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Influence of nitrogenous fertilizers (Urea and nano urea) on soil chemical properties: Post-harvest

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Abstract

Efficient nitrogen management is vital for sustaining soil fertility and enhancing crop productivity. This study evaluated the effects of different nitrogen fertilization strategies comprising conventional urea and nano urea on soil chemical properties following crop harvest. Twelve treatments were arranged using varying combinations and timings of urea and nano urea applications at three nitrogen levels: 100%, 75%, and 50% of the recommended dose (RDN). Soil samples collected after harvest were analyzed for pH, electrical conductivity (EC), and organic carbon (OC) content. Results revealed, plots receiving lesser quantity of conventional urea, exhibited higher soil pH and EC compared to the application of higher amount of conventional urea. The highest pH (7.51) and EC (0.34 dS/m) were recorded under the 50% RDN treatment with dual nano urea sprays. Additionally, organic carbon was generally higher in nano urea-treated plots, indicating improved soil organic matter retention. These findings indicated that the application of reduced quantity of urea in conjunction with nano urea, can maintain or enhance critical soil chemical properties, offering a promising strategy for improving nutrient use efficiency and soil health in sustainable crop production systems.

Keywords: Nano urea, soil pH, organic carbon, electrical conductivity, sustainable agriculture, fertilizer management, soil fertility

Introduction

Nitrogen (N) is one of the most critical macronutrients for plant growth and productivity, playing a central role in photosynthesis, protein synthesis and chlorophyll formation. However, the excessive and inefficient use of conventional nitrogenous fertilizers such as urea has led to significant agronomic and environmental concerns, including nutrient leaching, greenhouse gas emissions and deterioration of soil health (Zhang *et al.*, 2018; Kumar *et al.*, 2021) ^[14, 6]. It is estimated that crops utilize only 30-50% of applied nitrogen fertilizers, with the remainder contributing to various forms of nitrogen loss and environmental degradation (Ladha *et al.*, 2020) ^[16].

To address the low nitrogen, use efficiency (NUE) of conventional fertilizers, recent advances in nanotechnology have led to the development of nano fertilizers, particularly nano urea, which offers a promising alternative due to its enhanced surface area, targeted delivery and controlled release characteristics (Kottegoda *et al.*, 2017; Rajput *et al.*, 2023) ^[4, 11]. Nano urea, has been reported to improve nutrient uptake, reduce losses and increase crop productivity while minimizing environmental impacts (Adhikari *et al.*, 2022) ^[11].

Maintaining soil chemical balance is essential for sustainable crop production. Excessive use of urea often results in soil acidification, reduced microbial activity and degradation of organic matter (Mahmoud & El-Kader, 2014) ^[8], whereas nano urea, due to its lower application rates and higher efficiency, may mitigate these adverse effects and improve soil quality over time (Kumar & Dixit, 2023) ^[5]. However, comparative evaluations of nano urea and conventional urea on post-harvest soil properties remain limited under field conditions.

This study, therefore, aims to evaluate the effect of different nitrogen management strategies including varied doses and combinations of conventional urea and nano urea on the chemical properties of soil after crop harvest. The investigation focuses on key parameters such as soil pH, electrical conductivity and organic carbon, with the goal of assessing how these

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treatments influence soil health and contribute to more sustainable fertilizer management practices.

Materials and Methods

This research was undertaken at the College of Horticulture Bagalkot (2022-2023), located at 16°10' N latitude and 74°42' E longitude, with an elevation of 542 meters above sea level, in the northern dry agro-climatic zone of Karnataka (Zone-3), characterized by an average annual rainfall of 548 mm and a mean temperature of 23.01 °C. The soil at the experimental site was classified as red sandy loam. During the study period, the region experienced a total rainfall of 49.9 mm, with relative humidity averaging 77.64% in the morning and 28.75% in the afternoon. Temperature fluctuations ranged from 18.57 °C to 35.71 °C. The experiment employed a Randomized Complete Block Design (RCBD) with 12 treatments, each replicated three times. Tomato plants (Abhilash hybrid variety) were planted at 90 x 45 cm apart, and cultivated under irrigated conditions during the spring-summer season.

Experimental details

T₁ (100% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT

T₂ (100% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT + 25% urea at 45 DAT

T₃ (100% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L⁻¹) at 45 DAT

T₄ (100% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 and 45 DAT

T₅ (75% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT

T₆ (75% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT + 25% urea at 45 DAT

T₇ (75% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L⁻¹) at 45 DAT

T₈ (75% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 and 45 DAT

T₉ (50% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT

T₁₀ (50% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 DAT + 25% urea at 45 DAT

T₁₁ (50% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L⁻¹) at 45 DAT

T₁₂ (50% RDN): 50% as basal dose + nano urea (2 ml L⁻¹) at 30 and 45 DAT

RDN: recommended dose of nitrogen, **DAT:** Days after transplantation

Fertilizer application

Fertilizer application for tomato cultivation followed the University of Horticultural Sciences Bagalkot's guidelines, which prescribe 38 tons of FYM and 250:250:250 kg N: P₂O₅: K₂O per hectare. The application schedule included soil application of urea, single super phosphate (SSP), and muriate of potash (MOP), as well as foliar application of IFFCO nano urea. The fertilizers were applied in two stages: a basal dose consisting of half dose of nitrogen and full dose of phosphorus and potassium, followed by top dressing with urea and nano urea (2ml L⁻¹) at 30 and 45 days after transplanting.

Soil sample collection and analysis

Prior to the initiation of experiment, soil samples were collected from a depth of 0 to 15 cm and a composite sample was made using the quartering technique. The same procedure was adopted for soil sample collection after the harvest of the crop. The collected soil samples were shade dried, and passed through 2 mm sieve (Klute, 1986) [3]. These samples were analysed for different parameters by adopting appropriate protocols.

Soil pH was determined potentiometrically in a 1:2.5 soil-water suspension and EC (dS m⁻¹) was determined in a similar suspension by Conductometric method as suggested by Jackson (1973) [2] and organic carbon (OC%) content was assessed using the chromic acid wet digestion method (Walkley and Black, 1934) [12].

Statistical analysis

The data in respect of all the parameters were tabulated and subjected to the statistical analysis (ANOVA) by adopting Randomized Complete Block Design and results were tested at 5 percent level of significance using Fischer's method of analysis of variance as suggested by Panse and Sukhatme (1967) [9]. Critical difference at 5 percent was worked out whenever 'F' test was significant.

Result and Discussion

Application of nano urea significantly influenced the chemical properties of the soil after crop harvest, particularly in relation to soil pH, electrical conductivity (EC) and organic carbon (OC) content (Table 1). The soil pH ranged from 7.24 to 7.51, with the highest pH observed under the T₁₂ treatment (50% RDN with top dressing of nano urea at 30 and 45 DAT). This suggests that reduced urea application may help maintain or slightly increase soil alkalinity compared to application of large quantity of urea, likely due to reduced ammonium-induced acidification (Kumar *et al.*, 2021; Kumar & Dixit, 2023) [6, 5]. Conversely, the lowest pH (7.24) was recorded in T₁, which received the full RDN exclusively through conventional urea, aligning with previous findings that continuous urea application can lower soil pH due to nitrification and associated proton release (Zhang *et al.*, 2018) [14].

Electrical conductivity (EC) values remained within acceptable agronomic limits (0.25-0.34 dS/m), with T₁₂ again showing the highest EC. This moderate increase in EC in nano urea-treated plots may be due to the reduced application of conventional urea which can temporarily enhance ionic concentration in the soil solution without leading to salinity issues (Kumar *et al.*, 2021; Singh & Aulakh, 2019) [6, 15]. The lowest EC was observed in the T₁ treatment, possibly due to rapid uptake and leaching of conventional urea, a finding consistent with earlier reports on conventional nitrogen loss pathways (Mahmoud *et al.*, 2014) [8].

Soil organic carbon (OC) varied across treatments, ranging from 0.37% in T₉ (50% RDN with only urea) to 0.47% in T₂ and T₄, both of which incorporated nano urea into their fertilization strategy. These findings support previous reports suggesting that nano urea may enhance microbial activity and root biomass development, which contribute to greater organic matter retention in the soil (Yadav *et al.*, 2020; Prasad *et al.*, 2018) [13, 7, 10]. Higher OC levels under nano urea treatments also indicate a potential improvement

in soil structure and nutrient-holding capacity (Adhikari *et al.*, 2022)^[1].

Collectively, these results suggest that integrating nano urea into nitrogen management regimes, especially at reduced RDN levels, not only maintains but can improve key soil chemical properties. The T₁₂ treatment, with 50% RDN and nano urea applied at 30 and 45 DAT, emerged as the most

beneficial strategy in terms of enhancing pH, EC and OC. This aligns with recent studies that advocate for nano-fertilizers as efficient, environmentally friendly alternatives to conventional fertilizers, capable of sustaining soil health under lower nutrient input systems (Rajput *et al.*, 2023; Kottegoda *et al.*, 2017)^[11,4].

Table 1: Influence of nitrogenous fertilizers (urea and nano urea) on chemical properties of soil after the harvest of the crop

Treatments	pH	EC (dS/m)	OC (%)
Initial properties	7.62	0.43	0.41
T ₁ (100% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT	7.24 ^e	0.25	0.43
T ₂ (100% RDN): 50% as basal dose + nano urea (2 ml L ⁻¹) at 30 DAT + 25% urea at 45 DAT	7.25 ^d	0.26	0.47
T ₃ (100% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L ⁻¹) at 45 DAT	7.29 ^{cde}	0.29	0.45
T ₄ (100% RDN): 50% as basal dose + nano urea (2 ml L ⁻¹) at 30 and 45 DAT	7.36 ^{bc}	0.28	0.47
T ₅ (75% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT	7.29 ^{cde}	0.29	0.38
T ₆ (75% RDN): 50% as basal dose + nano urea (2 ml L ⁻¹) at 30 DAT + 25% urea at 45 DAT	7.36 ^{bc}	0.30	0.40
T ₇ (75% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L ⁻¹) at 45 DAT	7.34 ^{bcd}	0.28	0.42
T ₈ (75% RDN): 50% as basal dose + nano urea (2 ml L ⁻¹) at 30 and 45 DAT	7.41 ^b	0.28	0.44
T ₉ (50% RDN): 50% as basal dose + 25% urea at 30 DAT + 25% urea at 45 DAT	7.36 ^{bc}	0.30	0.37
T ₁₀ (50% RDN): 50% as basal dose + nano urea (2 ml L ⁻¹) at 30 DAT + 25% urea at 45 DAT	7.36 ^{bc}	0.32	0.38
T ₁₁ (50% RDN): 50% as basal dose + 25% urea at 30 DAT + nano urea (2 ml L ⁻¹) at 45 DAT	7.35 ^{bcd}	0.31	0.39
T ₁₂ (50% RDN): 50% as basal dose + nano urea (2 ml L ⁻¹) at 30 and 45 DAT	7.51 ^a	0.34	0.41
S.Em±	0.03	0.02	0.04
CD (5%)	0.10	NS	NS

Conclusion

The findings of this study underscore the potential of nano urea as a transformative input in modern nitrogen management strategies. Across all measured parameters soil pH, electrical conductivity, and organic carbon content treatments involving nano urea, particularly when combined with reduced doses of conventional nitrogen, demonstrated improved or comparable outcomes to full-dose conventional urea treatments. Notably, the application of nano urea at both 30 and 45 days after transplanting under a 50% RDN regime (T₁₂) yielded the most favorable soil chemical profile.

This improvement in soil chemical health is critical for long-term agricultural sustainability, as it reflects balanced nutrient cycling, better organic matter retention, and minimal risk of salinity or acidification. The results also point toward a paradigm shift in fertilizer use moving away from quantity toward precision, efficiency, and ecological responsibility. By enhancing nitrogen use efficiency and reducing chemical burden on the soil, nano urea offers a compelling path forward for integrated nutrient management systems that are both environmentally benign and agronomically effective.

In conclusion, the integration of nano urea into fertilizer regimes presents a viable solution to the dual challenge of improving crop nutrition and preserving soil health. Future research should focus on multi-season trials, crop yield responses, and long-term soil microbial dynamics to fully capture the agronomic and ecological benefits of this novel input. If scaled judiciously, nano urea could be a cornerstone in the evolution of sustainable agriculture.

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