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Nano urea vs. conventional urea: A comparative analysis of efficacy in major crops

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Abstract
The rapid advancement of nanotechnology has led to development of nano fertilizers as a promising alternative to conventional nutrient sources, with nano urea emerging as a novel nitrogen fertilizer for sustainable agriculture. This review critically examines comparative efficacy of nano urea and conventional urea across major field crops. Nano urea when applied as foliar spray has resulted in enhanced nitrogen use efficiency, reduced nitrogen losses through leaching and volatilization compared to the conventional urea. However, variability in crop response under different agroclimatic conditions and limited long term studies on soil-plant-microbe interactions necessitate comprehensive evaluation. The review also highlights that liquid nano urea is most effective as a supplement than a complete replacement for conventional urea and the integrated use of nano urea with conventional fertilizers is a sustainable solution for climate resilient agriculture with a need for long term safety evaluation and suitable regulatory frameworks.

Keywords: Foliar spray, nutrient use efficiency, nano urea, conventional urea

Introduction
Fertilizers have been integral to modern agriculture since the green revolution, significantly boosting crop productivity to meet the escalating global food demand driven by population growth. Conventional fertilizers like urea can supply essential nutrients such as nitrogen forming the backbone of high yielding farming systems. However, their extensive use has revealed critical drawbacks, including low nutrient use efficiency (NUE), often below 40% for nitrogen, leading to substantial losses through leaching, volatilization, and runoff (Savci, 2012) [1]. These inefficiencies contribute to environmental degradation, such as groundwater contamination, eutrophication, and greenhouse gas emissions, alongside soil health deterioration due to over reliance on chemical inputs (Krasilnikov *et al*., 2022) [2]. The energy intensive production and application of conventional fertilizers further exacerbate their ecological foot print, posing challenges to sustainable agriculture. In response to these limitations, nano urea has emerged as a promising alternative. Nano urea consists of nano scale urea particles designed to enhance nitrogen delivery to plants. Its benefits include high NUE, reportedly up to 80% greater than conventional urea due to improved foliar absorption and controlled nutrient release (Kumar *et al*., 2021) [37]. Additional advantages include reduced application rates, potentially lowering input costs, and a diminished environmental impact by minimizing nutrient losses (Upadhyay *et al*., 2023) [11]. The urgency to reconcile agricultural productivity with environmental sustainability underscores the need for this review. This paper aims to critically compare the efficacy of nano urea against conventional fertilizers across various crops by collecting evidence from field studies and trials. Its significance lies in providing a comprehensive assessment to guide farmers, researchers, and policymakers in adopting technologies that enhance yield, reduce costs, and mitigate environmental harm. As nanotechnology in agriculture gains traction, this analysis contributes to the scientific discourse on its practical viability and long term implications for food security.

Overview of Nano Urea and Conventional Urea
Conventional urea
Conventional urea is one of the most widely used nitrogenous fertilizers in agriculture, known

for its high nitrogen content. It is manufactured through regulated reactions between ammonia gas and carbon dioxide under high temperature and pressure, resulting in molten urea that is then shaped into spherical forms or solidified into prills (Hignett, 1985) [4]. It is a widely used nitrogen fertilizer in agriculture with multiple application methods such as starter, broadcast, top dress or as part of dry and liquid fertilizer mixes. In India, granular urea constitutes over 82% of nitrogenous fertilizer due to its affordability and effectiveness in enhancing crop yields. To ensure accessibility for farmers, the Indian government allocates substantial subsidies, reflected in the Union Budget 2022-23, which earmarked 67,187 crore rupees for fertilizer subsidies (Lakshman *et al*., 2022) [5]. Conventional urea is typically applied to soil either as a basal dose at sowing or in splits as top dressing. Its effectiveness is limited by significant nitrogen losses which include leaching, volatilization and denitrification, with only 25-30% of applied nitrogen being utilized by crops (Suthar *et al*., 2023) [6]. While conventional urea remains effective for crop production, its lower nitrogen use efficiency and higher environmental costs make it less sustainable in the long term.

Nano urea

Nano urea, a cutting edge agricultural product leveraging nanotechnology, features particle sizes ranging from 20-50 nm, resulting in a substantially greater surface area than traditional urea prills (Raliya *et al*., 2017; Mahapatra *et al*., 2022) [7, 8]. It is developed by the Indian Farmers Fertiliser Cooperative (IFFCO), this liquid nano urea has been officially approved by the Government of India under the fertilizer control order, 1985. With particles smaller than 100 nm, it contains 4% nitrogen and has shelf life of about two years (Madhavi *et al*., 2022) [9]. The liquid formulation, characterized by zeta potential exceeding 30 for enhanced stability, is applied through spraying at a dosage of 2-4 ml L^{-1} of water, tailored to the crop's nitrogen demands, canopy growth, and water requirements (Lakshman *et al*., 2022) [5]. Nano urea with its small particle size increases surface area and facilitates better penetration into plant cells, leading to improved nitrogen assimilation and physiological growth. Foliar application at critical growth stages ensures nitrogen is supplied when plant demand is highest, reducing wastage and environmental losses (Acharya *et al*., 2024) [27]. Studies have shown that two foliar sprays of nano urea and 75% of the recommended nitrogen dose through soil applied urea can match or surpass yields achieved with 100% conventional urea, while also improving nitrogen use efficiency and reducing greenhouse gas emissions (Upadhyay *et al*., 2023) [11].

Efficacy in Major Crops

Rice

In a study conducted by Gondwal *et al*. (2024) [12] reported that foliar application of nano urea at active tillering improved input efficiency and yield. Combining nano urea with conventional urea could reduce total nitrogen use by 25% or more while maintaining or improving yield and grain quality. Application of 100% RDN through conventional urea in conjunction with two foliar sprays of nano urea (4 ml L^{-1}) at 25 and 50 days after transplanting is most effective for higher productivity and profitability in hybrid rice cultivation (Namasharma *et al*., 2023) [13]. Application of 75% recommended nitrogen dose combined with two foliar sprays of nano urea significantly enhanced rice growth and yield under SRI, resulting in highest grain and straw yield and improved plant height, leaf area index and dry matter production compared to conventional practice (Bhargavi and Sundari, 2023) [14]. Foliar application of nano urea, especially when combined with 75% of the recommended soil applied nitrogen significantly improves crop growth, yield and nitrogen use efficiency, allowing for a 25% reduction in conventional urea without compromising productivity (Pedireddy *et al*., 2024) [15]. Foliar application of nano urea especially when 25% of nitrogen is supplied through two sprays of nano urea combined with 75% conventional urea, significantly improved rice plant height, tiller number, and grain protein content compared to conventional urea alone, while maintaining soil health and available nitrogen. This approach allows for a 25% reduction in conventional nitrogen fertilizer use without compromising crop growth, yield attributes, or quality, supporting more efficient and sustainable rice production (Katre *et al*., 2024) [16].

Wheat

Nano urea combined with 75% recommended dose of nitrogen can significantly increase wheat yield and can also reduce CO_2 emissions, helping in India's net zero emissions goal by 2070 (Tripathi *et al*., 2025) [17]. Application of 100% recommended dose of nitrogen along with foliar spray of nano urea at tillering stage @ 3 ml L^{-1} of water improved the growth and yield attributes of wheat under mid hills of Himachal Pradesh (Singh *et al*., 2025) [18]. In conservation tillage application of 150 kg N ha^{-1} in three equal splits with a single spray of nano urea at 60-65 DAS resulted in improved wheat yield, profitability and nitrogen use efficiency (Kumar *et al*., 2023) [19]. A field study reported that applying recommended nitrogen along with two foliar sprays of 5% urea at tillering and jointing significantly improved wheat performance under irrigated conditions. This treatment recorded highest grain yield (54.08 q ha^{-1}) and biomass yield (140.96 q ha^{-1}). Growth parameters such as plant height (82.40 cm) and effective tillers m^{-2} (505) were also highest in this treatment (Dabhi *et al*., 2024) [20]. Foliar application of nano urea at jointing and tillering stages, in conjunction with 100 per cent recommended dose of nitrogen showed markable effect on wheat's growth and yield (Rani *et al*., 2024) [21].

Maize

Nano urea, when supplemented or partially replaced in place of conventional urea can sustain maize yields, improve nitrogen use efficiency and reduce environmental impacts. A study conducted in maize showed that foliar application of nano urea @ 4 ml L^{-1} along with 100% recommended dose of nitrogen produced maximum plant height (220.33 cm), SPAD values and the maximum leaf (55.86 g $plant^{-1}$) and stem dry weight (160.73 g $plant^{-1}$). The treatment also recorded higher grain yield (9256 kg ha^{-1}) and stover yield (11474 kg ha^{-1}) and was statistically comparable with 75% recommended dose of nitrogen + nano urea @ 4 ml L^{-1}. Application of 75% recommended dose of nitrogen +2 foliar spray of nano urea at knee high and tasseling stage gave superior results on growth and yield attributes in kharif maize (Kundu, and Chhabra, 2023) [22]. A study revealed that kharif maize produced higher growth attributes, yield components, grain yield (66.74 q ha^{-1}) and stover yield (86.76 q ha^{-1}). These results were statistically on par with 75% N through urea + 25 per cent N supplied through nano urea sprays at 20, 40 and 60 DAS respectively (Dokhe *et al*., 2024) [23].

Oilseeds

Foliar application of nano urea can improve growth and yield attributes in oilseeds such as sesame, sunflower, groundnut, castor, linseed and flaxseed. In sesame cultivation soil

application of 100% recommended dose through mineral nitrogen and foliar application of 25% nitrogen through nano urea produced higher growth attributes, seed and straw yield compared to lower nitrogen levels (Singh *et al*., 2025) [18]. Studies have shown that combined application of sulphur (45 kg ha^{-1}), boron (200 ml ha^{-1}) along with nano urea exerted a synergistic effect on the growth, yield and quality of sunflower, compared to control and individual applications of sulphur and boron (Roy and Singh, 2024) [24]. Research under rainfed conditions has demonstrated that the application of 100% recommended basal nitrogen combined with foliar spray of nano urea at 2 ml L^{-1} at 30 and 60 DAS resulted in improved growth and yield attributes in castor (Veeramani *et al*., 2023) [25]. Application of 100% recommended dose of nitrogen combined with three foliar sprays of 0.4% nano urea at 30, 45 and 60 DAS recorded maximum yield and growth parameters in sunflower (Vyankatrao *et al*., 2024) [26]. Application of 75% recommended dose of nitrogen combined with foliar spray of nano urea at 6 ml L^{-1} significantly enhanced growth, yield attributes and yield in Indian mustard (Acharya *et al*., 2024) [27].

Horticultural crops

Foliar nutrition with nano urea has enhanced the nutrient use efficiency and overall crop performance in various horticultural crops. Application of 100% recommended dose of nitrogen through urea combined with one spray of 0.4% nano urea resulted in improved yield and growth attributes in strawberry (Sonkar *et al*., 2025) [28]. A study concluded that applying 100 per cent P_2O_5 and K_2O +75% recommended dose of nitrogen along with two foliar sprays of liquid nano urea or urea can effectively replace 25% of the recommended nitrogen dose while achieving yields equivalent to 100% recommended dose of nitrogen in sugarcane (Patel *et al*., 2024) [29]. A field study on onion showed that reducing the nitrogen dose by 25% and supplementing it with two foliar sprays of 0.4% nano urea at 30 and 60 DAT improved growth and yield attributes compared with both full and reduced nitrogen doses applied alone or with conventional urea sprays (Dubey *et al*., 2023) [30]. Balamurugan *et al*., (2024) [31] reported that the combined application of 75% nitrogen through soil along with two foliar sprays of nano urea at 30 and 45 DAT produced superior yield and growth attributes in onion. Results from on farm potato trials showed that applying two foliar sprays of nano nitrogen allowed farmers to reduce conventional urea use by 50% while still achieving equal or higher yields than the recommended dose (Tiwari *et al*., 2021) [32].

Environmental impacts

Increased use of mineral nitrogen fertilizers results in release of harmful air pollutants especially agricultural N_2O emissions. Replacing conventional urea with nano urea offers a promising strategy to mitigate the problems due to uncontrolled urea application. Studies have reported that applying 75% of the recommended nitrogen dose along with two foliar sprays of nano urea or 5% urea can increase wheat grain yield while reducing nitrogen use by approximately 25% (1.02 billion kg annually). This reduction has the potential to lower CO_2-equivalent emissions by about 5.06 billion kg each year, by improving nutrient efficiency and contributing to India's long-term net-zero emission goals for 2070 (Upadhyay *et al*., 2023) [11]. Nano urea combined with conventional urea can increase potato growth and yield, while maintaining safety and reducing chemical fertilizer by 50% (Hoque and Khan, 2024) [33]. Direct application of nitrogen fertilizers into soil can result in substantial nutrient losses specially through volatilization, leaching and denitrification resulting only about 20-50% of the applied nitrogen available for plant uptake. Foliar delivery of nitrogen using nano fertilizers ensures that greater amount of nitrogen remains available in a readily absorbable form for plants (Singh *et al*., 2025) [18].

Potential benefits of liquid nano urea over urea

Liquid nano urea is a major innovation in the field of fertilizer technology, utilizing nano scale characteristics to enhance nutrient uptake and use efficiency. It is also an eco-friendly, highly efficient nitrogen source that supports better crop growth, yield, and quality (Yogendra *et al*., 2020) [34]. The slow release mechanism of nutrients throughout the crop growth period can reduce the leaching losses and can enable plants to utilize maximum available supply (El-Saadony *et al*., 2021) [35]. Nano urea is economically viable and cheaper than conventional urea and can enhance the nutrient use efficiency, these fertilizers can also prevent nutrient overdose by reducing the frequency of use and minimizing the production costs (Kottegoda *et al*., 2011) [36]. Foliar application of liquid nano urea allows uptake through stomata, ensuring targeted nutrient supply. The nanoparticles move into plant tissues and release nutrients slowly to specific sites, thereby reducing nutrient loss and environmental risks (Raliya *et al*., 2017; Kumar *et al*., 2021) [7, 37]. Nano urea is cost effective and is more economical than the conventional urea, a 500 ml bottle of nano urea can replace at least one bag of granular urea when applied at key crop stages. This reduction in fertilizer cost increases farmer's income, with field studies indicating an average benefit of 2000 Rs per acre (Kumar *et al*., 2020) [3].

Challenges and Limitations

Nano urea offers numerous environmental and efficiency benefits while its entire replacement for conventional urea can result in significant challenges such as yield penalties, safety uncertainties and regulatory gaps. Multiple studies have shown that substituting conventional urea with nano urea alone or at high replacement rates can lead to reduced crop yields and lower nitrogen uptake, especially in rice, wheat and okra. Full or partial replacement beyond 25 -33% can decrease yields by 3-17% and reduce grain protein content, indicating that nano urea cannot fully meet crop nitrogen demands on its own (Reddy *et al*., 2024; Sikka *et al*., 2025; Mandal *et al*., 2023; Chudasama *et al*., 2025) [38, 39, 40, 41]. There are studies supporting using nano urea as a supplement to conventional urea, allowing 25% reduction in conventional urea without yield loss (Upadhyay *et al*., 2023; Behera *et al*., 2025) [11, 42]. The environmental fate, accumulation, and potential toxicity of nano urea particles in soil and water are not fully known. There are concerns about nano particle buildup and possible ecological or food chain impacts (Kumar *et al*., 2023; Seleiman *et al*., 2020; Bhardwaj *et al*., 2022) [19, 43]. Direct exposure for farm workers during handling and application require detailed study as the high reactivity of nano particles can cause health hazards (Priyam *et al*., 2023; Kumar *et al*., 2023) [44, 19]. There is also a lack of clear and globally accepted regulations for nano fertilizers, leading to uncertainty about their safe use and environmental impact (Bhardwaj *et al*., 2022) [43]. Farmers also report confusion about application methods and dissatisfaction with yields, highlighting the need for better education and extension services (Vishakha *et al*., 2023) [45].

References

1. Savci S. An agricultural pollutant: Chemical fertilizer. Int J Environ Sci Dev. 2012;3(1):77-80.
2. Krasilnikov P, Taboada MA, Amanullah. Fertilizer use, soil health and agricultural sustainability. Agriculture. 2022;12(4):462.
3. Kumar Y, Singh T, Raliya R, Tiwari KN. Nano fertilizers for sustainable crop production, higher nutrient use efficiency and enhanced profitability. Indian J Fertilisers. 2021;17:1206-1214.
4. Hignett TP. Urea. In: Hignett TP, editor. Fertilizer Manual. Dordrecht: Springer Netherlands; 1985. p. 109-121.
5. Lakshman K, Chandrakala M, Prasad PS, Babu GP, Srinivas T, Naik NR, *et al*. Liquid nano-urea: An emerging nano fertilizer substitute for conventional urea. Chron Bioresour Manag. 2022;6:054-059.
6. Suthar NK, Desai CK, Desai JS. Nano urea: A review paper. Int J Adv Biochem Res. 2023;7(2S):577-580.
7. Raliya R, Saharan V, Dimkpa C, Biswas P. Nanofertilizer for precision and sustainable agriculture: Current state and future perspectives. J Agric Food Chem. 2017;66(26):6487-6503.
8. Mahapatra DM, Satapathy KC, Panda B. Biofertilizers and nanofertilizers for sustainable agriculture: Phycoprospects and challenges. Sci Total Environ. 2022;803:149990.
9. Madhavi A, Pasha ML, Sudhakar KS, Goud G. Evaluation of foliar application of nano urea on performance of rabi sunflower (*Helianthus annuus* L.). Int J Environ Clim Change. 2022;12(11):2700-2706.
10. Acharya SM, Bhakare BD, Durgude AG, Thakare R. Effect of foliar application of nano urea on yield and yield contributing characteristics of wheat grown under normal and saline-sodic soils. Curr Agric. 2024;41(1).
11. Upadhyay PK, Dey A, Singh V, Dwivedi BS, Singh T, Babu S, *et al*. Conjoint application of nano-urea with conventional fertilizers: An energy-efficient and environmentally robust approach for sustainable crop production. PLoS One. 2023;18.
12. Gondwal P, Rana MK, Dhankar A, Sahil, Mohan J. Role of nano-urea in optimizing nitrogen use efficiency, yield and quality of rice: A review. Int J Res Agron. 2024;SP-7(10):182-187.
13. Namasharma S, Pahari A, Banik A, Pal S, Sana M, Banerjee H. Impact of foliar applied nano-urea on growth, productivity and profitability of hybrid rice (*Oryza sativa* L.). Oryza. 2023;60(3):464-472.
14. Bhargavi G, Sundari A. Effect of nano urea on growth and yield of rice (*Oryza sativa*) under SRI. Crop Res. 2023;58(1-2):12-17.
15. Pedireddy S, Kumar M, Saha S, Nag NK, Chandrakar TP, Singh DP. Effect of nano-urea on growth, productivity and economics of transplanted rice. Int J Econ Plants. 2024;11(3):217-221.
16. Katre NN, Kulkarni PP, Bhukya R. Effect of foliar sprays of nano-urea on growth and quality of transplanted paddy (*Oryza sativa* L.). Int J Adv Biochem Res. 2024;8(7):21-24.
17. Tripathi S, Kumar N, Venkatesh K. Nano urea's environmental edge and economic efficacy in boosting wheat grain yield across diverse Indian agro-climates. Sci Rep. 2025;15(1).
18. Singh H, Singh N, Singh B, Kaur V, Singh B. Effects of different nitrogen levels and nano urea sprays on growth, yield and economics of wheat (*Triticum aestivum* L.): A review. Annu Res Rev Biol. 2025;40.
19. Kumar N, Tripathi S, Yadav D, Samota S, Venkatesh K, Sareen S, *et al*. Boosting wheat yield, profitability and NUE with prilled and nano urea in conservation tillage. Sci Rep. 2023;13(1).
20. Dabhi MS, Patel MD, Patel AS, Vihol KJ, Patel VM. Effect of nano urea on growth, yield attributes and yield of wheat under irrigated condition. Int J Curr Microbiol Appl Sci. 2024;14(1):235-240.
21. Rani G, Lata S, Chaudhary S, Singh S, Prakash H. Effect of nano urea on growth and yield of wheat (*Triticum aestivum* L.) under irrigated condition. Int J Res Agron. 2024;7(8).
22. Kundu AK, Chhabra V. Effect of application of nano-urea on maize growth and yield under Punjab conditions. Ecol Environ Conserv. 2024;29:1604-1607.
23. Dokhe PK, Wadile SC, Shant PU, Gunjal BS, Ghutke TD, Bacchav DN. Effect of nano-urea application on yield and economics of kharif maize (*Zea mays* L.). Int J Res Agron. 2024;7(12S):102-105.
24. Roy A, Singh M. Synergic effect of nano urea, sulphur and boron fertilization on sunflower growth and quality. J Appl Nat Sci. 2024;16(3).
25. Veeramani P, Subrahmaniyan K, Manickam S, Ravichandran V, Saravanan PA, Jayakumar J, *et al*. Enhancing rainfed castor growth, seed and oil yield via nano urea application. Int J Environ Clim Change. 2023;13(12):46-52.
26. Vyankatrao KS, Baburao AP, Amrut RR, Jaipal KP, Ashroba IO. Effect of foliar application of nano-urea on sunflower growth, nutrient uptake and quality. Int J Plant Soil Sci. 2024;36(4):184-190.
27. Acharya P, Solanki NS, Gehlot JK, Rajwaniya A, Jaiswani S, Champawat TS, *et al*. Effect of nano urea on growth and yield attributes of Indian mustard (*Brassica juncea* L.). Int J Res Agron. 2024;SP-7(12):236-238.
28. Sonkar MK, Mandal G, Kumar N, Singh D. Effect of nano-urea on performance of strawberry (*Fragaria* × *ananassa* Duch.). Int J Plant Soil Sci. 2025;37(5):360-365.
29. Patel KK, Zinzala VJ, Chaudhari NM, Chaudhary BJ, Chudasama SD, Shiyal VN, *et al*. Effect of liquid nano urea fertilizer on growth and yield of sugarcane. Asian J Soil Sci Plant Nutr. 2024;10(3):343-355.
30. Dubey PM, Upadhyay J, Chowdhury S, Bagare V. Response of onion (*Allium cepa* L.) to foliar application of nano urea and urea. Int J Environ Clim Change. 2023;13(11):1816-1821.
31. Balamurugan P, Shinde SR, Patil BT, Durgude AG, Dahatonde KN. Effect of nano urea on yield and benefit-cost ratio of onion. Int J Adv Biochem Res. 2024;SP-8(10):833-837.
32. Tiwari KN, Kumar Y, Nayak RK, Rai A, Singh J, Srivastava SSA. Nano-urea for enhancing yield and farmers' profit with potato. Ann Plant Soil Res. 2021;23(4):495-500.
33. Hoque MR, Khan MSH. Growth and yield response of nano urea with conventional urea in potato. Int J Biol Eng Agric. 2024;3(3):378-385.
34. Yogendra K, Tiwari KN, Singh T, Sain NK, Laxmi S, Verma R, *et al*. Nanofertilizers for enhancing nutrient use efficiency and economic returns. Ann Plant Soil Res. 2020;22(4):324-335.
35. El-Saadony MT, Almoshadak AS, Shafi ME, Albaqami NM, Saad AM, El-Tahan AM, *et al*. Vital roles of sustainable nano-fertilizers in improving plant quality and quantity. Saudi J Biol Sci. 2021;28(12):7349-7359.

36. Kottegoda N, Munaweera I, Madusanka N, Karunaratne V. Green slow-release fertilizer based on urea-modified hydroxyapatite nanoparticles. Curr Sci. 2011;100:73-78.
37. Kumar YO, Tiwari KN, Singh T, Raliya R. Nanofertilizers and their role in sustainable agriculture. Ann Plant Soil Res. 2021;23(3):238-255.
38. Reddy KS, Shivay YS, Kumar D, Pooniya V, Prasanna R, Shrivastava M, *et al*. Relative performance of urea and nano-urea with zinc fertilization in spring wheat. J Soil Sci Plant Nutr. 2024;24(2):3593-3609.
39. Sikka R, Kalia A, Ahuja R, Sidhu SK, Chaitra P. Substitution of soil urea fertilization with foliar nano urea decreases rice and wheat yield. Plant Soil. 2025;512(1):1475-1491.
40. Mandal UK, Mal S, Naiya AK, Ghosh A, Nayak DB, Digar S, Bhardwaj A. Nano-urea for vegetable cultivation in coastal West Bengal. J Indian Soc Coast Agric Res. 2023;41(1).
41. Chudasama SD, Usadadia VP, Patel UJ, Ninama AR, Patel KS, Chaudhri KM. Impact of liquid nano urea on soil properties after harvest of summer rice. Int J Res Agron. 2025;SP-8(1):14-17.
42. Behera RD, Majhi P, Dash S, Mishra PJ, Sen J, Phonglosa A, *et al*. Effect of nano urea liquid fertilizer in paddy under different agroclimatic zones. Arch Curr Res Int. 2025;25(3):180-185.
43. Bhardwaj AK, Arya G, Kumar R, Hamed L, Pirasteh-Anosheh H, Jasrotia P, *et al*. Switching to nanonutrients for sustaining agroecosystems. J Nanobiotechnol. 2022;20(1):19.
44. Priyam A, Seth P, Mishra J, Manna P, Singh P. Occupational safety assessment of biogenic urea nanofertilisers. Heliyon. 2023;9.
45. Vishakha K, Deepa N, Rohini A, Vidhyavathi A, Ravikumar R. Awareness and perception of farmers and dealers on nano urea. Int J Environ Clim Change. 2023;13(10):981-991.