar (2013) performed a field experiment to investigate ZnO Nano particle Biosynthesis and its Effect on Phosphorous-Mobilizing Enzyme Secretion and Gum Contents in Cluster Bean (*Cyamopsis tetragonoloba* L.) at Central Arid Zone Research Institute, Jodhpur, Rajasthan, India. The findings show that oblate spherical and hexagonal nanoparticles with a size ranging between 1.2 and 6.8 nm were synthesised, at least in one dimension. The samples have 98% Zn in them. The described ZnO nanoparticles were foliar sprayed at a dosage of 10 ppm on the leaf of 14-day-old cluster bean plants. Application of nano ZnO above control resulted in a significant improvement in plant biomass (27.1%), shoot length (31.5%), root length (66.3%), and root area (73.5%) in 6-week-old plants.

Armin *et al.* (2014) conducted a study to assess the effects of various Nano-Fe fertiliser concentrations and application times on the quantitative and qualitative characteristics of wheat. In order to determine the impact of Nano-Fe concentration and application timing on wheat (*Triticum aestivum* L.) yield and yield components, a field experiment using a factorial arrangement of treatments in a randomised complete block design with three replicates was conducted in Sabzevar, north-eastern Iran, in 2011-2012. Treatments included four Nano-Fe application rates (spraying with concentrations of 0, 2%, 4%, and 6% as corresponding with 0, 2, 4, and 6 kg Fe ha^{-1} water-soluble Fe (Nano Fe Chelates)) and three application times (tillering, stem elongation, and tillering + stem elongation). The Nano Fe Chelates from Khazra Company that were employed in this investigation had 9% Fe, 1% Zn, and 1% Mn without any ethylene compounds. With 10 foliar applications of nano Fe at 4% concentrations, the results showed a noticeable improvement in tiller number and growth, with no discernible differences between 4% and 6% concentrations.

Tarafdar *et al*. (2014) performed a research to examine the biosynthesis of zinc nanoparticles that were applied as nano-fertilizer to improve crop production in pearl millet (*Pennisetum americanum* L.) cv. HHB 67 at Central Arid Zone Research Institute, Jodhpur, Rajasthan, India. The application of synthetic Zn nanoparticles with sizes between 15 and 25 nm increased shoot length (15.1%), root length (4.2%), root area (24.2%), and plant dry biomass (12.5%) significantly over control in plants that were 6 weeks old.

Benzon *et al*. (2015) performed an experiment in greenhouse to determine the effects of nano fertilizer application on the total phenolic content (TPC), antioxidant activity and yield of rice cv. Ilpum. The experiment was performed under greenhouse conditions at the Agricultural Experiment Station and Research Facility, Kyungpook National University, Daegu, South Korea. Results revealed that full recommended rate of conventional and nano fertilizer (FRR-CF+FRR-NF) significantly increase the growth and yield attributes viz. taller plant height, maximum chlorophyll content, number of reproductive tillers, panicles and spikelet over control. The magnitudes of increase over FRR-CF were 3.6%2.72%, 9.10%, 9.10% and 15.42% respectively. General observation showed that all treatment except HRR-NF were able to significantly taller plant height.

Manikandan and Subramanian (2015) performed an experiment to study the response of maize (NK-6240) to different fertilizer formulations during 2012 and 2013 at Tamil Nadu Agricultural University. The 5 treatments T_1 Urea alone, T_2 Zeolite + Urea (1:1 ratio - Physical mixing at equal proportion on w/w basis), T_3 Nano Zeolite + Urea (1:1 ratio - Physical mixing at equal proportion on w/w basis), T_4 Zeourea (1:1) - Intercalated, T_5 Nanozeourea (1:1) - Intercalated. Results indicate that the quality, growth and nutrient uptake were consistently higher for nano zeourea treatment than conventional urea.

Vafa *et al*. (2015) reported performance of nano zinc and humic acid on quantitative and qualitative characteristics of savory (*Satureja hortensis* L.) The experiment was carried out at the research greenhouse of University of Zabol, Iran, in 2013 cropping season. Plants were treated by different concentrations of humic acid (0, 0.5, 1, and 1.5cc on each one 1000 ml L^{-1} water) and nano Zn chelated fertilizer (0, 50, 100, and 200 mg; on each one at 1000 ml L^{-1}water) and control (without using fertilizer). The results indicates that in Savory plant, growth parameters like plant height, leaf number and content of chlorophyll were increased by nano-zinc application obtained in N_4 treatment over all other treatment.

Drostkar *et al*. (2016) studied the effect of foliar application of different nano-fertilizer (Zn, Fe and NPK) on the yield of chickpea (*Cicer arietinum* L.). The experiment was done during spring and summer 2013 at the experimental research farm of Kherkeh Dryland Agricultural Institute West of Iran. Higher seed yield (137.3 g m^{-2}) and biological yield was obtained by Fe + Zn foliar application and caused 34% and 14 % increase in seed yield respectively.

Davarpanah *et al*. (2017) performed an experiment for studying the effects of foliar fertilization with a nitrogen (N) fertilizer containing nano particles (nN) with those of foliar fertilization with urea on the characteristics of pomegranate *(Punica granatum)* orchard located in the central part of the Razavi Khorasan province in the northeastern Iran .Two foliar applications of N (0.25 and 0.50 g N L^{-1}, equivalent to (0.25 and 0.50 g N L^{-1}, equivalent to ≈1.3 and 2.7 g N per tree or 0.9 and 1.8 kg Nha^{-1}; 25 nN1 and nN2, respectively) and urea was applied at full bloom and 1 month later, and trees not treated with any N fertilizer were used in control. Results depicted that pomegranate fruit yield as well as fruits per tree improved expressively with two applications (at full bloom and one month later) of nano nitrogen fertilizer.

Gomaa *et al*. (2017) conducted a study to evaluate to compare some new maize hybrids response to mineral fertilization and some nano-fertilizers .Two field experiments were conducted at the Experimental Farm, Faculty of Agriculture (SabaBasha), Alexandria University, Abess Region , Egypt, during two summer seasons of 2016 and 2017.The results showed that foliar application of nano and soil application of mineral fertilization (K and P), significantly, influenced biological, grain, and straw yields during both growing seasons. The higher values of biological, grain, and straw yields (18.76 and 17.93 ton ha^{-1}), (8.68 and 8.35 ton ha^{-1}) and (10.08 and 9.58 ton ha^{-1}) were recorded with application of mineral fertilizer in the soil + foliar application of nanofertilizer followed by foliar nano- fertilization treatment as compared with other treatments, respectively. Meanwhile, the lower ones (14.47 and 13.42-ton ha^{-1}), (6.27 and 6.14 ton ha^{-1}) and (8.19 and 7.28 ton ha^{-1}) were recorded with foliar mineral fertilizer alone, respectively during two growing seasons.

Kandil *et al*. (2017) conducted an experiment to observe the response of some wheat cultivars to nano mineral fertilizers and amino acids foliar application. Two field experiments were conducted at El-Horaria village, Abou El- Matamir district, El- Behira Governorate, Egypt, during 2014/2015 and 2015/2016 growing seasons, the design used was split- plot with three replications . The main plots included foliar application (mineral, amino acids, nano fertilizer ,mineral + amino acids, mineral +nano- fertilizer, and amino acids + nano fertilizer), while three bread wheat cultivars (Sids 12 , Sids 11 and Giza 168) were allocated in the sub plot. The results obtained revealed such significant increases in grains number / spike, 1000- kernel weight, grain, straw, and biological yields /fed., as well as harvest index (%) using nano- fertilizer + aminoacids during both growing seasons. Data revealed that the higher values for grain yield (2620.76 and 2677.39 kg fed^{-1}), straw yield (3408.76 and 3402.55 kg fed $^{-1}$) and biological yield (6029.51 and 6079.94 kg fed^{-1}) were observed owing to foliar application with nano-fertilizer + amino acids treatment as compared with other treatments during both seasons of the study, respectively. However, the lower mean values for grain yield (1955.26 and 1920.58 kg fed^{-1}), straw yield (2743.26 and 2679.08 kg fed^{-1}) and biological yield (4698.51 and 4599.65 kg fed^{-1}) were achieved with mineral fertilizer during both seasons.

Abdel-Salam (2018) performed a field experiment on lettuce (*Lactuca sativa* L.) grown on heavy clay torrifluvent soil in order to study the effect of foliar application of nano-urea and biofertilization using Vesicular-arbuscular mycorrrhiza (VAM) and reported that the application of VAM biofertilizer combined with medium rate nano-urea spray (3750 mg L^{-1}) has shown the highest response on plant height (43.48 cm) and dry weight (30.94 g plant^{-1}) over control and ordinary urea.

Al-Juthery *et al*. (2018) performed an experiment on effect of foliar application of different sources of nano-fertilizers on growth and yield of wheat. A field experiment was performed on wheat cultivar Ebaa 99 which was achieved at Extension farm in Al-Shafeieyah included di spray application of N, P and K Nano-fertilizer (N+P), (N+K), (P+K) and tri (N+P+K), Super Micro Plus SMP nano-fertilizer, Traditional fertilizer (NPK+TE) (AGRIMEL) and without application as control for comparison with three replicates in a simple one-way experience using RCBD design. Results revealed significance response was spraying of SMP nano-fertilizer followed by the spraying combined of tri (N+P+K), di (N+P), (N+K) and (P+K) nano-fertilizer compared to control and traditional (NPK+TE) fertilizer treatments respectively in all yield parameters, harvest index and protein content. Higher biological yield (13.36 t ha^{-1}) and grain yield (5.99 t ha^{-1}) were identified in wheat grown at spraying nano super micro plus (NSMP) fertilizers.

Choudhary *et al*. (2018) performed an experiment to study to the intercession of legume based inter-cropping and nano phosphorus as managerial input for upland of 27 Jharkhand. Field experiment was conducted at BAU, Ranchi, during kharif seasons of two consecutive years, 2016 and 2017. Maximum grain yield of pigeon pea and black gram were recorded with 50% RDP+ Nano-P 40 ppm (P3) followed by 100% RDP (P4) and Nano-P 40 ppm (P2) while in case of maize, maximum grain yield. The grain yield of pigeon pea increased by application of Nano-P 40, maize and black gram compared to no phosphorus while minimum grain yield was registered under no phosphorus application (P1)

Hegab *et al*. (2018) evaluated a field experiment at Baloza Research Station of Desert Research Center, North Sinai, to investigate the effects of application for nitrogen fertilizer (urea), nano urea and biofertilization (*Azotobacter chroococcum*), on the chemical composition and productivity of sage plant (*Salvia officnalis* L.). Two mineral fertilizers, nano urea, urea and biofertilizer (A. *chroococcum*) were applied to the soil. The experiment was laid out in split plot design and each treatment was replicated thrice. Results showed that yield components of sage plants increased with increasing of nano urea and urea application rates during both cuts. The most effective treatment (Nano 500 ppm with bio N fertilizer) gave the highest significant values of yield components amounted to 2.77, 11249 and 4395 for oil (%), herb fresh and dry weight (kg fed^{-1}), respectively in first cut. In second cut yield components were higher than first cut.

Mahmoodi *et al*. (2018) in his experiment studied the effects of of nano fertilizers namely nano-Fe, nano-Zn, nanourea, nano-K and chemical fertilizers (iron sulphate, zinc sulphate, urea and potassium sulphate) on physiological efficiency and essential oil yield of *Borago officinalis* during 2013 and 2014 crop years and observed that application of nano-urea (4ml L^{-1}) increased essential oil yield upto 10.96% over control. The highest values for number of secondary branches (13.29) and leaf area (1706 cm^2) were also observed in the treatment with nano-urea fertilizer.

Rathnayaka *et al*. (2018) in his experiment studied the influence of urea and nano-nitrogen fertilizers on the growth and yield of rice (*Oryza sativa* L.) cultivar 'Bg 250' and concluded that application of 100% nano-nitrogen along with recommended dose of P and K recorded higher values for yield (2.8 tonnes ha^{-1}), plant height (57.9 cm), number of tillers per plant (6) and plant dry weight at ripening stage (9.9 g $plant^{-1}$).

Sohair *et al*. (2018) in his field experiment in carried out in years 2016 and 2017 at Agricultural and Experimental Research Station to evaluate NPK nano-fertilizers application, times, methods and rates on yield and fiber properties of Egyptian cotton (Giza, 90). The split- plot design based on randomised complete block design was used in the experiment. Treatments included two application times were applied in main plots, two application methods are foliar and soil in sub-plots and four rates applications of control (100% soil application traditional NPK Recommended Fertilizer Dose (RFD) and nano NPK fertilizers 12.5%, 25% and 50% RFD) were applied in sub-sub-plots. Significant increases of total and open bolls per plant, boll weight and seed cotton yield as a result of the application of three times NPK nano-fertilizers than two times. Maximum improvement was achieved when use of 50% RFD of nano NPK fertilizers which at par with control treatment in the second season.

Afify *et al*. (2019) performed a field experiments at Researches and Production Station of National Research Centre, Al Nubaria district, EL-Behaira Governorate, Egypt during the two successive summer seasons of 2017 and 2018 at newly reclaimed sandy soil to study the effect of potassium nano-fertilizer concentrations (100, 200, 300 and 400 ppm) were done as one dose at vegetative stages (30 days after sowing) and split twice (50+50, 100+100, 150+150 and 200+200 ppm) the first at vegetative stage (30 days after sowing) and the second at pod development period (60 days after sowing) on groundnut growth parameters, seed yield and quality which grown in sandy soil. Results revealed that foliar application with potassium nanofertilizers new methods to increase both seed yield and oil content peanut.

Marzouk *et al*. (2019) performed an experiment to study the impact of foliar aaplication of nano micronutrient fertilizers on the growth, yield, physical quality and nutritional value of two snap bean cultivars in sandy soils in the Experimental Station of the National Research Centre in El Nobaria region, Behira Governorate, Egypt, during two successive growth seasons (2017–2018). The split-plot design with three replications was used. The treatments comprised of two snap bean cultivars (Bronco and Flantino), nano micronutrient fertilizers as foliar spray (Mn, Fe, 29 and Zn), and control. Results showed that the combined effect of Flantino cultivar with zinc nano-fertilizer treatment recorded the higher values of fresh pod yield, pods physical quality and nutritional value. The higher values of pod physical quality and yield were recorded by Flantino cultivar when treated by zinc nano fertilizer. On the other hand, the lower values were recorded by Bronco cultivar without nano micronutrient fertilizer addition in both seasons.

Merghany *et al*. (2019) performed an experiment in the farm of faculty of Agriculture Cairo University, Giza, Egypt during winter season of 2017-2018 and 2018-2019 at plastic green house, to determine the effects of nano fertilizer on cucumber growth and fruit yield. The liquid nano NPK with different concentrations (3, 4.5, 6 and 9 ml) were used. In control the mineral fertilizer was used. In randomized complete block design with three replicates were arranged .The results showed that the nano-fertilizer treatments significantly improved the yield of cucumber compared with control treatment. All treatments of nano-fertilizer led to increase Chlorophyll content, yield and NPK % in leaves and fruits. The treatment of 6 ml NPK increases the yield by 4.84% and 53.42% in the first and second seasons respectively. Higher yield plant^{-1} (4.18 kg) were obtained from treatment of 6 ml NPK, followed by control NPK (3.99 kg) and 9 ml NPK (3.57 kg).

Satdev *et al*. (2020) conducted an experimental trial at college farm of Navsari Agricultural University, Navsari in field trial during 2017-18 to study the impacts of ZnO nanoparticles on growth and yield of sweet corn. Results revealed that foliar application of ZnO NPs or seed treatment ZnO NPs enhance the yield attributes and yield of sweet corn. Significantly higher cob yield of sweet corn and straw yield (16.85% increase over the control) was recorded under foliar application of ZnO-NPs (M3) @ 500 ppm (T_{12}) and which was at par with the treatment T_4, T_7, T_8, T_9, T_{10} and T_{11}.

Alimohammadi *et al*. (2020) in his experiment studied the effects of urea and nano-nitrogen chelate fertilizers on yield of sugarcane during 2017 and 2018 in Khuzestan province of Iran and observed that the yield (in terms of sugar) has increased by 6.5% on application of nano-nitrogen chelate over urea fertilizer.

Kumar *et al*. (2020) carried out his experiment on 600 on-farm trials to study the effect of nano-fertilizers (nano-N, nano-Zn and nano-Cu) on nutrient use efficiency and crop yield of 8 important winter season crops namely maize, wheat, barley, urdbean, chickpea, mustard, isabgol and rose in different districts of Rajasthan. They reported that application of 50% less N than farmer's fertilizer practice (FFP) along with 2 sprays of nano-N (first spray at 3 weeks after full germination and second at 5 weeks after full germination), resulted in 10.45%, 8.36%, 7.29%, 6.38% and 7.85% increased yield in urdbean, chickpea, maize, barley and rose respectively over FFP.

Sankar *et al* (2020) conducted a field experiment in sandy clay loam soil to study the fertilizer use efficiency of nano NPK and straight fertilizers with and without organic sources on baby corn (*Zea mays* L.) during winter of 2018- 19. The treatments comprise of nano NPK, straight fertilizers and organics (vermicompost and azotobacter) applied as alone and combinations. The results confirmed green forage yield of baby corn was significantly influenced by the nano NPK and straight fertilizers with and without organic sources. Also Agronomic efficiency of nutrients was observed to vary widely with nano NPK and straight fertilizers with and without organic sources.

Salama and Brady (2020) in their experiment studied the effect of partial substitution of bulk urea by nano-urea fertilizer on productivity and nutritive value of *Zea mays* (teosinte) varieties. They concluded that the combined application of 50% nano-urea with 50% bulk urea resulted in highest values for fresh yield (39.68 t ha^{-1}) at 3rd cut, plant height (58.74 cm), stem diameter (7.64 mm) and leaf area (130.07 m^2) at 1st cut.

Ajithkumar *et al*. (2021) conducted and an experiment during *kharif* seasons of 2019-20 and studied the effect of nano-fertilizers, namely nano-N, nano-Zn, nano-Cu and bio-fertilizer (Sagarika) on growth and yield of maize at Raipur and reported that among the different combinations of nano-fertilizers with recommended dose of fertilizers, application of 50% N, 100% PK, 0% Zinc with 2 sprays of nano N (4ml L^{-1}) mixed with sagarika (2ml L^{-1}) gave the maximum yield (58.90 q ha^{-1}) and highest B:C ratio (2.99).

Mejias *et al*. (2021) review that Nitrogen nano-fertilizers are expected to increase NUE by improving the effectiveness of N delivery to plants and reducing N losses to the environment. Information on the efficiency of the use of N nanofertilizers in grasslands species is scarce and the application strategies that can be used to avoid N losses are poorly understood. New scenarios of increasing economic and environmental constraints may represent an opportunity for N nano-fertilizers application in grasslands.

Sahu *et al.* (2022) studied the effect of nano-urea application on growth and productivity of rice under midland situation of Bastar region during *kharif* season of 2021 and observed that the application of 75% RDN with two foliar sprays of nano-urea (at tillering and panicle initiation) resulted in highest values for grain yield (5195.83 kg ha^{-1}) as well as straw yield (6250 kg ha^{-1}).

2.2 Effect of nano urea on quality

Jian *et al.* (2008) conducted a research experiment to explore the application effect of nano synergism fertilizer on winter wheat and reported that application of nano synergism fertilizer resulted in decreased protein content of the wheat (7.52 %) whereas, the fat content was increased significantly (33 %) upon application of these nano material.

Qiang *et al.* (2008) performed an experiment in order to evaluate the effectiveness of slow controlled release fertilisers made of nano-materials on the quality of winter wheat and summer maize, and found that application of nano fertilisers resulted in non-significant increase in protein content, whereas use of these fertilisers in comparison to conventional NPK chemical fertiliser was found to result in non-significant decrease in soluble sugar content.

Ghafari and Razmjoo (2013) carried out a research study in Isfahan (Iran) in order to evaluate the results of foliar application of nano iron oxide (2 g L^{-1}), iron chelate (4 and 8 g L^{-1}) and iron sulphate (4 and 8 g $litre^{-1}$) on the quality of bread wheat (*Triticum aestivum* L.) and found that application of 8 g L^{-1} iron sulphate followed by application of 2g L^{-1} of nano iron oxide significantly increased grain carbohydrate yield in addition to chlorophyll, grain protein, and iron contents than control plots in comparison.

Manikandan and Subramanian (2016) carried out an experiment to study the response of maize (NK-6240) to different fertilizer formulations. The results of the study confirmed that crude protein content of maize grains was the highest in nano- urea fertilizer plants regardless of light textured or heavy textured soils.

Also the crude proteins recorded in nano-urea treated plants in black and red soils were 26.1% and 36.1%, higher than urea fertilized treatments.

Juthery *et al*. (2018) carried out a field experiment in Al-Shafeieyah, Iraq, to examine the impact of foliar application of several nanofertilizer sources on wheat growth and yield with the use of fertiliser known as nano super micro plus (SMP) compared to other treatments, wheat grains had the highest protein content (13.69%).

Burhan and Hassan (2019) in their experiment studied the impact of nano NPK fertilizers on quality traits of three wheat varieties. The results of the study showed increases in protein percentage (27.24%), gluten ratio in flour (58.45%) its dry weight (41.89%), total chlorophyll content (18.33%), nitrogen (19.37%), phosphorus (44.11%) and potassium (12.03%) when fertilized with Fn1 treatment compared with the control treatment.

Merghany *et al*. (2019) in his study investigated the effect of nanofertilizer on quality parameters of cucumber. The results indicated that the nanofertilizer treatments significantly improved the quality parameters of cucumber such as total Soluble Solids (TSS) and Firmness. The highest values of total soluble solids (TSS) 2.73, 2.7 and 2.6 were recorded from treatment with 9 ml NPK, 6 ml NPK and control NPK in the first season. The highest firmness (3.68) was recorded from treatment with control NPK, followed by 6 ml NPK and 3 ml NPK in the first season.

2.3 Relative economic condition

Khan *et al*. (2019) carried out an experiment on comparative basis in apple orchards of Anantanag District during 2017 and 2018 crop year and studied the effect of N, P and K nano-fertilizers in comparison to humic and fulvic acid on yield and economics of red delicious (*Malus* x *domestica* Borukh.). The results revealed that application of nano-N fertilizers @ 300 ppm resulted in gross return of Rs. 31, 92,200 ha^{-1} with net return of Rs. 27,30,657.23 ha^{-1} and net B:C ratio of 5.92.

Mishra *et al*. (2020) studied an experiment during Rabi season of 2019 at Jajpur District of Odisa to study the effect of nano fertilizers (nano-N, nano-Zn and nano-Cu) on the growth, yield and economics of tomato variety Arka Rakshak and observed that application of farmers practice (50% N + 100% P + 50% Zn) with 1st spray of Nano N, 2nd spray of Nano Zn and 3rd spray of Nano Cu recorded the highest gross income of Rs. 2,12,620 ha^{-1} with net return Rs. 1,59,720 ha^{-1} and maximum B: C ratio of 4.01.

Kumar *et al*. (2020) carried out the mean effect of nano-fertilizers (nano-N, nano-Zn and nano-Cu) on nutrient use efficiency, grain yield of maize and economic returns and reported that the economic return over farmer's fertilizer practice (FFP) was found to be higher (Rs. 4118 ha^{-1}) when maize (*Zea mays* L.) was grown with 50% less N than FFP and 2 sprays of nano-N (first spray at 3 weeks after full germination and second spray at 5 weeks after full germination.

Tiwari *et al*. (2021) performed an experiment and evaluated total 187 trials on farmers' fields with potato in different districts of Uttar Pradesh during Rabi 2019-20 with five treatments but in this paper as they evaluated the effect of non-nano urea with nano-urea so the impacts of only two selected treatments viz., Farmer's Fertilizer Practice (FFP) (T_1) and FFP - 50% N + 2 Spray of Nano Urea (T_2) on potato based on 187 trials are being presented. Results revealed that B:C ratio obtained from FFP-50% N + 2 Sprays of Nano -N (T_2) is more than Farmer's Fertilizer Practice (FFP) i.e. T_1.

Neogi and Das (2022) carried out a field experiment during Rabi seasons of 2019-20 and 2020-21 to determine the effect of nitrogen and zinc, when applied in nano form fertilizers on the growth and productivity of potato in inceptisols. The more net return (▯ 1,71,466 ha^{-1}) and benefit cost ratio (2.69) was observed under the treatment T_8 with the application of 100% RDF of NPK+

foliar nano-N sprays + foliar nano-Zn sprays. The minimum net return (16080 ha^{-1}) and benefit cost ratio (0.80) was recorded under the treatment T_1 (control). It was evident that the application of 100% RDF of NPK+ 2 foliar spraying of nano-N + 2 foliar spraying of nano-Zn increased the net return by 64.7% over the application of hundred percent recommended dose of NPK.

Saitheja *et al*. (2022) performed a field experiment in wetland farm of Tamil Nadu Agricultural University, Coimbatore, during summer season, 2022 with an objective of maximizing the productivity and profitability of green gram by adopting varied dose of basal nitrogen and foliar application of nano and normal urea at Flower Initiation (FI) stage and 15 days thereafter. The perusal regards to profit earned in treatment combination of basal supply of 100% RDN with nano urea foliar spray @ 4ml L^{-1} water at flower initiation stage and 15 days thereafter as well as the treatment combination of basal dose of 80% RDN integrated with foliar spray of nano urea @ 4ml L^{-1} of water at flower initiation stage and 15 days thereafter accounted higher gross return of 100114 ha^{-1} and 99976 ha^{-1} , net return of 53549 ha^{-1} and 53475 ha^{-1} and BC ratio of 2.15 each respectively. Control + 1% urea (Normal) at flower initiation stage and 15 days recorded minimum gross return 53199 ha^{-1} , net return of 11068 ha^{-1} and B:C ratio was 1.26.

Chapter -3

MATERIALS AND METHODS

A field experiment entitled **"Effect of nano-urea on growth, yield and quality of fodder maize (*Zea mays* L.)"** was conducted at Agronomy Research Farm, Faculty of Agriculture, Wadura, Sopore, SKUAST-Kashmir, during *Kharif* 2022. The details of materials used, experimental procedures followed and techniques adopted during the course of the investigation have been depicted in this chapter.

3.1 Experimental site

The experimental investigation was carried out in the Research Farm of Division of Agronomy at Faculty of Agriculture, SKUAST-K, Wadura, Sopore during the *kharif* season 2022. The experimental site is situated between a latitude of 34^{o} 21' N and longitude of 74^{o} 23' E with 1590 m amsl. The site had uniform topography and well-drained soil.

3.2 Climate and weather conditions

The experimental site is situated in the North Western Himalayan temperate region. The average meteorological data was collected from Meteorological Observatory at Wadura. The data in (Fig. 3.1) showed that the total rainfall received during the cropping season was 319.8 mm. The minimum temperature ranged from 4.57 to 20.33^{o}C, maximum temperature ranged from 20.07 to 31.31^{o}C, average maximum relative humidity ranged from 77.43% to 92.86% and average minimum relative humidity ranged from 40.57% to 67.85% during the cropping season of *Kharif* 2022.

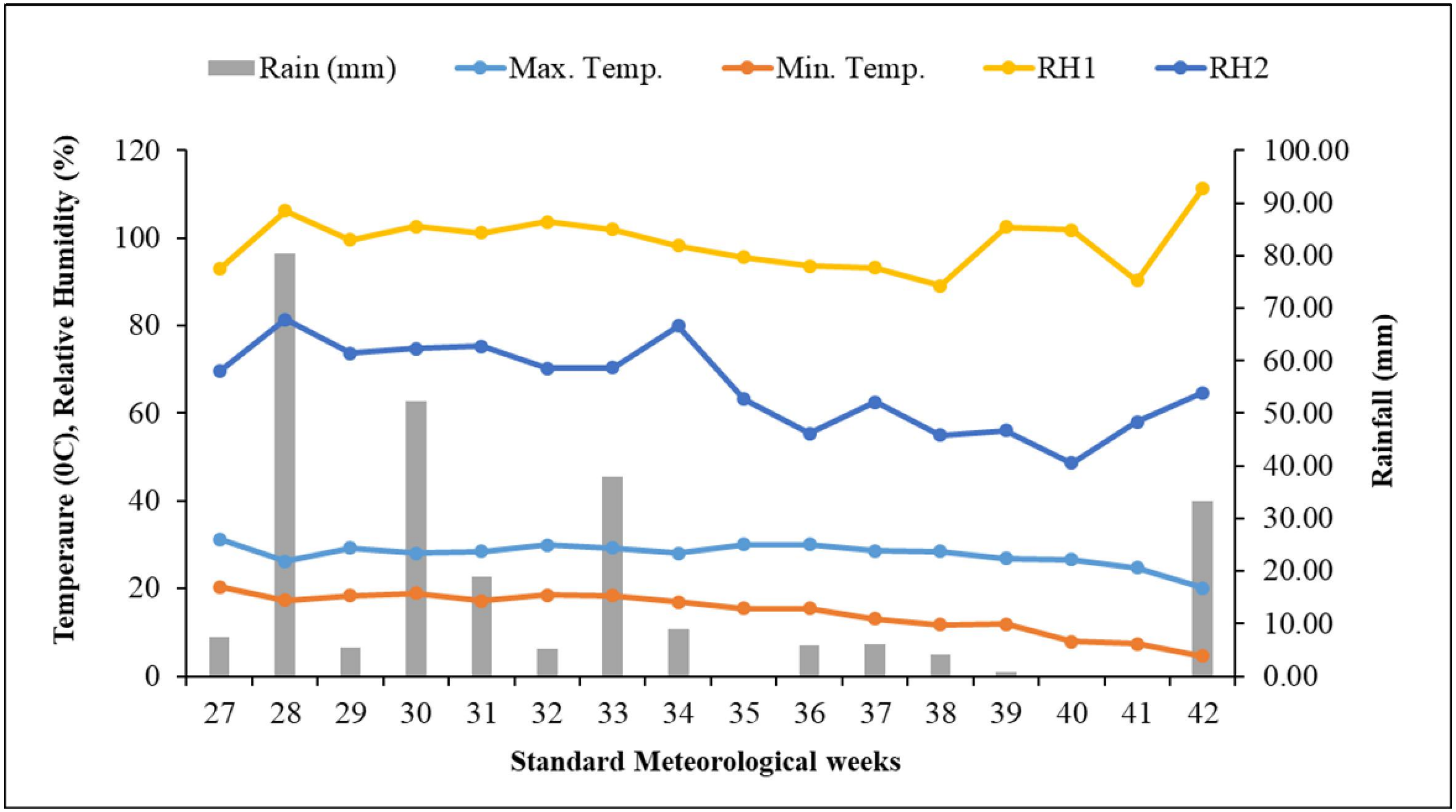

Fig. 3.1: Weather conditions during kharif season 2022

3.3 Cropping history of the experimental field

The cropping history of the experimental site for the preceding three years of experimentation is presented in Table 3.1.

Table 3.1: Cropping history of the experimental field

Year	Cropping season	
	Kharif	Rabi
2020	Fallow	Fallow
2021	Fallow	Fallow
2022	Maize (experimental crop)	------------

3.4 Soil characteristics

For physico-chemical characteristics of soil, composite soil samples were drawn from 0-15 cm depth from each replication of the experimental field before sowing of the crop. The processed samples were subjected to appropriate mechanical and chemical analysis. The results presented in (Table 3.2) depicted that the soil was silty clay loam in texture, with medium in available nitrogen, phosphorus and potassium and neutral pH.

Table 3.2: Initial physico-chemical parameters

Soil property (physical)	Value	Method
Fine sand (%)	19.3	
Clay (%)	30	
Silt (%)	51	
Texture	Silty Clay loam	International Pipette method (Piper, 1966)
Bulk density (g cm^3)	1.29	Pycnometer method (Prihar and Sandhu, 1968)
Chemical properties		
EC (ds^{-1} mol)	0.36	Solu-bridge conductivity meter (Jackson, 1973)
pH	6.77	Digital glass electrode pH meter (Jackson, 1973)
Organic carbon (%)	0.71	Walkley and Black's rapid titration method) (Black and Walkley, 1934)
Available N (kg ha^{-1})	350.67	Modified alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	17.5	Olsen's method $NaHCO_3$(Olsen' *et al.,* 1954)
Available K_2O (kg ha^{-1})	191.5	Ammonium acetate extraction method (Flame photometer), Jackson, 1973




Plate 1: Glimpses of some experimental activities

3.5 Experimental details

The experiment consists of one factor viz., nano urea spray laid out on the randomized block design with three replications.

T_1	:	Absolute Control.
T_2	:	Recommended dose of N @120 kg ha^{-1} (50% basal) as per package of practice
T_3	:	50% RDN +Spray of Nano urea @2ml L^{-1} at 20 and 40 DAS
T_4	:	50% RDN+Spray of Nano urea @4ml L^{-1} at 20 and 40 DAS
T_5	:	50% RDN+Spray of Nano urea @6ml L^{-1} at 20 and 40 DAS
T_6	:	50% RDN+Spray of Nano urea @4ml L^{-1} at 30 DAS
T_7	:	50% RDN+Spray of Nano urea @8ml L^{-1} at 30 DAS
T_8	:	50% RDN+Spray of Nano urea @12ml L^{-1} at 30 DAS

3.5.2 Other details of the experiment

Total no. of treatments	: 08
Replications	: 03
Total no. of plots	: 24
Crop	: Maize (*Zea mays* L.)
Season	: *Kharif*
Year	: 2022
Variety	: Karan-333
Spacing	: 30 cm x10 cm
Plot size	: 5 m x 3 m (15 m^2)
Design of Experiment	: Completely Randomised Block Design (RCBD)

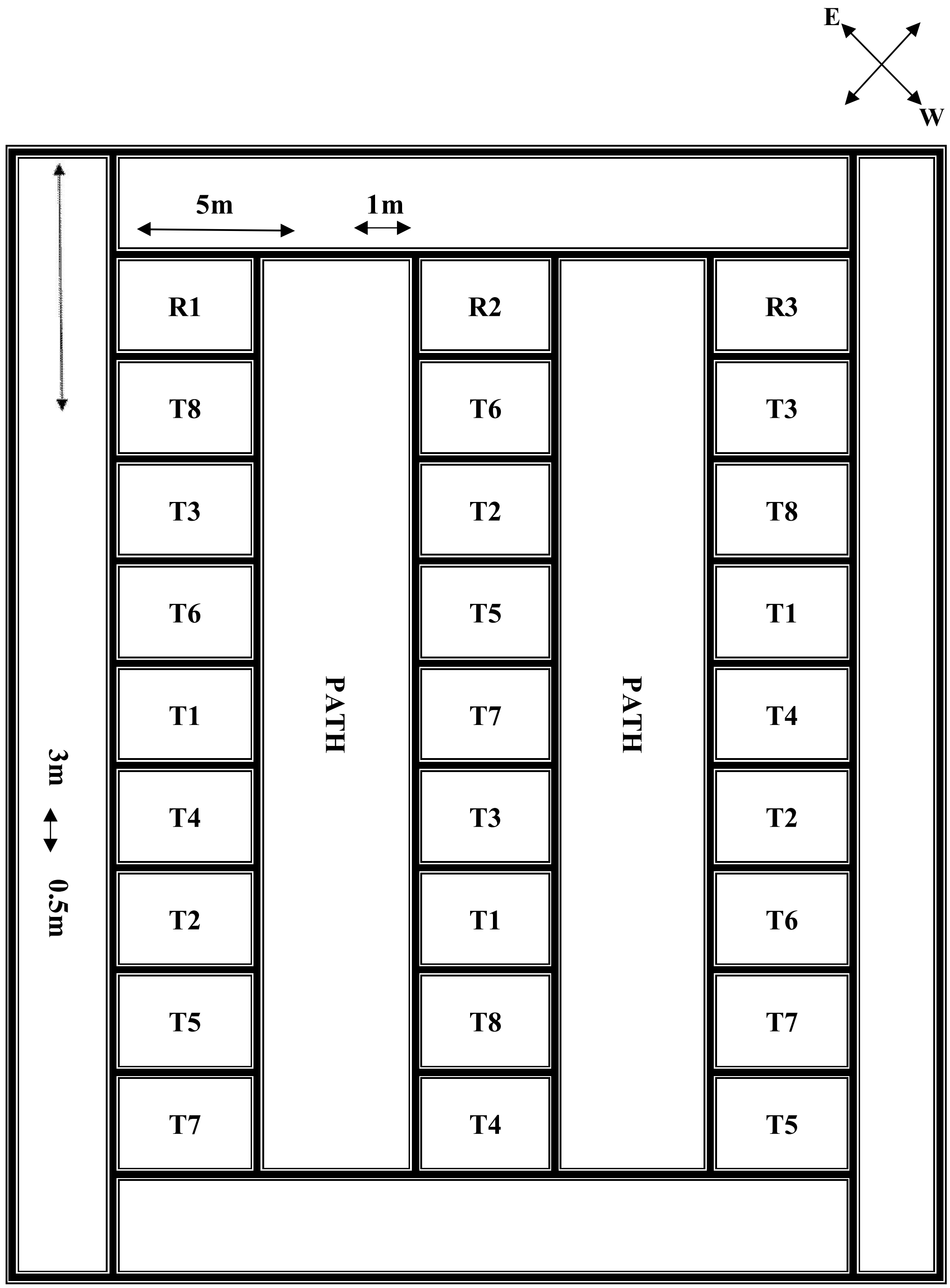

Fig 3.2: Layout plan of the experimental field

3.6 Details of field operations

The details of field operations and cultural practices performed during the experiment are given in Table 3.3.

Table 3.3: Details of field operations

Field Operations	Dates	Remarks
Ploughing with disc Harrow	12/07/2022	The field was harrowed with disc plough. Weeds and stubble whatsoever left were removed manually. Well decomposed FYM @ 10 t ha^{1} was evenly spread in the field
Ploughing with tiller	13/07/2022	The field was ploughed with tiller and FYM applied was well incorporated well in the soil.
Ploughing with rotavator	13/07/2022	The field was ploughed with rotavator to bring the soil to desired tilth
Layout	14/07/2022	Layout was done as per experimental details. Plot bunds, paths were made and the plots were well levelled
Application of basal dose of fertilizers	14/07/2022	Full P and K and half N were applied as basal dose to each plot except control plots where SSP was applied.
Sowing of seed	14/07/2022	Line sowing was done
Application of Atrazine as pre-emergence	15/07/2022	Pre-emergent spray of atrazine @ 1.5 kg *a.i* ha^{-1} was done
Earthing up	22/07/2022	Earthing up was performed at knee high stage and hand weeding was done for removal of weeds
Top dressing of N	22/07/2022	Nitrogen through urea was top dressed at knee high stage except control plots.
Harvesting	13/10/2022	Crop was harvested at 50% silking stage.

3.6.1 Land preparation

The experimental site was disc ploughed. Subsequently, three ploughings were given with a tractor to obtain desirable tilth. Plot bunds, replication borders etc. were made manually.

3.6.2 Fertilizer application

A uniform dose of phosphorous and potassium at the rate of 60 kg ha^{-1} and 30 kg^{-1} K_2O through Diammonium Phosphate (DAP) and Murate of Potash (MOP) respectively was applied as basal in all plots at the time of sowing by broadcasting methods .Nitrogen was applied with different doses as per treatments. The recommended dose of nitrogen (120 kg ha^{-1}) was applied as prilled urea at T_2 (as per farmer's practice), where half dose (60 kg ha^{-1}) was applied at the time of sowing and remaining half in two splits at knee high stage (30 kg ha^{-1}) and flag leaf emergence (30 kg ha $^{-1}$). The basal dose in all the plots was applied through prilled urea whereas the remaining doses were applied either through prilled urea (top dressing) or through IFFCO nano-urea (foliar spray) as per treatments. No nitrogen was applied in T_1 and left as control plot.

3.6.3 Sowing

Before the seed sowing operation, it was ensured that sufficient moisture for the germination of a seed is present in the soil. Immediately after sowing the lines were closed with soil and slightly pressed so as to have good seed-soil contact.

3.6.4 Irrigation

The crop was cultivated as rainfed crop so no irrigation was done in the crop.

3.6.5 Weed management

Atrazine @ 1.5 *a.i* kg ha^{-1} was applied as a pre-emergent herbicide. One-hand weeding along with inter-cultural operations were done in the experimental unit.

3.6.6 Plant protection measures

No plant protection measures were taken due to the non-observance of any diseases or insect-pest problems.

3.6.7 Harvesting

The crop was harvested at 50 % silking (leaving two crop rows from all sides of each plot). Then harvested crop was immediately weighed in kg $plot^{-1}$ separately from each net plot for fresh fodder yield and then converted into t ha^{-1}.

3.7 Details of observations recorded

For the purpose of recording data, five plants were randomly selected and tagged from every plot after excluding border and penultimate rows. The details of the observations recorded are given as follows.

3.7.1 Plant height (cm)

Plant height of five randomly selected plants was measured and tagged. Plant height was measured from the base of a plant to the apex of the flag leaf before tasselling and after tasselling upto the base of the tassel. Plant height was taken at 30 days intervals from sowing up to harvest in penultimate rows of each plot with the help of a meter scale and converted in cm.

3.7.2 Leaf area index

For estimation of leaf area index, five randomly plants were selected and measurements at 30, 60 DAS and at harvest was taken. Leaves of the plants which were taken for leaf stem ratio were separated and then leaf area was measured by leaf area meter. The leaf area index was computed by using the formula.

$$\text{LAI} = \frac{\textit{Total leaf Area } (cm^{-2})}{\textit{Ground Area } (cm^{-2})}$$

3.7.3 Leaf-stem ratio

For the leaf stem ratio, five plants from each plot were cut from the base of the plant and then leaves were separated from the stem of each plant. The leaves and stems from each plot were sun-dried and weighed separately. Then leaf stem ratio was determined as.

$$\text{Leaf stem ratio} = \frac{\textit{Dry weight of leaves}}{\textit{Dry weight of stem}}$$

3.7.4 Number of functional leaves plant^{-1}

Five randomly plants were selected for counting the number of leaves plant^{-1}. The number of green leaves considered as leaves plant^{-1} were taken at 30, 60 DAS and at harvest.

3.7.5 Dry matter accumulation (t ha^{-1})

Plant samples were taken from each plot from the penultimate rows at 30, 60 DAS and at harvest. After drying for 5-6 days, the samples were oven dried at 60-65 ^{0}C to a constant weight. The weight was recorded in grams and then converted in to t ha^{-1}.

3.7.6 Crop growth rate (g m^{-2} day^{-1})

Crop growth rate was measured by the increase in plant biomass and was computed by the formula given by Redford (1967). Crop growth rate was calculated from each plot at intervals between 0 -30 DAS, 30 - 60 DAS and 60-90 DAS and recorded in g day^{-1}.

$$\text{CGR (g day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 = Dry matter production per plant at time t_1 and t_2, respectively.

3.7.7 Relative growth rate (g g^{-1} day^{-1})

Relative growth rate was calculated by using the formula suggested by Blackman (1919). Relative growth rate was calculated from each plot at intervals between 0-30 DAS, 30 - 60 DAS and 60- 90 DAS and obtained in g g^{-1} day^{-1}.

$$RGR\ (g\ g^{-1}\ day^{-1}) = \frac{Log\ e\ W_2 - Log\ e\ W_1}{t_2 - t_1}$$

Where, W_1 = Dry weight of plant at time t_1, W_2 = Dry weight of plant at time t_2

3.7.8 Net assimilation rate (g m^2 day^1)

Net assimilation rate was calculated in intervals between 0-30 DAS, 30 - 60 DAS and 60- 90 DAS from each plot using the following formula. It was recorded in g m^2 day^{-1}.

$$\mathrm{NAR}\ (g\,m^{-2}\,day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log e\ L_2 - \log e\ L_1}{L_2 - L_1}$$

Where, L_2 and L_1 are the leaf area, W_2 and W_1 are dry weight at time t_2 and t_1 respectively. Leaf area was calculated by multiplying leaf area index with ground area.

3.8 Yield and yield attributes

3.8.1 Green fodder yield (t ha^{-1})

The fodder yield of each net plot (leaving border and penultimate rows) was harvested and weight from each plot was recorded separately as kg plot^{-1} and then converted into t ha^{-1}.

3.8.2 Dry fodder (t ha^{-1})

The fodder yield of each net plot (leaving border and penultimate rows) was harvested and dried for at least for 5 to 7 days then weight from each plot was recorded separately as kg plot^{-1} and then converted into t ha^{-1}.

3.9 Studies on plant nutrient content and uptake

Plant samples of fodder maize at harvest were oven dried at 60-65 ±5 ^{o}C to a constant weight. The samples were ground and subsequently used for chemical analysis.

3.9.1 Nitrogen content

Nitrogen content of the ground plant samples collected at harvest was estimated by digesting 0.5 g sample with 10 ml concentrated sulphuric acid and digestion mixture (K_2SO_4 + $FeSO_4$ + $CuSO_4$ in the ratio of 20 :2 :1). N uptake was calculated by multiplying dry matter production with corresponding nutrient content and was expressed as kg ha^{-1}.

3.10 Nutrient use efficiences

A. Agronomic efficiency (Kg yield increase kg^{-1} nutrient applied)

Agronomic efficiency of added nutrient *viz*., N following formulae (Cassman *et al*., 1998):

$$\text{AE (Kg yield increase kg}^{-1}\text{ nutrient applied)} = \frac{\text{(Fodder yield in fertilized plots)} - \text{(Fodder yield in control plot)}}{\text{Quantity of fertilizer applied in fertilized plot}}$$

B. Apparent nutrient recovery (%)

Recovery efficiency of added nutrients N was calculated by the following formulae (Cassman *et al*., 1998):

$$\text{RE} = \frac{\text{(Total uptake in fertilized plots) - (Total uptake in control plot)}}{\text{Quantity of fertilizer applied in fertilized plot}}$$

C. Physiological efficiency (kg fodder kg^{-1} nutrient uptake)

Physiological efficiencies of nutrient N were computed by the following formulae (Baligar *et al*., 2001).

$$\text{PE} = \frac{\text{Fodder yield in fertilized plot - Fodder yield in control plot}}{\text{(Total uptake in fertilized plots) - (Total uptake in control plot)}}$$

D. Partial factor productivity (kg fodder kg^{-1} nutrient)

Partial factor productivity was computed by the formula given by Cassman *et al*. (1998).

$$PFP = \frac{\text{Fodder yield in fertilized plot}}{\text{Quantity of fertilizer applied}} \times 100$$

3.11 Fodder quality analysis

3.11.1 Crude protein content (%)

The nitrogen (N) content was estimated by the modified micro Kjeldahl procedure and expressed in percentage. Protein content was calculated from the N content by multiplying with a factor 6.25.

3.11.2 Neutral detergent fibre (NDF %) and acid detergent fibre (ADF %)

The concentrations of neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using proximate analysis (Van Soest fibre analysis, Goering and Van, 1970). When sample is boiled (refluxed) in neutral detergent solution for one hour, all the cell contents will dissolve in neutral detergent solution. The residue left after boiling is known as cell wall content. The cell wall content is dried at 100-105 ^{0}C for overnight and weighed to determine % cell wall content present in sample. Cell content is determined by difference *i.e.,* % cell content = 100 - % cell wall content.

Calculation:

Weight of sample = W_1 (g)

Weight of empty crucible = W_2 (g)

Weight of crucible + NDF = W_3 (g)

Weight of NDF = (W_3- W_2) (g)

$$\% \text{ of NDF} = \frac{W_3 - W_2 \times 100}{W1}$$

When sample is boiled in acid detergent solution for an hour all the cell content and hemicellulose will dissolve in acid detergent solution. The residue left after boiling is known as acid detergent fibre. Acid detergent fibre (ADF) is then dried and washed to determine % ADF present in the sample.

Calculation:

$$\text{Weight of sample} = W_1 \text{ (g)}$$

$$\text{Weight of empty crucible} = W_2 \text{ (g)}$$

$$\text{Weight of crucible + ADF} = W_3 \text{ (g)}$$

$$\text{Weight of ADF} = (W_3 - W_2) \text{ (g)}$$

$$\% \text{ of ADF} = \frac{W_3 - W_2 \times 100}{W1}$$

Total ash content (%)

The Ash content of ground samples was determined by the method described by (AOAC (1995)). The total ash was calculated by the following formula and expressed in percentage.

$$\text{Total ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

4.12 Relative Economics

The relative economic was worked out in terms of cost of cultivation, gross returns, net returns and benefit: cost ratio. The cost of cultivation was worked out for each treatment based on price of inputs. Gross returns was computed based on existing price of output (green fodder).

Net returns = Gross returns – Total cost of cultivation

Benefit: cost ratio = Net returns ÷ Total cost of cultivation

4.13 Statistical Analysis

The Software package used for analysis of data was “OP-stat,” wherever the ‘F-test’ was found significant at 5 per cent probability; critical difference values were used to compare the treatment means.

Plate 2: Field visit by inspection team

Plate 3: Spraying of nano-urea

Chapter – 4

EXPERIMENTAL FINDINGS

The interpretation of the data collected throughout the experiment is included in this chapter. The experimental findings have been analysed, summarised in various tables, and illustrated in figures wherever it is required. In this chapter, the results of the treatments are discussed from the perspective of statistical analysis.

4.1 Growth parameters

4.1.1 Plant height (cm)

Data presented in Table 4.1 and illustrated in Fig. 4.1 indicated that plant height of maize was markedly influenced by spray of nano-urea. There was a consistent increase in plant height upto 60 DAS, thereafter, the increase was marginal. Among different dosage of nano-urea sprayed maximum plant height (220.07cm) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1}(30 DAS). Lowest plant height (169.33) was recorded in control (T_1).

4.1.2 Leaf area index

The results on leaf area index (LAI) at different growth stages as affected by different treatments at 30 days interval upto harvest are presented in Table 4.2 and illustrated in Fig 4.2. The data revealed that the significant difference was observed with different dosage of nano urea sprays, with increase in dosage of nano-urea leaf area index increased. Numerically highest LAI (6.18) was observed in treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1}(30 DAS). However, the lowest

LAI (4.25) was recorded in control.

4.1.3 Leaf stem ratio

The data on leaf stem ratio was recorded at 30 days interval is presented in Table 4.3 and illustrated in Fig. 4.3. The results indicated that the leaf stem ratio consistently decreased as the crop age advanced. However, treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) recorded higher leaf stem ratio (0.29) as compared to other treatments at harvesting.

4.1.4 Number of functional leaves plant^{-1}

Data presented in Table 4.4 and illustrated graphically in Fig. 4.4 revealed that at different intervals the number of leaves increased up to harvest. Number of leaves increased with increasing dosage of nano-urea, numerically maximum number of leaves (12.57) were observed in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4ml L^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN) @ 120 kg ha^{-1} (50% basal) and T_8 (50%RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS). However, the lowest number of leaves (7.90) were recorded in control.

Table 4.1: Effect of different treatments of nano-urea on plant height at different growth stages of fodder maize

Treatments	Plant height (cm)		
	30 DAS	60 DAS	Harvest
T_1 Absolute Control	33.77	133.53	169.33
T_2 Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	40.35	165.13	208.47
T_3 50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	37.87	147.07	182.53
T_4 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	41.50	168.20	215.00
T_5 50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	42.86	169.77	220.07
T_6 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	36.40	143.47	180.40
T_7 50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	38.93	155.60	191.87
T_8 50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	39.60	163.80	201.67
SEm ±	1.36	2.35	2.91
CD (p≤0.05)	**4.13**	**7.12**	**8.82**

Table 4.2: Effect of different treatments of nano-urea on leaf area index at different growth stages of fodder maize

Treatments		Leaf Area Index		
		30 DAS	60 DAS	Harvest
T_1	Absolute Control	1.73	3.35	4.25
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	2.07	5.04	6.11
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	1.98	4.19	5.09
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	2.13	5.67	6.16
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	2.34	5.73	6.18
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	1.96	4.43	4.90
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	1.99	4.73	5.45
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	2.02	5.26	6.09
SEm ±		0.14	0.12	0.20
CD ($p \leq 0.05$)		**NS**	**0.36**	**0.66**

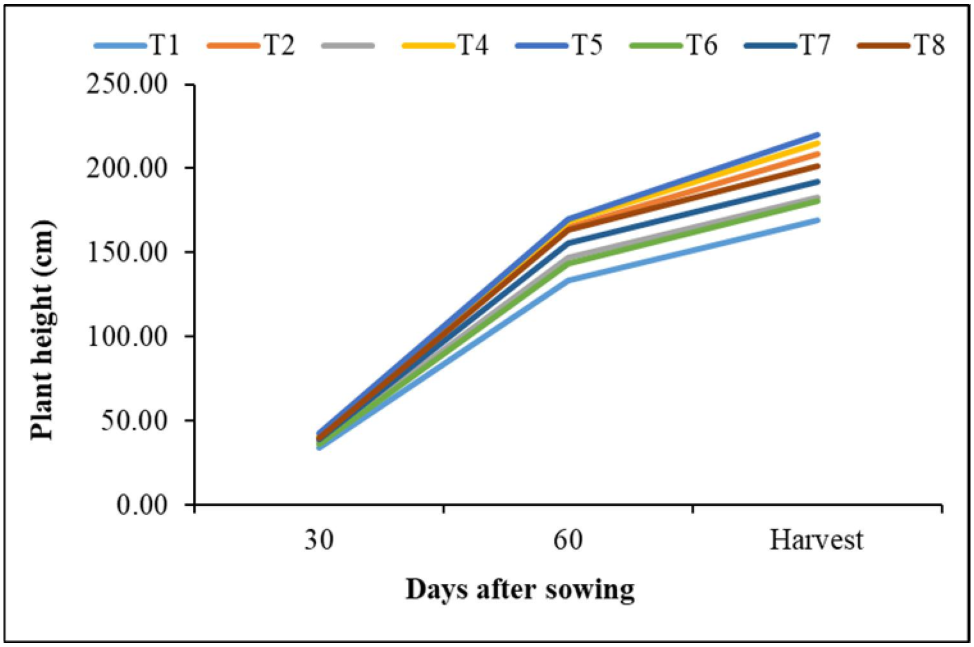

Fig 4.1: Effect of different treatments of nano-urea on plant height at different growth stages of fodder maize

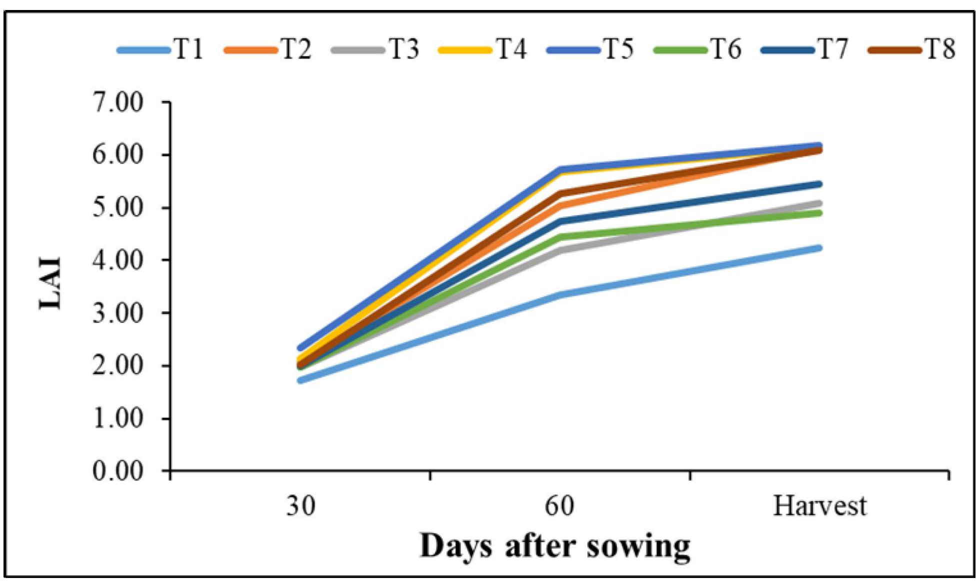

Fig 4.2: Effect of different treatments of nano-urea on leaf area index at different growth stages of fodder maize

Table 4.3: Effect of different treatments of nano-urea on leaf stem ratio at different growth stages of fodder maize

Treatments	Leaf Stem Ratio		
	30 DAS	**60 DAS**	**Harvest**
T_1 Absolute Control	1.21	0.43	0.22
T_2 Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	1.44	0.57	0.27
T_3 50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	1.36	0.47	0.25
T_4 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	1.47	0.58	0.28
T_5 50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	1.58	0.58	0.29
T_6 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	1.36	0.46	0.25
T_7 50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	1.39	0.51	0.26
T_8 50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	1.42	0.53	0.26
SEm ±	0.09	0.02	0.02
CD ($p \leq 0.05$)	**0.27**	**0.07**	**0.06**

Table 4.4: Effect of different treatments of nano-urea on number of functional leaves at different growth stages of fodder maize

Treatments	No. of functional leaves		
	30 DAS	**60 DAS**	**Harvest**
T_1 Absolute Control	4.80	5.93	7.90
T_2 Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	5.22	9.53	11.80
T_3 50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	5.02	8.90	9.53
T_4 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	5.29	9.80	12.17
T_5 50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	5.30	10.70	12.57
T_6 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	4.81	7.83	9.14
T_7 50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	5.14	9.13	10.47
T_8 50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	5.15	9.27	11.43
SEm ±	0.15	0.33	0.23
CD ($p \leq 0.05$)	**NS**	**0.99**	**0.70**

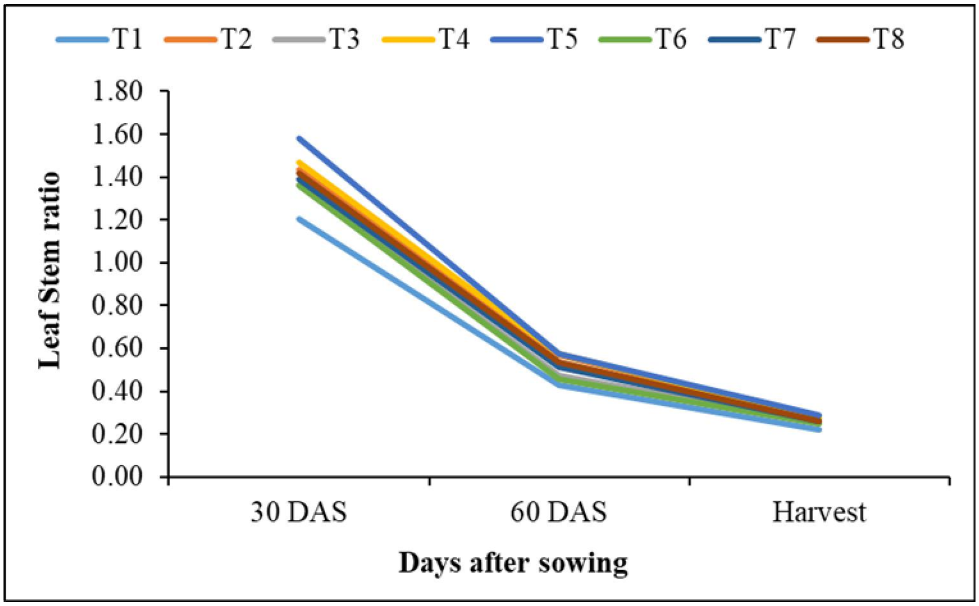

Fig 4.3: Effect of different treatments of nano-urea on leaf stem ratio at different growth stages of fodder maize

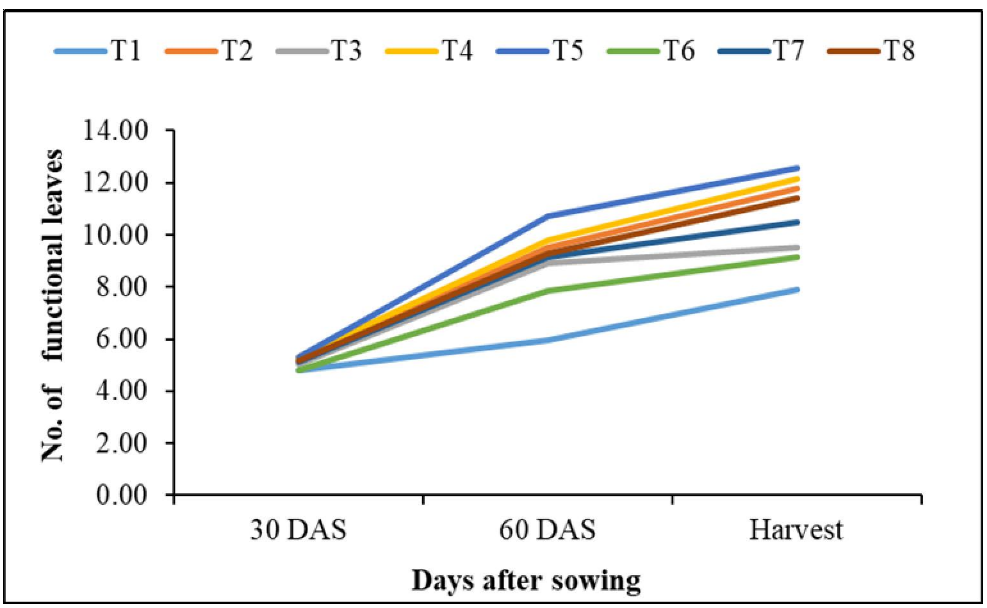

Fig 4.4: Effect of different treatments of nano-urea on no. of functional leaves at different growth stages of fodder maize

4.1.5 Dry matter accumulation

The perusal data in Table 4.5 and illustrated in Fig. 4.5 reported that dry matter accumulation at 30 days interval differed markedly with respect to different dosage of nano-urea. Highest dry matter accumulation (17.52 t ha^{-1}) was obtained in treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS). The lowest dry matter accumulation (9.04 t ha^{-1}) was recorded in control.

4.1.6 Crop growth rate

Data presented in Table 4.6 and illustrated in Fig 4.6 indicated that different dosage of nano-urea spray had statistically significantly affected crop growth at 0-30 DAS, 30-60 DAS and 60-90 DAS respectively. Treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)) recorded highest CGR (22.30 gm^{-2} day^{-1}) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1}(30 DAS). However, lowest CGR (13.40) was recorded in control.

4.1.7 Relative growth rate

Data represented in (Table 4.7) and illustrated in Fig 4.7 determined that different dosage of nano-urea spray had statistically significantly affected crop growth at relative growth rate at 0-30, 30-60 DAS and 60-90 DAS respectively. Highest RGR (0.0151 g $g^{-1}day^{-1}$) was recorded in Treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1}(30 DAS). However, control recorded lowest relative growth rate.

Table 4.5: Effect of different treatments of nano-urea on dry matter accumulation at different growth stages of fodder maize

Treatments		Dry matter accumulation (t ha^{-1})		
		30 DAS	60 DAS	Harvest
T_1	Absolute Control	2.18	5.37	9.04
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	3.40	9.24	15.04
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	2.71	6.89	11.29
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	3.51	9.55	15.52
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	3.58	9.75	16.21
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	2.59	6.39	10.90
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	3.08	7.85	13.02
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	3.35	8.79	14.66
SEm ±		0.08	0.27	0.37
CD ($p \leq 0.05$)		**0.24**	**0.81**	**1.11**

Table 4.6: Effect of different treatments of nano-urea on crop growth rate at different growth stages of fodder maize

Treatments		Crop Growth Rate (g m $^{-2}$ day $^{-1}$)		
		0-30 DAS	**30-60 DAS**	**60-Harvest**
T_1	Absolute Control	7.27	16.13	13.40
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	11.33	24.79	20.69
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	9.04	19.47	18.02
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	11.70	26.04	20.65
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	11.92	26.48	22.30
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	8.63	17.24	17.13
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	10.27	20.45	19.33
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	11.18	23.55	20.80
SEm ±		0.26	0.99	1.33
CD (p≤0.05)		**0.79**	**3.00**	**4.03**

Table 4.7: Effect of different treatments of nano-urea on relative growth rate at different growth stages of fodder maize

Treatments		Relative Growth Rate (g g $^{-1}$ day $^{-1}$)		
		0-30 DAS	30-60 DAS	60-Harvest
T_1	Absolute Control	0.178	0.0398	0.0154
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	0.194	0.0385	0.0153
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	0.186	0.0381	0.0169
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	0.195	0.0380	0.0152
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	0.196	0.0392	0.0151
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	0.185	0.0359	0.0181
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	0.191	0.0352	0.0179
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	0.194	0.0368	0.0168
SEm ±		0.001	NS	NS
CD (p≤0.05)		**0.004**	**NS**	**NS**

Table 4.8: Effect of different treatments of nano-urea on net assimilation rate at different growth stages of fodder maize

Treatments		Net assimilation Rate (g m^{-2} day^{-1})		
		0-30 DAS	**30-60 DAS**	**60-Harvest**
T_1	Absolute Control	28.35	6.19	3.37
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	36.65	7.14	3.67
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	30.55	6.66	3.89
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	36.97	7.18	3.49
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	35.84	7.11	3.77
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	29.33	5.96	3.76
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	34.73	6.40	3.73
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	36.98	7.38	3.63
SEm ±		2.60	1.30	0.77
CD (p≤0.05)		**NS**	**NS**	**NS**

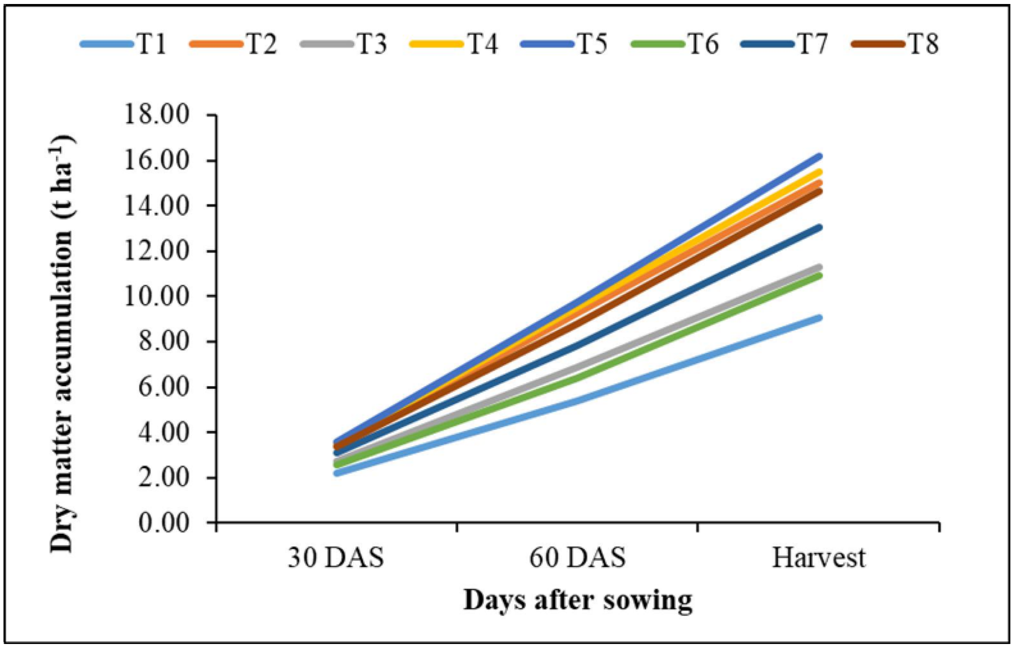

Fig 4.5: Effect of different treatments of nano-urea on dry matter accumulation at different growth stages of fodder maize

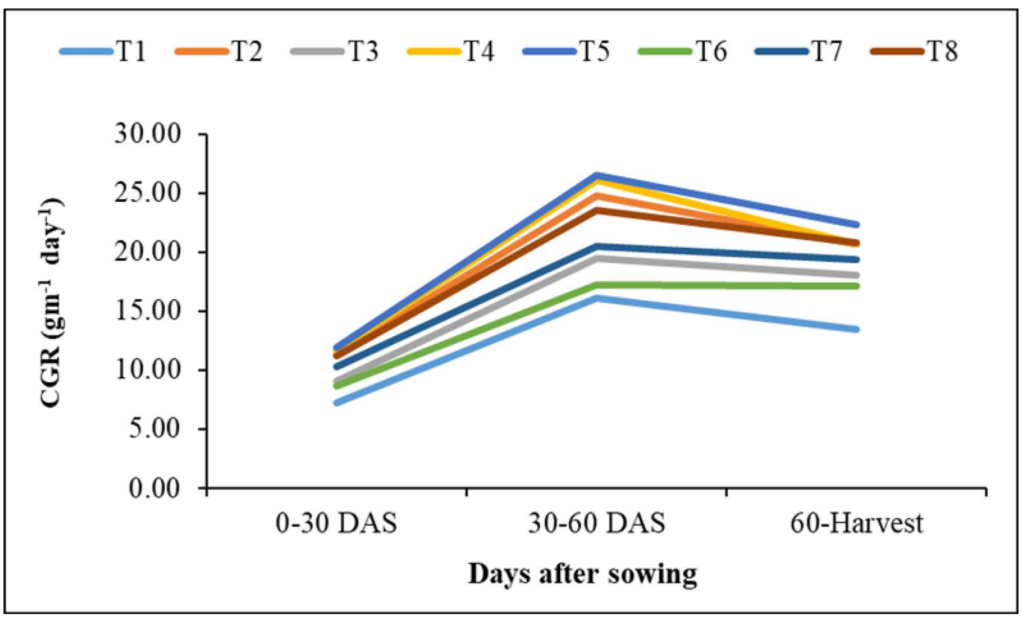

Fig 4.6: Effect of different treatments of nano-urea on crop growth rate at different growth stages of fodder maize

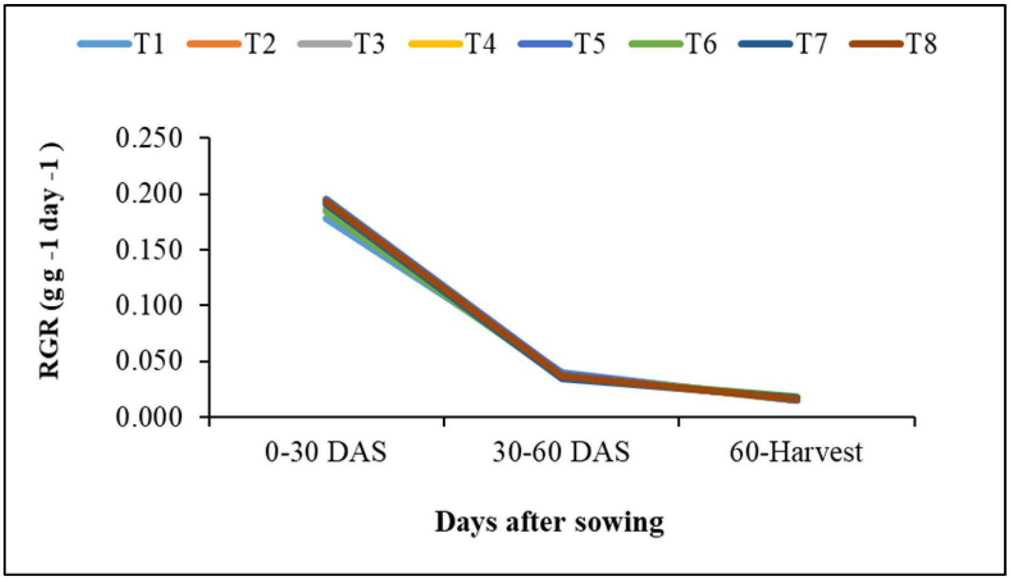

Fig 4.7: Effect of different treatments of nano-urea on relative growth rate at different growth stages of fodder maize

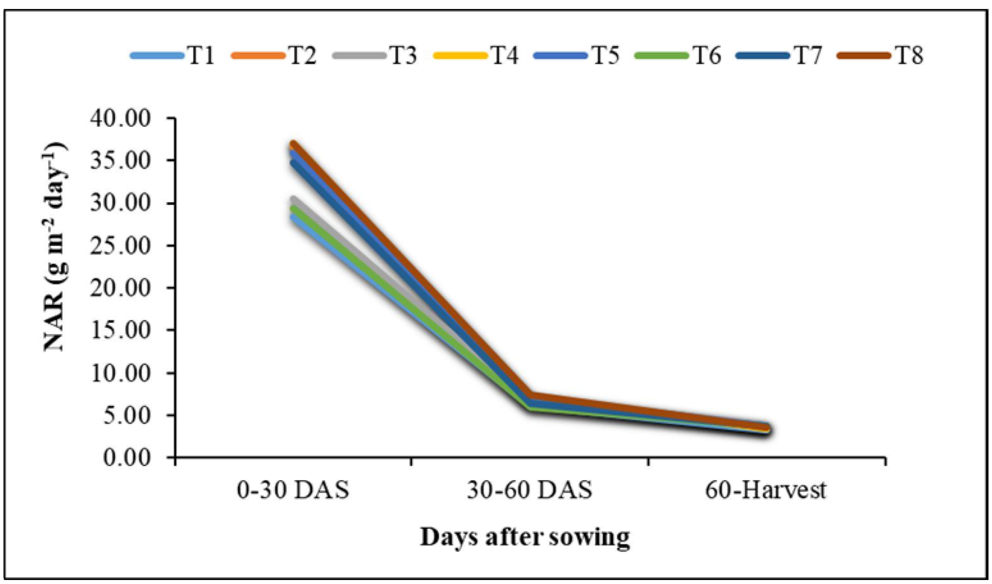

Fig 4.8: Effect of different treatments of nano-urea on net assimilation rate at different growth stages of fodder maize

4.1.8 Net assimilation rate

Data presented in (Table 4.8) and represented in Fig 4.8 indicated that net assimilation rate at 0-30, 30-60 DAS and 60-90 DAS due to different dosage of nano-urea spray is statistically non-significant at 0-30, 30-60 DAS and 60-90 DAS respectively. However highest NAR (3.77 g $m^{-2}day^{-1}$) was recorded in treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1}(30 DAS). However, control recorded lowest net assimilation rate.

4.2 Yield studies

4.2.1 Green fodder yield (t ha^{-1})

Data on green fodder yield as affected by different treatments is presented in Table 4.9, Fig 4.9. The data revealed that green fodder yield was statistically significantly influenced by different dosage of nano-urea spray. Among different treatments maximum green fodder yield (50.82 t ha^{-1}) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1}(30 DAS). Lowest green fodder yield (37.83t ha^{-1}) was recorded in control (T_1).

4.2.2 Dry fodder yield (t ha^{-1})

Data on green fodder yield as affected by different treatments is presented in Table 4.9 and represented in Fig 4.9. The data revealed that dry fodder yield was also significantly influenced by different dosage of nano-urea spray. Among different treatments maximum dry fodder yield (22.76 t ha^{-1}) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by

T_2 (Recommended dose (RDN) @ 120 kg ha^{-1} (50% basal) and T_8 (50%RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS). However, lowest dry fodder yield (15.21t ha^{-1}) was recorded control recorded lowest.

4.3 Studies on plant nutrient content and uptake

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

The data on nitrogen content and uptake in dried fodder as affected by different treatments is presented in Table 4.10.The analysed data revealed that among different dosage of nano- urea sprayed the maximum nutrient content and uptake (1.41% and 319.89 kg ha^{-1}) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) ,T_2 (Recommended dose (RDN)@ 120 kg ha^{-1} (50% basal) and T_8(50%RDN + spray of nano-urea @ 12ml L^{-1}(30 DAS). However, control recorded lowest n

4.4 Nutrient use efficiencies

4.4.1 Agronomic efficiency (kg yield /kg Nutrient applied)

The data presented in Table 4.11 represents data of agronomic efficieny. The analysed data revealed that among different dosage of nano- urea sprayed the maximum agronomic efficiency(125.64 kg/kg) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) , However, lowest agronomic efficiency (19.75 kg/kg) was recorded in treatment T_6 (50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS).

4.4.2 Apparent nutrient recovery (%)

The data on apparent nutrient recovery as affected by different treatments is presented in Table 4.11. The analysed data revealed that among different dosage of nano- urea sprayed the maximum apparent nutrient recovery (227.06 %) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS), However, lowest apparent nutrient recovery (31.04%) was recorded in treatment T_6 (50 % RDN + spray of nano-urea @ 4 ml L-1 (30 DAS).

4.4.3 Physiological efficiency (kg /kg Nutrient uptake)

The data on physiological efficiency as affected by different treatments is presented in Table 4.11. The analysed data revealed that among different dosage of nano- urea sprayed the maximum physiological efficiency was (72 kg/kg) recorded in T_8 (50% RDN + spray of nano- urea @ 12ml L^{-1} (30 DAS). However, lowest physiological efficiency (12.99kg/kg) was recorded treatment T_6 (50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS).

4.4.4 Partial factor productivity (kg yield kg^{-1} Nutrient applied)

The data on partial factor productivity as affected by different treatments is presented in Table 4.11. The analysed data revealed that among different dosage of nano- urea sprayed the maximum partial factor productivity (376.74 kg/kg) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) followed by T_8 (50% RDN + spray of nano- urea @ 12ml L^{-1} (30 DAS) However, lowest partial factor productivity was recorded in control.

4.5 Fodder quality analysis

4.5.1 Crude protein content

The data presented in Table 4.12 represents data of crude protein content. The analysed data revealed that among different dosage of nano- urea sprayed. the maximum crude protein content (8.60 %) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) which was at par with T_4 (50% RDN + spray of nano-urea @ 4mlL^{-1} (20 and 40 DAS) , However, lowest protein (7.9%) was recorded in control.

Table 4.9: Effect of different treatments of nano-urea on yield

Treatments	Yield (t/ha)	
	Green fodder	**Dry fodder**
T_1 Absolute Control	37.83	15.21
T_2 Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	49.32	22.58
T_3 50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	42.05	17.14
T_4 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	50.12	22.68
T_5 50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	50.82	22.76
T_6 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	40.93	16.39
T_7 50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	45.24	17.91
T_8 50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	48.26	22.15
SEm ±	0.90	0.75
CD ($p \leq 0.05$)	**2.74**	**2.28**

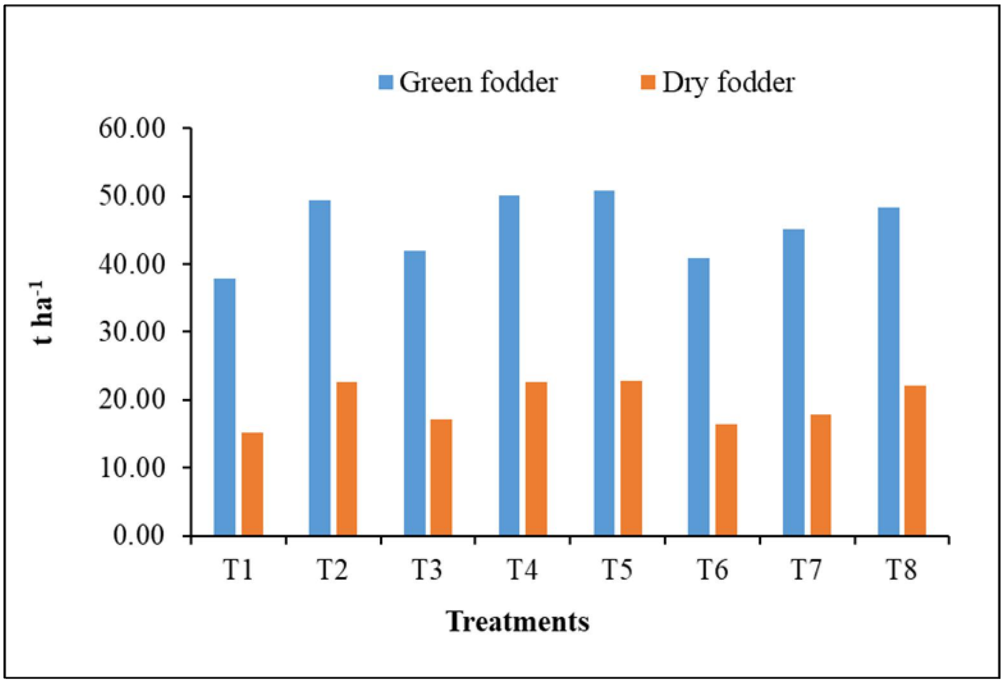

Fig 4.9: Effect of different treatments of nano-urea on yield at different growth stages of fodder maize

Table 4.10: Effect of different treatments of nano-urea on N content and uptake

Treatments		N content	N uptake (kg ha^{-1})
T_1	Absolute Control	1.22	183.33
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	1.28	287.53
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	1.23	211.04
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	1.31	296.40
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	1.41	319.89
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	1.24	201.98
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	1.24	222.21
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	1.26	279.08
	SEm ±	0.05	8.09
	CD ($p \leq 0.05$)	**NS**	**24.06**

Table 4.11: Effect of different treatments of nano-urea on nutrient use efficiencies

Treatments	Nutrient use Efficiency (NUE)			
	AE	PFP	ANR	PE
T_1 Absolute Control	–	–	–	–
T_2 Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	61.44	188.19	86.84	71.52
T_3 50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	32.12	285.21	46.12	62.90
T_4 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	124.05	376.74	187.85	67.72
T_5 50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	125.64	378.54	227.06	55.95
T_6 50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	19.75	272.84	31.04	12.99
T_7 50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	44.97	297.66	64.61	70.48
T_8 50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	115.00	367.29	158.83	72.63
SEm ±	6.27	4.21	8.14	4.02
CD ($p \leq 0.05$)	**18.81**	**13.12**	**19.14**	**12.06**

4.5.2 Neutral detergent fibre (NDF %) and acid detergent fibre (ADF %)

The data marked in Table 4.12 indicated that neutral detergent fibre and acid detergent fibre differed significantly with respect to different dosage of nano-urea. Among different dosage of nano-urea sprayed, both neutral detergent fibre and acid detergent fibre were seen to be decreasing with an increase in nano-urea dosage where control (N_1) reported the highest neutral detergent fibre (68.75%) and acid detergent fibre (45.35%) respectively than other treatments. Lowest neutral detergent fibre (67.87%) and acid detergent fibre (44.57 %) were recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS).

4.5.3 Ash content (%)

Data marked in (Table 4.12) reported that ash content was non significantly influenced by different dosage of nano-urea. Treatment (T_5) (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) recorded the highest ash content (8.67%). However lowest ash content (8.14%)was recorded in control.

4.6 Soil physico-chemical properties after harvest

Data attributing to soil physico-chemical properties after harvest *viz.*, pH, EC, Organic carbon is indicated in Table 4.13. The data analysis showed that different dosage of nano-urea sprayed showed no significant impact on pH, EC, K and OC of soil. However, it was inferred that the various dosage of nano-urea sprayed influenced the availability of nutrients N in the soil after the harvest of crop.

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

The data presented in Table 4.13 indicated that treatment T_2 (RDN) had the highest available nitrogen (307.09 kg ha^{-1}) in soil which was followed by treatment T_6 (50 % RDN + spray of nano-urea @ 4 ml L^{-1} at 30 DAS) and T_7 (50 % RDN + spray of nano-urea @ 8ml L^{-1} at 30 DAS).The lowest available nitrogen in soil (265.09 kg ha^{-1}) was observed in control treatment (T_1).

Table 4.12: Effect of different treatments of nano-urea on quality parameters

Treatments		Quality Parameters			
		Crude protein (%)	Ash Content (%)	NDF (%)	ADF (%)
T_1	Absolute Control	7.94	8.14	68.75	45.35
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	8.52	8.59	65.64	41.60
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	8.34	8.44	67.88	45.11
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	8.56	8.63	67.34	43.71
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	8.60	8.67	67.87	44.57
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	8.21	8.47	68.31	44.88
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	8.35	8.52	66.77	42.84
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	8.47	8.57	66.47	42.51
SEm ±		0.16	0.11	0.16	0.26
CD ($p \leq 0.05$)		**0.49**	**NS**	**0.47**	**0.79**

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

The different dosage of nano-urea sprayed had a significant impact on the availability of phosphorous in soil after the crop harvest as shown in Table 4.13. The available phosphorous was found in higher amount in control (19.25 kg ha^{-1}). However, T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) recorded lowest amount of available phosphorous (17.67 kg ha^{-1}).

4.7 Relative economics

Relative economics in terms of gross profit, net profit and benefit-cost ratio with respect to green fodder yield and dry fodder yield was worked out for various treatments (Table 4.14). It was evident that the highest gross profit (₹ 184656.8), net profit (₹ 121174.8) and benefit-cost ratio of (1.91) was recorded in T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) (8.60 %) which was at par with T_4 (50% RDN + spray of nano-urea @ 4ml L^{-1} (20 and 40 DAS) , The lowest gross profit (₹ 137425.1), net profit (₹ 77045.13) and benefit-cost ratio of (1.28) was recorded in control (T_1).

Table 4.13: Effect of different treatments of nano-urea on soil pysio-chemical properties

	Treatments	pH	OC (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
T_1	Absolute Control	6.79	0.68	265.09	19.25	172.34
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	6.68	0.70	307.09	18.20	168.70
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	6.75	0.70	276.95	18.59	169.78
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	6.76	0.68	270.22	17.90	168.30
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	6.74	0.67	269.08	17.67	167.50
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	6.73	0.68	305.97	18.49	171.66
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	6.67	0.70	291.41	18.67	169.67
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	6.71	0.69	289.50	17.83	166.32
	SEm ±	**0.05**	**0.01**	**4.24**	**0.44**	**4.85**
	CD (p≤0.05)	**NS**	**NS**	**12.86**	**1.32**	**NS**

Table 4.14: Effect of different treatments of nano-urea on relative economics

	Treatments	Cost of cultivation (₹)	Gross returns (₹)	Net returns (₹)	B:C ratio
T_1	Absolute Control	60380	137425.1	77045.13	1.28
T_2	Recommended dose (RDN) @ 120 kg ha^{-1} (50%basal as per package of practice)	61784	179014.5	117230.5	1.90
T_3	50% RDN + spray of nano-urea @ 2 ml L^{-1} at (20 and 40 DAS)	61882	152667.5	90785.5	1.47
T_4	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (20 and 40 DAS)	62682	182012.2	119330.2	1.90
T_5	50 % RDN + spray of nano-urea @ 6 ml L^{-1} (20 and 40 DAS)	63482	184656.8	121174.8	1.91
T_6	50 % RDN + spray of nano-urea @ 4 ml L^{-1} (30 DAS)	61882	148750.3	86868.31	1.40
T_7	50 % RDN + spray of nano-urea @ 8ml L^{-1} (30 DAS)	62682	164265.3	101583.3	1.62
T_8	50% RDN + spray of nano-urea @ 12ml L^{-1} (30 DAS)	63482	175283.1	111801.1	1.76
	SEm ±	60380	137425.1	77045.13	1.28
	CD ($p \leq 0.05$)	**61784**	**179014.5**	**117230.5**	**1.90**

Chapter -5

DISCUSSION

The field experiment entitled **"Effect of Nano-Urea on Growth, Yield and Quality of Fodder Maize (*Zea mays* .L)"** was conducted at Research Farm of Agronomy at Faculty of Agriculture (FOA) Wadura, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *Kharif*, 2022. The detailed description of treatment effects on various characters studied has been presented in preceding chapter. This chapter will provide an insight about the reasons behind the results obtained. The present study has been backed and supported by the research findings of the earlier workers

5.1 Influence of different dosage of nano – urea spray on growth parameters

5.1.1 Plant height

The maximal plant height was obtained under the application of treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS). This performance can be explained by the fact that impact of nano urea on fodder maize growth and development was clear, as shown by significance of nitrogen in plants as a primary component of proteins, amino acids, vitamins, hormones and enzymes all of which show an immediate effect in promoting cell division and enlargement both transversely and longitudinally and increased meristematic activities resulting in an increased plant height. These results corroborate with the findings Burhan and AL-Hassan (2019), Abd El-Aal and Rania (2018), Mahil and Kumar (2019) and Kumar *et al*. (2020).

5.1.2 Leaf Area Index and Number of Functional Leaves

The maximum leaf area index and number of functional leaves were obtained under the application of treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS). This can be due to adequate supplement of nitrogen through application of nano-fertilizers. The primary function of nitrogen is multiplication, cell elongation and tissue differentiation that ultimately enhanced vegetative growth through parameters like larger leaf area and more number of leaves (Samui *et al*., 2022). These results are in accordance with the findings of Singh *et al*. (2023).

5.1.3 Dry Matter Accumulation

Treatment with 50 % RDN + spray of nano-urea @6ml L^{-1} (20 and 40 DAS) (T_5) produced significantly higher dry matter as compared to other treatments and absolute control. Dry matter production is dependent upon the plant's metabolic activities and its corresponding growth. Foliar application of nano-urea increased metabolic activities due to enhanced availability of nitrogen through easy penetration of nano-urea through stomata of leaves (Rajasekar *et al*., 2017). Nitrogen not only participates in structure of purines, pyrimidines and enzymes but also participates in chlorophyll and cytochrome structure (Gendy *et a*l., 2013), which are essential for the process of photosynthesis. With higher chlorophyll content, the plant exhibited higher photosynthetic activities (Peng *et al*., 1995) which ultimately led to greater dry matter production. As a result of the unique properties like small size and increased effective surface area, nanoparticles also have the potential to mobilize native nutrients, such as phosphorus. (Saharan *et al*., 2016; Zahra *et al*., 2015). As phosphorus is involved in root growth, it helps in development of a vibrant root system, which in turn increases absorption of other micro-nutrients from soil as well. Moreover, this increase could also be attributable to the ability of nano-fertilizers to release nutrients for a longer period of time which helps in sustaining the nutrient supply of the plant, which has a positive effect on increasing the production of dry matter till harvest.These results are in line with the findings of Sharma *et al*. (2022).

5.1.4 Crop growth rate and relative growth rate

The growth of a plant changes in response to increase in the amount of a nutrient. Growth is the irreversible increase in size or dry weight. The data presented in Table 4.6 showed that treatment with (50% RDN + spray of nano-urea @ 6ml L^{-1} (20 and 40 DAS) (T5) recorded the highest crop growth rate and relative growth rate for 30 -60 and 60 -90 DAS period, which was at par with 50 % RDN + sprays of nano-urea @ 4 ml L-1(20 and 40 DAS) (T4). This might be due to better availability of nutrients and higher dry matter accumulation. The results are in line with the findings of Singh *et al*. (2023).

5.2 Yield attributes and yield

Data obtainable in Table 4.11 revealed that application of various sprays of nano-urea had significant effect on green fodder yield and dry fodder yield of maize crop. Among the different treatment of nitrogen sources that the determined highest green fodder yield as well as dry fodder was recorded treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) it may be due that the use of conventional fertilizer in conjunction with nano fertilizer had a substantial impact on the green fodder yield as well as dry fodder. Green fodder yield is the metric used to judge the potential of any experiment with fodder crops .The reason behind that nano fertilizer has a harmonious effect on the practicality of conventional fertilizer for enhanced nutrient fascination by plant cells resultant in optimal growth of plant parts and metabolic processes such as photosynthesis which translates to higher photosynthates accumulation and translocation to the economically important plant parts resulting in maximum fodder yield. These findings were similar with results of Benzon *et al*. (2015).

5.3 Plant nutrient content and uptake

The chemical analysis of plant samples showed that different treatments of nano-urea didn't have significant effect on N content on fodder yield of maize crop. However, higher values of N content in maize was observed in (50% RDN +

spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) as compared to other treatments. On the other hand, significant influence was observed on nutrient uptake in treatments with (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) (T5) recorded significantly higher N uptake in dry fodder. The positive influence of nitrogen application on nutrient uptake appears to be due to increased availability of nitrogen in root zone coupled with increased metabolic activity at cellular level. Moreover, application of nano-urea through foliar spray reduced losses through denitrification and volatilization. The increased nutrient uptake also leads to more accumulation in vegetative plant parts along with better translocation. These results are in close conformity with Mandeewal *et al.* (2020) and Sharma *et al*. (2022).

5.4 Fodder quality parameters

5.4.1 Crude protein content

Due to its critical significance in the development and productivity of animals, crude protein is the most crucial of all quality indicators. Ruminants are able to utilise both real protein and non-protein nitrogen, and it contains both. Furthermore, forages with higher protein content have proportionately lower crude fibre levels, indicating a larger total amount of digestible nutrients. Among different treatments (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) (T_5) being superior among nano –urea levels obtained the highest crude protein content. Significantly higher value of crude protein through nano-urea could be due to sufficient supply of N. Aside from essential nutrient, N is an indispensable content of amino acids which is the basic unit of proteins. sufficient N supply through urea and foliar spray through nano-N would have kept maize free from Nitrogen stress and also sufficient Nitrogen supply accelerated the protein synthesis from carbohydrates and reduced the rate of lignifications, thereby maintaining fodder quality. These results are in close conformity with Kumar *et al*. (2021).

5.4.2 Ash Content

Ash content was non-significantly affected by different levels of nano-urea However, results showed that (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)) (T_5) has highest ash content compared to rest of treatments. The improvement in ash content may be contributed by more dry matter content which improved the uptake of nutrients by the plants. Significantly higher value of ash content through nano-urea could be due to sufficient supply of N. Aside from essential nutrient, N is an indispensable content of amino acids which is the basic unit of proteins. Sufficient N supply through urea and foliar spray through nano-N would have kept maize free from Nitrogen stress and also sufficient nitrogen supply accelerated the protein synthesis from carbohydrates and reduced the rate of lignifications, thereby maintaining fodder quality. . These results are in close conformity with Rajesh *et al*. (2022).

5.4.3 NDF and ADF

The contents of neutral detergent fibre (NDF) and acid detergent fibre (ADF) are mainly composed of cellulose, lignin, hemicellulose, ash and N compounds. NDF measures most of the structural components in plant cells (lignin, hemicellulose and cellulose), but not pectin and its concentration in feeds is negatively correlated with energy concentration. ADF includes the least digestible portion of the plant cell viz; cellulose and lignin. So, low ADF values mean higher energy values and digestibility. Both neutral detergent fibre (NDF) and acid detergent fibre (ADF) were seen to be decreasing with an increase in nano-urea dosage. (Table 4.12). This decrease in NDF and ADF values might be due to the production of plants with soft stem. These results are in close conformity with Rajesh *et al*. (2022).

5.5 Nitrogen-use efficiencies of maize

5.5.1 Agronomic efficiency

Data obtainable in Table 4.10 revealed that application of various sprays of nano-urea had significant effect on agronomic efficiency. The treatment (T_5) (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) resulted in highest agronomic efficiency which was statistically at par with T4 (50% RDN + spray of nano- urea @ 4ml L^{-1} (20 and 40 DAS)). Nanoparticles have distinctive magnetic/optical properties, a huge specific surface area, and catalytic reactivity, which makes them more reactive than comparable bulk materials. (Agarwal and Rathore, 2014). The delivery mechanism of nano-fertilizers is to increase the availability of nutrients to the plant system, increasing production even with a less amount of applied nutrients. (Hediat and Salama, 2012). These findings were similar with results of Kumar *et al*. (2021b) and Kumar *et al*. (2020b).

5.5.2 Apparent Nutrient Recovery

Data obtainable in Table 4.10 revealed that application of various sprays of nano-urea had significant effect on apparent nutrient recovery. The treatment (T_5) (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)) resulted in highest agronomic efficiency which was statistically at par with T_4 (50% RDN + spray of nano- urea @ 4ml L^{-1} (20 and 40 DAS). However the treatment T_6 (50% RDN + spray of nano- urea @ 4ml L^{-1} (30 DAS) recorded the lowest. Improving apparent nutrient recovery requires increasing the penetration and absorption of nitrogen through foliar spray. Through leaching, volatilization, or denitrification, a significant amount of inorganic fertilisers supplied to the soil are lost and become inaccessible to plants. The chemical makeup, surface area, size, and reactivity of nanoparticles, among other factors, all have an impact on their effectiveness. (Khodakovskaya *et al*., 2012). Due to the partial replacement of conventional urea with nano-urea in these treatments, there may have been an increase in these properties, which increased nutrient availability to the developing plant and decreased traditional N losses. These findings were in accordance with results of Kumar *et al*. (2021b) and Rajesh *et al*. (2021).

5.5.3 Physiological efficiency

Data obtainable in Table 4.10 revealed that application of various sprays of nano-urea had significant effect on physiological efficiency. The treatment (T_8) (50% RDN + spray of nano- urea @ 12ml L^{-1} (30 DAS)) resulted in highest agronomic efficiency However the treatment T_6 (50% RDN + spray of nano- urea @ 4ml L^{-1} (30 DAS)) recorded the lowest. Nano-fertilizers are a smart delivery strategy because of their high volume to surface area ratio, excellent sorption capacity, and controlled release kinetics to specified spots. (Tarafdar *et al*., 2012; Solanki *et al*., 2015).

5.5.4 Partial factor productivity

The data presented in Table 4.10 revealed that application of various sprays of nano-urea had significant effect on partial factor productivity The treatment (T_5) (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)) resulted in highest partial factor productivity which was statistically at par with T4 (50% RDN + spray of nano- urea @ 4ml L^{-1} (20 and 40 DAS) and (T_8) (50% RDN + spray of nano- urea @ 12ml L^{-1} (30 DAS)). Nano- fertilizers are generated in a method that can increase the nutrient's penetration, absorption, and availability to the plant. When it comes to N fertilisers, nanotechnology can be used to create fertilisers that release N when crops need it, ultimately increasing N efficiency by reducing N leaching and emissions and long-term absorption by soil microorganisms. (Naderi and Danesh, 2013). Similar results are also reported by Kumar *et al*. (2020b).

5.6 Post harvest soil status

The present study revealed that soil organic carbon, electrical conductivity, potassium and pH did not differ significantly among different treatments. However highest soil available nitrogen was observed in T_2 (RDN) which might be due to higher fertilization through soil application. The results also revealed that the highest soil available phosphorus was recorded in control (no nitrogen application) treatment. This increase in availability of nutrients may be caused by reduced application of prilled urea into soil as a result, the over-accumulation of salt in soil is minimized. Thus, reducing residual acidic effect and increasing the availability of nutrients to plants. The results are in close conformity with Rathore *et al*. (2022)

5.7 Relative Economics

The economic efficiency of a farming practice / treatment is ultimately decided in terms of economic advantage which is reflected by indices like gross returns, net returns and benefit: cost (B:C) ratio. In the present investigation highest gross, net returns and benefit: cost (B: C) ratio (1.91) were realized in treatment (T5) (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS). The major cause for higher net returns could be the reduction of 50 % basal dose which further reduced the cost involved with fertilizers coupled with higher returns in terms of grain as well as stover yield. Similar findings were also reported by Singh *et al*. (2023).

Chapter-6

SUMMARY AND CONCLUSION

A field experiment entitled "**Effect of nano-urea on Growth, Yield and Quality of Fodder maize (*Zea mays* L.)**" was conducted in Research Farm of Division of Agronomy at Faculty of agriculture, Wadura, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *kharif* 2022. The objectives were to find out the suitable dose of nano urea for enhanced yield and quality of fodder maize, estimate the crop growth indicies of fodder maize and work out relative economics.

Eight treatments were laid out in a randomised complete block design with three replications. The treatments included T_1: Control, T_2: Recommended dose of Nitrogen (RDN) as basal (prilled urea), T_3: 50% RDN + spray of nano-urea @2ml L^{-1} (20 and 40 DAS), T_4: 50% RDN + spray of nano-urea @4ml L^{-1} (20 and 40 DAS),T_5: 50% RDN + spray of nano-urea @6ml L^{-1} (20 and 40 DAS), T_6: 50% RDN + spray of nano-urea @4ml L^{-1} (30 DAS),T_7: 50% RDN + spray of nano-urea @4ml L^{-1} (30 DAS) and T_8: 50% RDN + spray of nano-urea @12ml L^{-1} (30 DAS).

The important findings observed during the present investigation are summarized in this chapter with appropriate headings and brief conclusion of the study.

- Remarkable variation was observed on growth parameters like plant height, leaf area index, leaf stem ratio, number of functional leaves plant, dry matter accumulation, crop growth rate, relative growth rate, net assimilation rate, and green fodder yield by different sprays of nano-urea. Plant height, leaf area index and leaf stem ratio at all growth stages were significantly higher with treatment (T_5) (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)) whereas the lowest was recorded with control (T_1).

- Treatment with 50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) recorded significantly higher values of CGR and RGR at different periodic intervals.
- Treatment with (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) recorded significantly higher green fodder and dry fodder yield as compared other treatments and control.
- As for as quality parameters are considered fascinating variations were observed in different treatments. Treatment T_5 (50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS) recorded significantly statistically higher crude protein content digestibility, lowest neutral detergent fibre and acid detergent fibre.
- There was no drastic change in soil pH, EC, OC and potassium before sowing and after harvest. Soil available Nitrogen was recorded highest in T_5. However higher available P in soil was observed in control treatment (T_1).
- The highest average gross returns (₹ 184656.8), net returns (₹ 121174.8) and B:C ratio (1.91) were realized in treatment T_5(50% RDN + spray of nano- urea @ 6ml L^{-1} (20 and 40 DAS)).

CONCLUSION

Based on the results of one year experimentation, it may be concluded that the treatment T_5 (50% RDN + Spray of nano-urea @ 6ml L^{-1} (20 and 40 DAS) gave significantly higher green and dry fodder yield (50.82 t $ha^{-1}$and 22.76 t ha^{-1} respectively), net returns ((₹ 121174.8) and also recorded increased growth parameters and nutrient use efficiency.

However, these results are only indicative and require further experimentation to arrive at some more consistent and final conclusion.

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APPENDIX- I

SMW	Max. Temp.	Min. Temp.	Rain (mm)	RH1	RH2
27	31.31	20.33	8.8	77.43	58
28	26.21	17.29	96.4	88.57	67.86
29	29.29	18.43	6.4	83	61.43
30	28.09	18.93	62.8	85.57	62.29
31	28.43	17.21	22.6	84.29	62.71
32	29.86	18.57	6.2	86.43	58.57
33	29.29	18.36	45.6	85	58.71
34	28.07	16.99	10.8	81.86	66.57
35	30	15.5	0.2	79.71	52.71
36	30	15.43	7	78	46.14
37	28.57	13.07	7.4	77.71	52.14
38	28.43	11.71	4.8	74.29	45.86
39	26.93	11.86	0.8	85.43	46.71
40	26.57	7.93	0	84.86	40.57
41	24.73	7.3	0	75.29	48.43
42	20.07	4.57	40	92.86	53.86

APPENDIX- II

Analysis of variance for green fodder yield as influenced by different treatments of nano-urea

Sources of Variation	DF	Sum of Squares	Mean Sum of Squares
Replication	2	95.850	
Treatment	7	490.338	70.048
Error	14	34.297	2.450
Total	**23**	**620.485**	

Analysis of variance for dry fodder yield as influenced by different treatments of nano-urea

Sources of Variation	DF	Sum of Squares	Mean Sum of Squares
Replication	2	60.778	
Treatment	7	219.841	31.406
Error	14	23.784	1.699
Total	23	304.402	

APPENDIX -III

Common cost of cultivation (ha^{-1}) during *kharif* 2022

S. No	Particulars	Rate (₹)
01	Cost of seed	50 kg^{-1}
02	Tractorization	10000 ha^{-1}
03	Cost of labour	500 day^{-1}
04	Cost of prilled Urea	7 kg^{-1}
05	Cost of nano-urea	250/500 ml
06	Cost of DAP	26 kg^{-1}
07	Cost of MOP	19 kg^{-1}
08	Cost of SSP(control plot)	20kg ha^{-1}
09	Herbicide cost	850 kg ha^{-1}
10	Green fodder	3.5 kg ha^{-1}
11	Dry fodder	0.5 kg ha^{-1}

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner **Dr. Nazim Hamid Mir,** Scientist, Agronomy, ICAR-IGFARI- Regional Research Station, Srinagar during Viva-Voce examination held on 08-09-2023 have been incorporated in the manuscript entitled, **"Effect of Nano-Urea on Growth, Yield and Quality of Fodder Maize (*Zea mays* L.)".**

(Dr. Amal Saxena)
Chairman
Advisory Committee