International Journal of Research in Agronomy 2024; 7(2): 346-350

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(2): 346-350
Received: 28-12-2023
Accepted: 30-01-2024

Sarvajeet
Department of Soil Science and Agricultural Chemistry, RBS College, Agra, Uttar Pradesh, India

PK Sharma
Department of Soil Science and Agricultural Chemistry, IAS, BHU, Varanasi, Uttar Pradesh, India

Abhishek Panchadi
Department of Soil Science and Agricultural Chemistry, IAS, BHU, Varanasi, Uttar Pradesh, India

Munesh Kumar Shukla
Department of Soil Science and Agricultural Chemistry, IAS, BHU, Varanasi, Uttar Pradesh, India

Varun Kumar
Department of Soil Science and Agricultural Chemistry, RBS College, Agra, Uttar Pradesh, India

Corresponding Author:
Sarvajeet
Department of Soil Science and Agricultural Chemistry, RBS College, Agra, Uttar Pradesh, India

Effect of integrated application of nano urea and other organic sources of nitrogen on growth parameters of rice in an inceptisol of Varanasi

Sarvajeet, PK Sharma, Abhishek Panchadi, Munesh Kumar Shukla and Varun Kumar

DOI: https://doi.org/10.33545/2618060X.2024.v7.i2e.354

Abstract
With the global population rising at an uncontrollable pace, achieving sustainable agriculture and ensuring food security are of great importance. Nitrogen is an important nutrient for plant growth, and its efficient utilization is essential for maximizing agricultural productivity. However, conventional nitrogen fertilizers often exhibit low absorption efficiency and contribute to environmental pollution. This research explores the effect of the integrated application of nano urea and other organic nitrogen sources on the growth parameters of rice crop in an Inceptisol of Varanasi. The study investigates the potential of nano urea liquid, farmyard manure (FYM), vermicompost, and poultry manure as alternative nitrogen sources for rice cultivation. Nano urea, with its ultra-small particle size and high absorption efficiency, shows promise as an effective supplement to conventional urea. Additionally, organic sources like FYM, vermicompost, and poultry manure offer benefits such as improved soil health and reduced environmental pollution. The research methodology involves field experiments conducted in Varanasi's Inceptisol to assess the growth parameters of rice plants under different nitrogen treatments. Parameters such as plant height, chlorophyll content and tiller count are measured to evaluate the efficacy of the integrated application of nano urea and organic nitrogen sources. The findings of this study contribute to the understanding of sustainable nitrogen management practices in rice cultivation, particularly in regions with Inceptisols like Varanasi. By exploring the synergistic effects of nano urea and organic nitrogen sources, this research aims to enhance agricultural productivity while minimizing environmental impact.

Keywords: Sustainable agriculture, nano urea, vermicompost, poultry manure, farmyard manure

Introduction
Sustainable agriculture and food security are critical concerns for humanity, especially with the projected global population reaching 9.6 billion by 2050 (FAO, 2020) [5]. Way to achieve these goals is the efficient utilization of nutrients, particularly nitrogen, in crop production systems. Nitrogen is a vital nutrient for plant growth, and its management plays a pivotal role in maximizing agricultural productivity while minimizing environmental degradation (Govindasamy *et al.*, 2023; Rodríguez-Espinosa *et al.*, 2023) [6, 11]. However, traditional nitrogen fertilizers, such as conventional urea, often suffer from low absorption efficiency and contribute significantly to environmental pollution through processes like nitrogen leaching and greenhouse gas emissions (Yadav M. K. *et al.*, 2023) [21]. In response to these challenges, researchers are exploring innovative approaches to nitrogen management, including the integration of nano fertilizers and organic sources in crop production systems. Nano fertilizers have a great potential to increase use efficiency in crop production (Yadav A. *et al.*, 2023) [20]. Nano urea, characterized by its ultra-small particle size and high absorption efficiency, holds promise as a sustainable alternative to conventional urea fertilizers (Kumar *et al.*, 2023) [7]. Whereas organic sources used from past are always suggested to be best supplements to chemical fertilizers (Naher *et al.*, 2019) [9]. Organic nitrogen sources, such as farmyard manure (FYM), vermicompost, and poultry manure, offer multiple benefits, including improved soil health and reduced environmental impact (Subbaiah, 2019; Kumari *et al.*, 2024) [15, 8].

Nano fertilizers, particularly nano urea, exert significant effects on crucial growth parameters including plant height, tiller count, and chlorophyll content (Bolashetti *et al*., 2023; Subramani *et al*., 2023; Bhargavi and Sundari, 2023) [2, 16, 1]. Studies indicate that the application of nano fertilizers enhances nutrient absorption, resulting in accelerated growth rates and taller plants compared to conventional fertilizers (Subramani *et al*., 2023) [16]. Moreover, nano fertilizers promote increased tiller count by improving nutrient availability in the soil, thereby stimulating the development of lateral shoots and tillers, which ultimately contributes to higher yield potential in crops (Bhargavi and Sundari, 2023) [1]. Additionally, nano urea positively influences chlorophyll content in plants, crucial for photosynthesis, by providing readily available nitrogen that enhances chlorophyll synthesis and photosynthetic activity (Bolashetti *et al*., 2023) [2]. Organic nitrogen sources, such as FYM, vermicompost, and poultry manure, play a pivotal role in enhancing the growth parameters of rice crop. These organic sources contribute to improved soil structure and fertility, providing optimal conditions for root development and nutrient uptake. Studies have shown that the application of organic nitrogen sources results in increased plant height, as well as a higher tiller count, indicating enhanced vegetative growth and greater yield potential in rice plants. Furthermore, organic nitrogen sources enrich the soil with essential nutrients and micronutrients (Dhaliwal *et al*., 2019) [4], leading to a higher chlorophyll content in rice plants, which is crucial for efficient photosynthesis and overall plant vigor. The present research focuses on investigating the effect of the integrated application of nano urea and organic nitrogen sources on the growth parameters of rice crops in the Inceptisol soil of Varanasi. Inceptisols, characterized by their mineral-rich properties and wide distribution in tropical regions, are prevalent in areas like Varanasi, making them suitable for this study (Brady and Weil, 2008) [3]. Understanding the synergistic effects of nano urea and organic nitrogen sources on rice growth in such soils is important for developing sustainable nitrogen management practices specific to different agroecological conditions. The primary objective of this study is to evaluate the efficacy of nano urea, FYM, vermicompost, and poultry manure as alternative nitrogen sources for rice cultivation in Inceptisol soil. Through field experiments conducted in Varanasi, the research aims to assess various growth parameters of rice plants under different nitrogen treatments. Parameters such as plant height, chlorophyll content, and tiller count will be measured to determine the effect of integrated nitrogen application on rice productivity and growth. By elucidating the effects of nano urea and organic nitrogen sources on rice growth parameters, this research seeks to contribute to the development of sustainable agricultural practices that enhance productivity while mitigating environmental risks. The findings of this study are expected to inform farmers, policymakers, and agricultural practitioners about the potential benefits of adopting integrated nitrogen management strategies in rice cultivation, particularly in regions of Indo-Gangetic plains. In summary, this paper aims to investigate the effect of the integrated application of nano urea and organic nitrogen sources on the growth parameters of rice in Varanasi's Inceptisol soil.

Materials and Methods

Study area

The present investigation was comprised two field trial during Kharif season 2021 and 2023 conducted at Agricultural Research Farm of the Institute, followed by laboratory analysis of the grain, straw and soil samples in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Varanasi is geographically situated at 25 0 18’ N altitude and 83 0 3’ E longitude of 76.10 meters above mean sea level of Northern Indo -Gangetic plains of Uttar Pradesh, on the left side of Ganga river. Varanasi are falling under semi-arid to sub humid climate. The normal period for onset of monsoon in this area is the 3rd week of June month which going to last up to end of September or sometimes extends up to the 1st week of October. Showers of rain are often experienced during winter season. The annual rainfall of this region is about 1100 mm.

Experiment details

In the years of experimentation, specifically during the Kharif seasons of 2021 and 2023, a recommended dose of fertilizers 150:60:60 kg N: P_2O_5: K_2O per hectare was utilized. The experimentation involved a total of 12 treatments replicated thrice, resulting in a total of 36 plots. Each plot measured 4.0 meters by 3.0 meters, with rice crop, specifically the improved Sambha Mahsuri (BPT-5204) variety, being cultivated. The planting arrangement included a spacing of 20.0 centimetres between rows and 15.0 centimetres between plants within rows. The experimental design employed was a Randomized Block Design.

Treatment details

Combination	Treatment details
Control	No + 100% P_2O_5 & K_2O application
Control + NU	Control + 2 sprays of Nano Urea (@4 ml/ litre)
Control + NU (2X)	Control + 2 sprays of Nano Urea 2X (@8 ml/litre)
RDF	Recommended dose of fertilizer’s (RDF) (100% NPK)
U50+ NU	50% of N through Urea (163.04 kg ha^{-1})+ 2 spray of Nano Urea
FYM50 + NU	50% of N through FYM (15 t ha^{-1}) + 2 spray of Nano Urea
VC 50 + NU	50% of N through Vermicompost (6.25 t ha^{-1})+2 spray of Nano Urea
PM50 +NU	50% of N through Poultrymanure (2.5 t ha^{-1}) +2 spray of Nano Urea
U75 + NU	50% of N through Urea (244.56 kg ha^{-1})+ 2 spray of Nano Urea
FYM75+NU	75% of N through FYM (22.5 t ha^{-1}) + 2 spray of Nano Urea
VC 75+NU	75% of N through Vermicompost (9.38 t ha^{-1})+2 spray of Nano Urea
PM75 +NU	75% of N through poultry manure (3.75 t ha^{-1})+2 spray of Nano Urea

Where RDF is recommended dose of fertilizers, U is Urea, NU is Nano urea, FYM is Farmyard manure, VC is vermicompost and PM is poultry manure

Growth parameters

In the assessment of growth attributing characters for rice plants, various parameters were evaluated. Plant height (cm) was measured at intervals of 30, 60, 90 days after planting, and at harvest, by selecting five representative plants and recording the distance from the surface to the tip of the flag leaves using a centimetre scale. Similarly, chlorophyll content was assessed at the same intervals by selecting five plants and measuring the chlorophyll content from the middle portion of mature leaves using an SPAD meter. The number of plants per square meter and the number of tillers per hill were recorded at the specified intervals by selecting five plants (hills) and counting. Additionally, dry matter accumulation was determined by cutting five plants, air-drying them in shade, recording their weight, drying them at 65 °C until reaching a constant weight, and recording the final weight at the specified intervals.

Statistical analysis

We conducted analysis of variance (ANOVA) to analyse the data obtained from the randomized block design (RBD) experiment. This statistical method allowed us to assess the significance of differences among treatment means. Subsequently, Tukey's test was performed to conduct post-hoc pairwise comparisons and identify significant differences between treatment groups. All the statistical analysis was performed using Origin Pro 2024 [10] software (Origin Lab Corporation).

Results and Discussion

Plant height

The highest plant height were recorded with Recommended dose of fertilizers (RDF) at 30 DAT (72.24cm), 60 DAT (88.98cm), 90 DAT (103.74 cm) and at harvest (107.39cm) followed by 50% N through Urea + 2 spray of nano urea (U50+NU) at 30 DAT (68.82 cm), 60 DAT (83.51 cm), 90 DAT (101.23 cm) and at harvest (103.39 cm). The lowest plant height was found in control treatment at all stages. At 30, 60, 90 DAT, and at harvest the maximum plant height with RDF was significantly at par with 75% N through urea combined with 2 spray of nano urea (U75+NU). During the second year experiment (2023) the plant height of rice (ISM) showed similar trend with considerable increase in plant height with application of Nano urea, RDF, and Nano urea in combined with conventional urea, FYM, vermicompost, and poultry manure. N fertilization has a significant impact on plant height due to the fact that the inorganic fertilizer provides readily available nutrients to plants, which they utilize in their growth and development. The application 100% RDF is statistically at par with 75% N through urea combined with 2 spray of nano urea. The application of 75% N through poultry manure and vermicompost it combining with nano urea recorded significantly lower plant height as compared to RDF but statistically at par 75% N through urea combined with 2 spray of nano urea (U75+NU) treatment. Nano urea alone did no significantly enhance the plant height and also found that combining Nano urea with conventional urea or organic manure treatments led to numerically higher plant height and then using Nano urea alone. Singh *et al.* (2018) [13] and Shankar *et al.* (2020) [12] observed noticeably greater plant heights in treatments where 100% RDN was sprayed chemically rather than organically. This may be because divided application of urea at distinct developmental phases allowed for an adequate and enhanced availability of N, which aided in the rapid growth and development of plant cells (Tomar *et al*., 2018) [19]. The combination of treatment and nitrogen source application resulted in an increase in plant height, which may have been caused by more nitrogen being available to developing plants from both inorganic and organic sources (Soleimanzadeh & Gooshchi, 2013) [14].

Table 1: Effect of Nano urea and organic sources of N on plant height (cm) of rice at 30, 60, 90 DAT, and at harvest

Treatment	30 DAT		60 DAT		90 DAT		At harvest	
	2021	2023	2021	2023	2021	2023	2021	2023
Control	46.35±0.75g	47.21±1.16f	67.23±0.9e	68.24±2.26e	83.61±1.13f	84.89±1.3g	84.61±1.18f	85.37±0.87h
Control +NU	48.42±0.57fg	48.62±1.28ef	69.25±1.05de	70.62±1.24de	85.36±1.6ef	87.51±0.49fg	87.57±1.03ef	88.32±0.6gh
Control +NU (2X)	49.55±0.86efg	50.34±1.02def	69.56±0.56de	71.53±0.77de	86.19±1.48def	90.29±1.01ef	88.23±1.08ef	91.13±0.63fg
RDF	72.24±0.92a	72.56±0.6a	88.98±0.89a	89.9±1.09a	103.74±1.21a	106.85±0.98a	107.39±1.02a	107.56±0.68a
U50+NU	61.68±1.31b	62.23±0.56b	77.46±0.94b	78.35±1.48bc	97.83±1.06ab	99.02±0.9bc	101.2±1.4abc	101.13±0.95bc
FYM50+NU	52.52±0.91def	53.07±1.25cdef	70.91±0.62cde	72.32±0.74cde	87.63±0.61cdef	90.56±0.47ef	91.66±1.08de	91.9±0.98fg
VC50+NU	53.62±1.24de	53.88±0.69cde	71.32±1.27cde	73.56±1.44cde	88.52±1.2cdef	90.87±0.98ef	91.7±0.75de	92.13±0.69ef
PM50+NU	55.63±1.2cd	56.12±2.1bcd	72.26±1bcde	74.06±0.75cde	89.86±1.46cde	91.28±0.48ef	92.29±0.97de	93.17±1.12ef
U75+NU	68.82±0.59a	69.22±0.53a	83.51±2.05a	84.25±1.14ab	101.23±1a	103.03±1.47ab	103.39±0.86ab	104.6±1.3ab
FYM75+NU	55.74±0.45cd	56.26±1.88bcd	72.29±1.45bcde	74.53±1.06cd	90.63±1.13cde	92.48±1.61def	93.63±1.48de	94.67±0.65def
VC75+NU	58.65±0.51bc	59.03±1.09bc	74.58±0.45bcd	75.35±1cd	91.85±1.16cd	95.19±0.82cde	96.74±1.89cd	96.55±1.04def
PM75+NU	60.13±0.88bc	60.76±1.45b	75.83±0.82bc	76.23±0.96cd	92.86±0.19bc	96.66±0.49cd	97.74±1.53bcd	98.21±0.74cd

(Mean of three replicate ± standard error. Value with same letter differ non-significantly (p>0.05). Different letters for each parameter show a significant difference at p<0.05)

Chlorophyll content

The chlorophyll content of rice leaves (ISM) at 30, 60, 90 DAT, and at harvest is ranged from 30.87 to 39.51, 32.93 to 41.96, 23.87 to 35.73, and 22.82 to 32.19 respectively during first year. The application of RDF and Nano urea alone or combined with urea and FYM, Vermicompost, and poultry manure chlorophyll content at all growing period of rice crop. The highest chlorophyll content was recorded with Recommended dose of fertilizers (RDF) at 30 DAT (39.51), 60 DAT (41.96), 90 DAT (35.73) and at harvest (32.19) followed by 50% N through Urea + 2 spray of nano urea (U50+NU) at 30 DAT (37.12), 60 DAT (41.05), 90 DAT (34.03) and at harvest (31.95). The lowest greenness index was found in control treatment at all stages. At 30, 60, 90 DAT, and at harvest the maximum plant height with RDF was significantly at par with 75% N through urea combined with 2 spray of Nano urea (U75+NU) while application of 75% N through organic sources it is statistically at par with each other. Application of Nano urea alone is statistically at par with control treatment. During second year of experiment showed similar trend of chlorophyll content were increases with application of nano urea and urea conventional alone or in combination with organic manure. Nano urea provides nitrogen to plant in direct contact to leaves stomata and it increased photosynthesis of the plant and conventional urea were providing nitrogen to plant rapidly as compared with nano urea and organic manure. The chlorophyll content increases from 30 DAT to 60 DAT and recorded gradual decrease in chlorophyll content was recorded at harvest stages of rice crop. According to Taiz and Zeiger (2006) [17], leaves begin their development as sink organs. A transition from sink to source status occurs later in development. The maturation of leaves is accompanied by a large number of functional and anatomic changes, resulting in a reversal of transport direction from importing to exporting. Nano fertilizer may have affected these processes through its transportation capabilities in terms of penetration and movements within the plant systems.

Table 2: Effect of Nano urea and organic sources of N on chlorophyll content (SPAD reading) of rice at 30, 60, 90 DAT, and at harvest.

Treatment	30 DAT		60 DAT		90 DAT		at harvest	
	2021	2023	2021	2023	2021	2023	2021	2023
Control	30.87±0.21f	31.05±0.07g	32.93±0.38e	33.93±0.19e	23.87±0.37f	24.37±0.23g	22.82±0.21d	23.11±0.18f
Control +NU	30.94±0.14f	31.4±0.1fg	33.45±0.45de	34.11±0.08de	24.1±0.06f	24.83±0.45g	23.03±0.18d	23.18±0.11f
Control +NU (2X)	31.28±0.31ef	31.67±0.23fg	34.92±0.55cde	35.53±0.34de	24.35±0.23f	25.6±0.32g	23.13±0.16d	23.7±0.18ef
RDF	39.51±0.4a	40.17±0.74a	41.96±0.78a	42.5±1.14a	35.73±0.52a	36.67±0.71a	32.19±0.34a	32.51±0.57a
U50+NU	34.27±0.53c	34.9±0.64c	38.02±0.36bc	38.97±0.94bc	31.03±0.25b	31.23±0.55c	29.01±0.12b	29.2±0.43b
FYM50+NU	31.32±0.29ef	31.77±0.28efg	35.34±0.78cde	36.23±0.17cde	25.01±0.11f	25.93±0.13fg	23.81±0.12d	24.14±0.12ef
VC50+NU	32.02±0.43def	32.23±0.17defg	35.47±0.63cde	36.33±0.19cde	25.67±0.52ef	26.3±0.2fg	24.46±0.26cd	24.91±0.11de
PM50+NU	33.32±0.4cde	33.5±0.38cdef	36.02±0.44cde	36.43±0.28cde	27.67±0.31de	27.97±0.08ef	25.92±0.56c	26.1±0.11d
U75+NU	37.12±0.93b	37.23±0.88b	41.05±0.67ab	41.63±0.88ab	34.03±0.66a	34.27±0.99b	31.89±0.74a	31.95±0.68a
FYM75+NU	33.67±0.26cd	33.9±0.24cde	36.03±0.3cde	36.63±0.19cde	27.98±0.51de	28.63±0.32de	26.01±0.09c	26.43±0.28cd
VC75+NU	33.84±0.46cd	34.12±0.08cd	36.57±0.93cd	36.83±0.39cd	28.63±0.34cd	29.07±0.1cde	26.22±0.12c	26.57±0.3cd
PM75+NU	34.21±0.3cd	34.27±0.29cd	37.75±0.7c	38.93±0.19bc	30.17±0.56bc	30.53±0.37cd	28.93±0.54b	27.82±0.17bc

(Mean of three replicate ± standard error. Value with same letter differ non-significantly (p>0.05). Different letters for each parameter show a significant difference at p<0.05)

Plant population

The plant population of rice at 30, 60 DAT, and at harvest is ranged from 26.87 to 28.68, 26.51 to 27.78 and 26.26 to 27.53 respectively. The numerically highest plant population were recorded with RDF treatment at 30 DAT (28.68), 60 DAT (27.98), and at harvest (27.73) it is statistically at par with all the treatment. The lowest value of the plant population were found in control treatment during first year of experiment (2021). During second year of experiment (2023) showed a similar pattern with considerable decrease of plant population from 30 DAT to at harvest is due to some environmental factors and nutrient availability. The N fertilization increases plant population it is due to application of 100% RDF through inorganic fertilizers it provided readily available nitrogen to plant and support to plant withstand in adverse condition when application of organic manure it release nutrient slowly. Data on the growth characteristics of rice, as measured by the number of plants observed at various growth stages, showed that different treatments had no significant effect on the number of plants. However, treatments involving the application of chemical fertilizers, Nano urea either alone or in combination with different manures, showed numerically higher plant populations, which may have been caused by the improved crop stand resulting from the higher availability of nutrients in plant-available form and the ease with which plants could absorb them. Shankar *et al.* (2020) [12] and Tiwari (2019) [18] noted similar results.

Table 3: Effect of Nano urea and organic sources of N on number plant population m^{-2} of rice at 30, 60 DAT, and at harvest

Treatment	30 DAT		60 DAT		At harvest	
	2021	2023	2021	2023	2021	2023
Control	26.87±0.02a	26.91±0.05a	26.51±0.35a	26.53±0.19a	26.26±0.35a	26.28±0.34a
Control +NU	27.02±0.87a	27.05±0.3a	26.6±1.22a	26.63±0.07a	26.35±1.45a	26.38±0.63a
Control +NU (2X)	27.08±0.13a	27.07±0.12a	26.62±0.37a	26.64±0.26a	26.37±0.62a	26.39±0.39a
RDF	28.68±0.46a	28.72±0.39a	27.98±0.75a	28.01±0.17a	27.73±0.2a	27.76±0.22a
U50+NU	28.28±0.24a	28.31±0.27a	27.73±0.38a	27.76±0.36a	27.48±0.62a	27.51±0.59a
FYM50+NU	27.12±0.44a	27.16±0.44a	26.62±0.65a	26.68±0.61a	26.37±0.51a	26.43±0.46a
VC50+NU	27.23±0.4a	27.27±0.42a	26.68±0.49a	26.72±0.46a	26.43±0.69a	26.47±0.65a
PM50+NU	27.35±0.42a	27.38±0.45a	26.71±0.26a	26.75±0.22a	26.46±0.5a	26.5±0.46a
U75+NU	28.43±0.55a	28.48±0.58a	27.78±0.54a	27.81±0.24a	27.53±0.38a	27.56±0.36a
FYM75+NU	27.26±0.31a	27.31±0.3a	26.83±0.59a	26.87±0.04a	26.58±0.39a	26.62±0.37a
VC75+NU	27.38±0.67a	27.44±0.72a	26.91±0.34a	26.96±0.36a	26.66±0.35a	26.71±0.33a
PM75+NU	27.44±0.42a	27.49±0.41a	26.98±0.71a	27.01±0.13a	26.73±0.35a	26.76±0.32a

(Mean of three replicate ± standard error. Value with same letter differ non-significantly (p>0.05). Different letters for each parameter show a significant difference at p<0.05)

Conclusion

Based on the present investigation, it can be inferred that integrated application of nano-urea with conventional nitrogen fertilizer and with organic sources have potential to enhance crop plant height, chlorophyll content and plant population per square meter. Application of 75% recommended N through conventional N fertilizer (urea) in rice (two equal split) +full dose of P_2O_5 and K_2O along with 2 time sprays of nano-urea (1250 ml ha^1 spray^1) resulted statistically at par over recommended dose of fertilizer (100%N + full dose of P_2O_5, and K_2O). Therefore, there is a possibility of cur- tailing up to 25% of the recommended dose of N by application of two sprays of nano-urea in rice was observed. Thus, nano-urea appeared to hold the key to a paradigm shift in the global and Indian fertilizer consumption scenarios. Before implementing the strategy, the nano-urea results must be further verified over a wider range of crops and regions.

References

1. Bhargavi G, Sundari A. Effect of nano urea on the growth and yield of rice (*Oryza sativa*) under SRI in the Cauvery delta zone of Tamil Nadu. Crop Research. 2023;58(1and2):12-17.
2. Bolashetti S, Hilli JS, Uppar DS, Hiremath SM. Influence of foliar nutrition through nano urea and boron on plant growth characters and seed yield in onion (*Allium cepa* L.). Crop Research. 2023;58(1and2):12-17.
3. Brady NC, Weil RR. The Nature and Properties of Soils. Pearson Education; c2008.
4. Dhaliwal SS, Naresh RK, Mandal A, Singh R, Dhaliwal MK. Dynamics and transformations of micronutrients in agricultural soils as influenced by organic matter build-up: A review. Environmental and Sustainability Indicators. 2019;1:100007.
5. Food and Agriculture Organization (FAO). How to Feed the World in 2050. [Online]; c2020. Available from: http://www.fao.org/3/a-i3027e.pdf
6. Govindasamy P, Muthusamy SK, Bagavathiannan M, Mowrer J, Jagannadham PTK, Maity A, *et al*. Nitrogen use efficiency-a key to enhance crop productivity under a changing climate. Frontiers in Plant Science. 2023;14:1121073.
7. Kumar A, Ram H, Kumar S, Kumar R, Yadav A, Gairola A, *et al*. A Comprehensive Review of Nano-Urea vs. Conventional Urea. International Journal of Plant & Soil Science. 2023;35(23):32-40.
8. Kumari M, Sheoran S, Prakash D, Yadav DB, Yadav PK, Jat MK. Long-term application of organic manures and chemical fertilizers improve the organic carbon and microbiological properties of soil under pearl millet-wheat cropping system in North-Western India. Heliyon; c2024, e09277.
9. Naher UA, Ahmed MN, Sarkar MIU, Biswas JC, Panhwar QA. Fertilizer management strategies for sustainable rice production. In: Organic farming. Woodhead Publishing; c2019. p. 251-267.
10. Origin Lab Corporation. Origin Pro (Version 2024) (Computer software). Northampton, MA, USA; c2024.
11. Rodríguez-Espinosa T, Papamichael I, Voukkali I, Gimeno AP, Candel MBA, Navarro-Pedreño J, *et al*. Nitrogen management in farming systems under the use of agricultural wastes and circular economy. Science of The Total Environment. 2023;876:162666.
12. Shankar T, Maitra S, Ram MS, Mahapatra R. Influence of integrated nutrient management on growth and yield attributes of summer rice (*Oryza sativa* L.). Crop Research. 2020;55(1 & 2):1-5.
13. Singh H, Singh RP, Meena BP, Lal B, Dotaniya ML, Shirale AO, *et al*. Effect of integrated nutrient management (INM) modules on late sown Indian mustard [*B. juncea* (L.) Cernj. Cosson] and soil properties. Journal of Cereals and Oilseeds. 2018;9(4):37-44.
14. Soleimanzadeh H, Gooshchi F. Effects of Azotobacter and nitrogen chemical fertilizer on yield and yield components of wheat (*Triticum aestivum* L.). World Applied Sciences Journal. 2013;21(8):1176-1180.
15. Subbaiah PV. Review on vermicompost, poultry manure, farmyard manure, biogas digest, biochar, urban compost and biofertilizers as potential alternate nutrient sources for sustainable agriculture. International Journal of Chemical Studies. 2019;7(4):255-258.
16. Subramani T, Velmurugan A, Bommayasamy N, Swarnam TP, Ramakrishna Y, Jaisankar I, *et al*. Effect of Nano Urea on growth, yield and nutrient use efficiency of Okra under tropical island ecosystem. International Journal of Agricultural Sciences. 2023;19:134-139.
17. Taiz L, Zeiger E. Plant Physiology. 4th Edition. Sinauer Associates, Inc. Sunderland, Massachusetts, USA; c2006.
18. Tiwari RK. Yield and economics of rice as influenced by organic, inorganic and integrated nutrient management practices. M. Sc. Thesis, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur; c2019.
19. Tomar R, Singh NB, Singh V, Kumar D. Effect of planting methods and integrated nutrient management on growth parameters, yield and economics of rice. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):520-527.
20. Yadav A, Yadav K, Abd-Elsalam KA. Exploring the potential of nanofertilizers for sustainable agriculture. Plant Nano Biology; c2023, 100044.
21. Yadav MR, Kumar S, Lal MK, Kumar D, Kumar R, Yadav RK, *et al*. Mechanistic Understanding of Leakage and Consequences and Recent Technological Advances in Improving Nitrogen Use Efficiency in Cereals. Agronomy. 2023;13(2):527.