International Journal of Biological Engineering and Agriculture
ISSN: 2833-5376
Volume 03 Number 03 (2024)
https://journal.academicjournal.id/index.php/ijbea/index

Article

Greater Growth and Yield Response of Nano Urea with Conventional Urea for Potato (*Solanum tuberosum*) Cultivation

Md. Rayhanul Hoque[1], Md. Shahadat Hossain Khan[2*]

1. Department of Soil Science, Hajee Mohammad Danesh Science & Technology University, Dinajpur, Bangladesh
2. Department of Soil Science, Hajee Mohammad Danesh Science & Technology University, Dinajpur, Bangladesh

* Correspondence: khan_bely@yahoo.com

Abstract: In today's world, adopting new technology is essential to sustain future production. Nanotechnology is becoming increasingly popular due to its efficiency in various scientific applications. In agriculture, nanomaterials significantly enhance the effectiveness of fertilizers and pesticides. Nano fertilizers, in particular, require very small quantities and leave negligible residues, making them environmentally friendly. With this in mind, an experimental trial was conducted during the winter (Rabi) season of 2023-2024 at the Department of Soil Science, HSTU, Dinajpur. The trial used a randomized complete block design (RCBD) with 7 treatments and three replications, focusing on nano-urea i.e., T_1 = Control, T_2 =100% RDF, T_3 = Only Nano urea (3 sprays), T_4 = Nano urea (3 sprays) + rest all (no urea), T_5 = 50% urea + Nano urea (3 sprays) + rest all, T_6 = No urea + no Nano + rest all and T_7 = Only urea, respectively. The results revealed that most of the growth parameter with tuber yield was achieved highest in treatment T_5, which involved 50% urea combined with nano-urea (3 sprays) and all other standard practices, followed by treatment T_2 with 100% recommended doses of fertilizers (RDF). Nano-urea showed promising results in terms of dry matter percentage, chlorophyll content, % protein, and starch levels. It proved to be economically viable by reducing the use of chemical fertilizers by 50%, controlling nutrient release from the soil, providing crops with precise nutrient amounts, increasing yield, and maintaining environmental safety through improved nutrient use efficiency.

Keywords: nanotechnology, plant nutrition, nano urea, nutrient use efficiency

Citation: Hoque, R., & Khan, S. H. Greater Growth and Yield Response of Nano Urea with Conventional Urea for Potato (*Solanum tuberosum*) Cultivation. International Journal of Biological Engineering and Agriculture 2024, 3(3), 378-385.

Received: 29th Jul 2024
Revised: 5th Aug 2024
Accepted: 12th Aug 2024
Published: 19th Aug 2024

1. Introduction

Bangladesh is the fourth largest potato producing country and ranks among the top 15 globally. All agro-ecological zones of Bangladesh are suitable for potato cultivation following wheat and rice, and it holds significant importance in for the consumers along with industries. Major potato productions are covered by northern part of Bangladesh. As nanotechnology emerges as a promising strategy to boost agricultural output, its application in agriculture has become crucial. Potatoes, being heavy feeder crops, require substantial amounts of fertilizer for growth, development, and production (Nityamanjari, 2018).

Effective nutrient management for potatoes is essential to maintain soil and environmental health without compromising crop yield. Potato crops need 180-240 kg N/ha fertilizers to achieve a tuber yield of 35-45 t ha^{-1}, yet the nitrogen use efficiency (NUE) in potatoes is only 40-50%, with the remaining nitrogen lost to the environment (Trehan and Singh, 2013). A bulk volume of commercial urea is needed for potato production that requires a number of labors including the investments of extra money. The addition of macro and micronutrients to crop fields is a common agricultural practice, with NPK fertilizers being widely used to boost crop productivity. However, these fertilizers are often applied without considering their negative impacts on soil characteristics and nutritional values. The overuse of chemical fertilizers can significantly alter soil physiology, reduce soil fertility, damage plant life, and lead to soil erosion due to exposure to wind and rain. Excessive fertilizer runoff into water bodies can cause eutrophication, posing a threat to aquatic life. Specifically, the conventional use of nitrogenous fertilizer (urea) in rice results in low nutrient use efficiency (around 30%), which is lower compared to many other upland crops (50%) (Vijayakumar et al., 2022).

Urea molecules sized between 20-50 nanometers can deliver nitrogen to crops more precisely. A single nano-urea liquid particle has a surface area to volume ratio 10,000 times greater than that of conventional granular urea. Due to their extremely small size and surface properties, nano-urea liquid particles are more effectively absorbed by plants when sprayed on their leaves (Valojai *et al*., 2021; Midde *et al*., 2022). Therefore, applying nano-urea liquid foliarly at critical growth stages is expected to meet the plant's nitrogen needs, potentially leading to higher crop productivity and quality compared to conventional urea. In contrast, traditional pellet urea, when spread on the soil, provides only 30-50% of nitrogen to crops, with the remainder being wasted due to leaching, which also contaminates soil and water bodies (Prasad *et al.,* 2014).

Thus, finding alternative ways to mitigate nitrogen loss and improve fertilizer use efficiency is critical for sustainable agriculture. Nano-urea, introduced by IFFCO in India and authorized under the fertilizer control order (FCO), has shown advantages over traditional methods through extensive investigations and trials. Despite numerous efforts, NUE in agriculture remains below 50%. Achieving targeted crop yields often leads to nitrogen overuse, posing economic and environmental challenges worldwide. Continuous exploration of innovative solutions has led to the development of novel nanomaterials, providing powerful tools for new technological advancements (Mejías *et al.,* 2021). Nitrogen use efficiency is a well-established metric for assessing nitrogen management, though finding a comprehensive resource that consolidates various NUE indices and their strengths and weaknesses is challenging (Congreves *et al*., 2021). Observations suggest that the future of agriculture will benefit greatly from the efficiencies of nano fertilizers (Dutta and Bera, 2021). With these considerations, a field trial was conducted with the following objectives:

1. To determine the effect of nano fertilizers on the growth and yield of the potato crop, and
2. To evaluate the feasibility of reducing the doses of commercial urea fertilizers.

2. Materials and Methods

Location and season:

The field trial was conducted at research field under the Department of Soil Science, HSTU, Dinajpur during the winter (Rabi) season of 2023-2024.

Planting materials, time of sowing and spacing:

The potato cultivar used in the experiment was Diamant (BARI Alu-7) and medium size tubers (30-35 g) were planted on 16-11-2023 at a spacing of 8 inches (seed to seed) and 24 inches (row to row) and thus covered with soil.

Type of soil and land preparation:

The soil of the experimental plot was sandy loam. Normal land preparation was done with plowing, followed by harrowing and planking or leveling.

Experimental design, treatment and layout:

The experiment was consisted 7 treatments with 3 replications i.e., arranged in RCBD (Randomized Completely Block Design). The treatments are as follows-T_1 = Control, T_2 =100% RDF, T_3 = Only Nano urea (3 sprays), T_4 = Nano urea (3 sprays) + rest all (no urea), T_5 = 50% urea + Nano urea (3 sprays) + rest all, T_6 = No urea + no Nano + rest all and T_7 = Only urea, respectively.

Fertilization:

Nano urea 500 ml per acre (4ml/L) and the recommended doses of fertilizer urea, TSP, MoP, gypsum, magnesium, $ZnSO_4$ and boric acid were used @ 370, 370, 270, 100, 100, 10 and 20 kg ha^{-1}, respectively for potato (FRG, 2018). TSP, gypsum, magnesium, and boric acid was applied on final land preparation except zinc that were applied separately without mixing others, two split application of urea and MoP were done where half was applied at planting time on first earthing up and half at 45 days after planting on second earthing up, which is generally recommended in potato for better efficiency. Nano fertilizers were applied thrice, at 30, 45 and 60 days after planting.

Data collection and sample (Plant leaves, tuber and soil) analysis:

The parameter was recorded at harvest and during the growing period i.e., plant height (cm), number of branches per plant, stem diameter, fresh weight per plant, dry weight per plant, number of tubers per plant, rejected tuber per plant, single tuber weight (g), diameter of tuber, tuber weight per plant (g), total tuber yield (t ha^{-1}) and rejected tuber yield (t ha^{-1}), respectively. Chemical analysis of potato tuber like % Dry matter, chlorophyll content, % protein and total carbohydrate was estimated. The soil chemical properties of % total N content was analyzed by Semi micro-Kjeldahl method in the laboratory of the Department of Soil Science, HSTU, Dinajpur.

Statistical Software:

The data were analyzed by using the statistical software Statistix 10.0 and mean difference were at 5% level of significance.

3. Results and Discussion

Effects of nano urea on potato tuber growth and yield:

It was observed that plant height (80.05 cm), number of branches per plant (3.0), stem diameter (10.16 cm), fresh and dry weight(36.00 and 7.5 g) per plant were maximized and statistically identical mostly with treatment T_5 (Table 1), where the crop was fertilized with 50% urea + nano urea (3 sprays) + rest all as standard practices, compared to the recommended doses of fertilizers used in farmer's level with the values 80.0 cm, 3.35, 10.17, 36.09 g, and 7.90 g, respectively.

Table 1. Effects of nano urea combined with chemical fertilizers of potato on plant height (cm), number of branches per plant, stem diameter, fresh weight per plant, dry weight per plant, number of tubers per plant, respectively

Treatment	Plant height (cm)	No. of Branches plant^{-1}	Stem diameter(cm)	Fresh wt. plant^{-1} (g)	Dry wt. plant^{-1} (g)	Number of tuber plant^{-1}
T_1	64.00ab	3.00	5.93b	14.73f	5.65d	6.33c
T_2	80.00a	3.35	10.17a	36.09a	7.90a	8.67b
T_3	59.00bc	3.00	8.47 ab	21.69d	2.19e	6.00cd
T_4	50.66bc	3.00	8.46ab	20.22e	5.76d	5.33de
T_5	80.08a	3.00	10.16a	36.00a	7.50b	12.00a
T_6	39.33c	3.33	6.77b	26.61c	6.22c	5.00e
T_7	46.67bc	3.00	8.04ab	33.22b	7.47 b	5.00e
SE (m) ±	9.12	0.26	1.54	0.46	0.10	0.43
CV %	18.64	10.38	22.85	2.14	2.19	7.63

Effects of nano urea combined with chemical fertilizers of potato on plant height (cm), number of branches per plant, stem diameter, fresh weight per plant, dry weight per plant, number of tubers per plant, respectively. Presented data are the mean value of three replications, CV= Coefficient of variance at 5% level of significance ($p \leq 0.05$). Treatment combinations were as follows: T_1 = Control, T_2 =100% RDF, T_3 = Only Nano urea (3 sprays), T_4 = Nano urea (3 sprays) + rest all (no urea), T_5 = 50% urea + Nano urea (3 sprays) + rest all, T_6 = No urea + no nano + rest all and T_7 = Only urea, respectively.

Treatment T_5 was found to be the best among all treatments in terms of the number of tubers (12.0) per plant and the second highest on treatment T_2 (8.67) but sizes were bigger than the best one (Table 1). Table 2 represented with zero numbers of rejected tubers per plant on treatment T_5 @ 50% urea + nano urea (3 sprays) + rest all while the 100% RDF treatment (T_2) showed the highest number of rejected tubers (1.67) which returns less benefit on B:C ratios (Table 3). Additionally, single tuber weight (162.45g), tuber diameter (45.51 cm), tuber weight per plant (369.81 g), and total tuber yield (21.0 t ha^{-1}) were mostly similar between the 100% RDF treatment and treatment T_5 (50% urea + nano urea (3 sprays) + rest all) with values 147.71 g, 44.68 cm, 374.54 g and 21.08 t ha^{-1}, respectively. However, the yield of rejected tubers was 1.24-fold lower in the T_5 treatment compared to treatment T_2 (100% RDF), which (T_2) recorded the highest number and yield of rejected tubers (Table 3).

A critical examination of the data reveals that treatment T_5 with 50% urea + nano urea (3 sprays) + rest all proved significantly superior to T_2 (100% RDF) in terms of potato growth and tuber yield. Higher yield with 50% less fertilizers and 2 sprays of nano urea on 187 trials than recommended doses of fertilizers were observed by Tiwari KN *et al.*, 2021and Raliya *et al*. 2017. Growth and yield contributing traits of potato tubers might be increased due to the fact that nano-nitrogen release slowly (Rameshasiah and Jpallavi, 2015) by providing crops with the exact amounts of nutrients in the right proportions (DeRosa *et al*. 2020) and increased the average weight of individual tubers, more marketable grade tuber production, thereby increasing the total tuber yield due to increased translocation of starch from source to sink (Neogi and Das, 2022). Similar findings were reported (Das and Chakraborty, 2018; Manikanta *et al.* 2023; and Lenka and Das, 2019) in potato. Whereas, in control treatment T_1 the total tuber yield including other parameters reduced drastically as potato is a heavy feeder crop.

Table 2. Effects of nano urea combined with chemical fertilizers of potato on rejected tuber per plant, single tuber weight (g), diameter of tuber, tuber weight per plant (g), total tuber yield (t ha^{-1}) and rejected tuber yield (t ha^{-1}), respectively

Treatment	Rejected tuber $plant^{-1}$	Single tuber wt. (g)	Diameter of tuber (cm)	Tuber wt. $plant^{-1}$ (g)	Total tuber yield (t ha^{-1})	Rejected tuber yield (t ha^{-1})
T_1	1.33 ab	97.93 d	40.24 b	110.49 d	9.67 d	1.25b
T_2	1.67 a	162.45 a	45.51 a	369.81 a	21.00 a	2.38a
T_3	1.33 ab	124.47 c	35.43 d	276.52bc	14.85 b	1.42ab
T_4	0.33 c	88.27e	35.85 cd	146.46 d	10.17 d	1.25b
T_5	0.00 c	147.71ab	44.68 a	374.54 a	21.08 a	1.08b
T_6	0.67 bc	88.70 e	37.77 c	215.09 c	12.92 c	1.92ab
T_7	0.33 c	136.33 b	45.89 a	292.33 b	13.50 bc	1.79ab
SE (m) ±	0.43	1.71	0.98	28.29	0.63	0.49
CV %	65.11	1.71	2.96	13.59	5.24	36.62

Effects of nano urea combined with chemical fertilizers of potato on rejected tuber per plant, single tuber weight (g), diameter of tuber, tuber weight per plant (g), total tuber yield (t ha^{-1}) and rejected tuber yield (t ha^{-1}), respectively. Presented data are the mean value of three replications, CV= Coefficient of variance at 5% level of significance ($p \leq 0.05$). Treatment combinations were as follows: T_1 = Control, T_2 =100% RDF, T_3 = Only Nano urea (3 sprays), T_4 = Nano urea (3 sprays) + rest all (no urea), T_5 = 50% urea + Nano urea (3 sprays) + rest all, T_6 = No urea + no nano + rest all and T_7 = Only urea, respectively.

Table 3. Effects of nano urea combined with chemical fertilizers on % Dry matter, chlorophyll content, % protein and total carbohydrate, respectively

Treatment	Dry matter (%)	Total chlorophyll (mg/ml)	Protein (%)	Carbohydrate (%)	Benefit-cost ratio
T_1	23.68b	11.98d	2.18c	18.83e	-0.04
T_2	24.03ab	13.27a	2.64a	19.15c	0.77
T_3	21.05e	10.67e	1.73e	13.28g	-0.86
T_4	22.45c	12.76c	1.87d	19.79b	-0.12

T_5	24.37a	13.25a	2.61ab	19.04d	0.80
T_6	21.99d	9.95f	1.62f	20.00a	0.13
T_7	22.73c	13.03b	2.54b	18.587f	-0.88
SE (m) ±	0.21	0.04	0.04	0.03	
CV %	1.10	0.41	2.31	0.23	

Effects of nano urea combined with chemical fertilizers on % Dry matter, chlorophyll content, % protein and total carbohydrate, respectively. Presented data are the mean value of three replications, CV= Coefficient of variance at 5% level of significance ($p \leq 0.05$). Treatment combinations were as follows: T_1 = Control, T_2 =100% RDF, T_3 = Only Nano urea (3 sprays), T_4 = Nano urea (3 sprays) + rest all (no urea), T_5 = 50% urea + Nano urea (3 sprays) + rest all, T_6 = No urea + no nano + rest all and T_7 = Only urea, respectively.

Chemical Analysis of potato leaves and tubers:

Chemical parameters (Table 3) for tuber quality analysis showed significant differences with the application of nano urea. The highest percentage of dry matter (24.37 %) was found in treatment T_5 (50% urea + nano urea (3 sprays) + rest all), which was statistically similar (24.03%) to treatment T_2 (100% RDF). Nano-fertilizers provide more surface area for different metabolic reactions in the plant, which increases the rate of photosynthesis and bulking of tubers as well as increased dry matter percentage (Qureshi *et al.* 2018; Rahman *et al*. 2018). The total chlorophyll content (13.27 mg/ml) and protein percentage (2.64%) were highest in treatment T_2, which was statistically identical to treatment T_5 (13.25 mg/ml and 2.61%). Chlorophyll content increased due to the application nano nutrients and biofertilizer which plays a major role in the process of photosynthesis, leaf colour, and overall plant growth (Lichtenthaler and Rinderle, 1988; Babaei *et al.* 2017).

Potatoes are good source of amino acids (lysine and tryptophan) which is ultimately the protein that increased extra protein produced and helps the plant to grow larger when nano-chelated nitrogen applied (Lawlor *et al.* 1989; Mu *et al.* 2009). Treatment T_5 also had the highest carbohydrate percentage (20.0 %), indicating that it is the best treatment compared to T_2 (100% RDF). Important roles of N in chloroplast structure, CO_2 assimilation, and activation of enzymes involved in photosynthesis, which leads to an increase in photosynthesis and carbohydrate accumulation also consequently increase in starch content which is a primary nutrient from potatoes (Aditi Chauhan *et al.,* 2023; Kumar *et al.* 2014). The benefit-cost ratio (B:C) indicated that T_5 was superior to the other treatments, yielding maximum output compared to treatment T_2 (100% RDF). The increase in B:C ratio might be due to an increase in yield with the foliar application of both nano nitrogen and zinc which fetched more prices in the market (Neogi and Das, 2022).

Percent total nitrogen content on Post-harvested soils:

Figure 1 illustrates the effect of nano urea on post-harvest soil, with treatment T_5 (50% urea + nano urea (3 sprays) + rest all) recording the maximum amount of nitrogen, which is statistically similar to the second-best treatment. The application of nano urea significantly influences soil nitrogen levels post-harvest. Compared to conventional urea, nano urea has been found to enhance nitrogen use efficiency and reduce nitrogen losses through leaching and gaseous emissions. This improved efficiency is attributed to the nanoscale size of the fertilizer particles, which increases the surface area and allows for more controlled release of nitrogen in soil (Yogananda, S. B and Sowmyalatha, B. S., 2024).

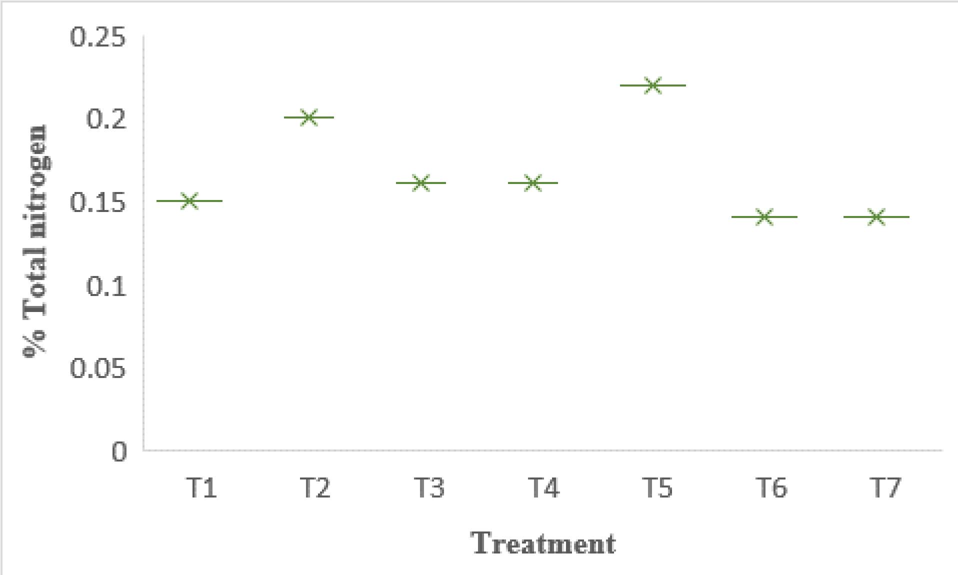

Figure 1. Represents the effects of nano urea combined with chemical fertilizers on % total nitrogen content for post harvested soil

4. Conclusion

From the present study, it can be concluded that reducing the recommended nitrogen fertilizer dose by 50% through conventional urea and substituting it with Nano Urea (N) in liquid form is feasible without compromising yield. This approach has been shown to be satisfactory and can lead to additional income for farmers. The application of nano-fertilizer can be considered a sustainable management practice as it not only reduces the cost of cultivation but also improves soil health.

Acknowledgement

This research was financially supported by Bangla Mark Company. IFFCO (Indian Farmers Fertilizer Company, New Delhi) made nano urea was supplied by the Bangla Mark Company, Dhaka, Bangladesh.

REFERENCES

Babaeian, M., Piri, I., Tavassoli, A., Esmaeilian, Y., & Gholami, H. (2011). Effect of water stress and micronutrients (Fe, Zn, and Mn) on chlorophyll fluorescence, leaf chlorophyll content, and sunflower nutrient uptake in Sistan region. *African Journal of Agricultural Research, 6*(15), 3526-3531.

Chauhan, A., Pallvi, Rattan, P., Ludarmani, & Sharma, A. (2023). Effect of pre-soaking of potato (Solanum tuberosum L.) tubers in nano-urea and nano-zinc on its growth, quality, and yield. *The Pharma Innovation Journal, 12*(7), 980-995.

Congreves, K. A., Otchere, O., Ferland, D., Farzadfar, S., Williams, S., & Arcand, M. M. (2021). Nitrogen use efficiency definitions of today and tomorrow. *Frontiers in Plant Science, 12*, 637108. https://doi.org/10.3389/fpls.2021.637108

Das, S. K., & Chakraborty, A. (2018). Response of potato (Solanum tuberosum L.) to zinc application under lower Gangetic plains of West Bengal. *Journal of Crop and Weed, 14*(2), 112-116.

DeRosa, M. C., Monreal, C., Schnitzer, M., Walsh, R., & Sultan, Y. (2010). Nanotechnology in fertilizers. *Nature Nanotechnology, 5*, 91-94.

Dutta, D., & Bera, A. (2021). Nano fertilizer on sustainable agriculture: A review. *International Journal of Environment and Climate Change, 11*(8), 1-5. https://doi.org/10.9734/ijecc/2021/v11i830451

Kumar, R., Bohra, J. S., Kumawat, N., & Singh, A. K. (2015). Fodder yield, nutrient uptake, and quality of baby corn (Zea mays L.) as influenced by NPKS and Zn fertilization. *Research on Crops, 16*(2), 243-249.

Lawlor, D. W., Kontturi, M., & Young, A. T. (1989). Photosynthesis by flag leaves of wheat in relation to protein, ribulose bisphosphate carboxylase activity, and nitrogen supply. *Journal of Experimental Botany, 40*(1), 43-52.

Lenka, B., & Das, S. K. (2019). Effect of boron and zinc application on growth and productivity of potato (Solanum tuberosum L.) at alluvial soil (Entisols) of India. *Indian Journal of Agronomy, 64*(1), 129-137.

Lichtenthaler, H. K., & Rinderle, U. (1988). The role of chlorophyll fluorescence in the detection of stress conditions in plants. *CRC Critical Reviews in Analytical Chemistry, 19*(1), 29-85.

Manikanta, B., Channakeshava, S., Bhausaheb Tambat, B. M., & Gayathri, B. (2023). Effect of nano-nitrogen, copper, and zinc liquid fertilizers on growth, yield, and quality of potato (Solanum tuberosum L.). *The Pharma Innovation Journal, 2*(4), 2590-2596.

Mejías, J. H., Salazar, F. J., Pérez, L., Hube, S., Rodriguez, M., & Alfaro, M. A. (2021). Nano fertilizers: A cutting-edge approach to increase nitrogen use efficiency in grasslands. *Frontiers in Environmental Science, 9*, 52.

Midde, S. K., Perumal, M. S., Murugan, G., Sudhagar, R., Mattepally, V. S., & Bada, M. R. (2022). Evaluation of nano urea on growth and yield attributes of rice (Oryza sativa L.). *Chemical Science Review and Letters, 11*(42), 211-214.

Mu, T. H., Tan, S. S., & Xue, Y. L. (2009). The amino acid composition, solubility, and emulsifying properties of sweet potato protein. *Food Chemistry, 112*(4), 1002-1005.

Nityamanjari, M. (2018). Effect of fertilizers on growth and productivity of potato: A review. *International Journal of Agriculture Sciences, 10*, 5183-5186.

Prasad, R., Pathak, H., Patra, A. K., & Shivay, Y. S. (2014). Nitrogen management. In *Textbook of Plant Nutrient Management* (pp. 73-92).

Qureshi, A., Singh, D. K., & Dwivedi, S. (2018). Nano-fertilizers: A novel way for enhancing nutrient use efficiency and crop productivity. *International Journal of Current Microbiology and Applied Science, 7*(2), 3325-3335.

Rahman, M. H., Azad, M. O. K., Islam, J., Rana, M. S., Li, K. H., & Lim, Y. S. (2021). Production of potato (Solanum tuberosum L.) seed tuber under artificial led light irradiation in plant factory. *Plants, 10*(2), 297.

Raliya, R., Saharan, V., Dimkpa, C., & Biswas, P. (2017). Nano fertilizer for precision and sustainable agriculture: Current state and future perspectives. *Journal of Agricultural and Food Chemistry, 66*, 6487-6503.

Rameshaiah, G. N., & Jpallavi. (2015). Nano fertilizers and nano sensors: An attempt for developing smart agriculture. *International Journal of Engineering Research and General Science, 3*(1), 314-320.

Tiwari, K. N., Yogendra Kumar, Nayak, R. K., Abhimanyu Rai, Jashvir Singh, Singh, S. P., & Anand Srivastava. (2021). Nano-urea for enhancing yield and farmers profit with potato in Uttar Pradesh. *Annals of Plant and Soil Research, 23*(4), 495-500.

Trehan, S. P., & Singh, B. P. (2013). Nutrient efficiency of different crop species and potato varieties: In retrospect and prospect. *Potato Journal, 40*, 1-21.

Valojai, S. T. S., Niknejad, Y., Amoli, H. F., & Tari, D. B. (2021). Response of rice yield and quality of nano-fertilizers in comparison with conventional fertilizers. *Journal of Plant Nutrition, 44*(13), 1971-1981.

Vijayakumar, S., Lokesh, G. D., Hareesh Reddy, C. H., Mahender Kumar, R., & Sundaram, R. M. (2022). Efficient nitrogen management technologies for sustainable rice production. *Journal of Rice Research, 15*(2), 1-19.

Yogananda, S. B., & Sowmyalatha, B. S. (2024). Comparative evaluation of nano urea and urea foliar sprays on nutrient uptake and soil fertility in fodder maize (Zea mays L.) production. *Journal of Scientific Research and Reports, 30*(5), 939-946.