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Nano fertilizers as a sustainable approach to improve nutrient content and uptake of potato (*Solanum tuberosum* L.)

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Abstract

The study was conducted at the Main Experiment Station (MES) Vegetable Research Farm, Acharya Narendra Dev University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.), during *Rabi* season 2021-22, to assess the performance of nano fertilizers on nutrient content and uptake of potato (*Solanum tuberosum* L.). Before the conducting of the experiment, the sodic soil was reclaimed, and its initial soil properties showed a silty loam texture, slightly alkaline in reaction (pH 8.12), with low available nitrogen ($147.20 \text{ kg ha}^{-1}$), medium in available phosphorus (14.20 kg ha^{-1}), and high in available potassium ($267.00 \text{ kg ha}^{-1}$). The experiment comprised nine treatments in a randomized block design (RBD) with three replications. The treatments combinations were T₁ [Absolute Control (Water spray)], T₂ [100% RDF (150:100:120 kg ha⁻¹ N:P₂O₅:K₂O)], T₃ (Recommended PK + 50% RDN + Two spray of Nano N), T₄ (T₃ + Two spray of Nano Zn), T₅ (T₃ + Two spray of Nano Cu), T₆ (T₃ + One spray of Nano Zn + One spray of Nano Cu), T₇ (Recommended PK + Two spray of Nano N), T₈ (Recommended PK + Two spray of Nano N + Two spray of Nano Cu), T₉ (Recommended PK + Two spray of Nano N + Two spray of Nano Zn). The results of the present study revealed that the application of RDF recorded the highest nutrient content and uptake in potatoes. Among all treatments, treatment T₂ RDF (150:100:120 kg ha⁻¹ N:P₂O₅:K₂O) recorded the highest nutrient content in soil. It also resulted in higher nutrient content and uptake in tuber and haulm of Potato. However, nano-fertilizer treatments integrated with reduced nitrogen levels produced comparable results, indicating their potential to improve nutrient use efficiency.

Keywords: Nano Cu, Nano Fertilizers, Nano N, Nutrient Content, Nutrient Uptake

Introduction

Potato (*Solanum tuberosum*) is the most important vegetable crop in the world due to its high production potential, remunerative income and good nutritional value (Ojha *et al.*, 2025) [12]. Potato belongs to the Solanaceae family and were first domesticated in the Andes mountains of South America around 8,000 years ago. It is the third most important crop in the world after rice and wheat, in terms of human consumption (Ojha *et al.*, 2025) [12]. It was the fourth most important food crop in production after maize, wheat and rice (Kennedy *et al.*, 2019) [9]. Globally, it is widely cultivated on an area of 17.07 million hectares, production is about 390.4 million tonnes and the productivity is $22.8 \text{ tonnes ha}^{-1}$. Now, China is the largest potato producer, with a production of 94.86 million tonnes and almost one-third of all the potato is harvested in China and India (FAOSTAT, 2024) [4]. In India, it was cultivated on an area of 2.36 million hectares with a production of 58.11 million tonnes and productivity of 24.62 tonnes per hectare (AGRISTAT, 2026) [2]. The states such as UP, West Bengal, Punjab, Bihar and Gujarat accounted for more than 80% share in total production. In India, the estimated demand for potatoes in 2050 will be 122 million tons, as compared to 48.60 million tons, which is 2.5 times more than the current production. At present in India, about 68% of potato production is consumed as fresh, while the rest is utilized as seed (8.5%) and processing purposes (7.5%), while the remaining (16%) goes as waste due to various reasons that include rotting and wastage during the entire potato supply chain (Singh *et al.*, 2014) [14].

Being a short-duration crop, it produces a greater quantity of dry matter, edible energy, sufficient protein, minerals, fiber and vitamin B&C in appreciably good quantity. Potato has been discovered as the largest crop in the group of tuber and root crop in the world. According to FAO, potato is consumed by more than one billion people worldwide. It is a high-quality vegetable cum food crop that is used in more than 100 types of different Indian recipes. It can be processed into diversified value-added products such as chips, wafers, flakes, granules, flour, starch, potato custard powder, soup etc. Also, potato is widely utilized for production of starch and alcoholic beverages. With the tremendous increase in population, there is an urge for nutritional and food security and hence potato has become a staple food and important component of human diet.

Fertilizers are very important sources of plant nutrients for boosting agricultural production. Using large amounts of fertilizers to achieve more production per unit area per unit time leads to several problems like environmental pollution, low input efficiency, deficiency of macro and some micronutrients and decreased quality of food products. Therefore, nutrient management is one of the important approaches in achieving high productivity of the potato crop. Excessive use of chemical fertilizers has led to decreased crop yield, less availability of nutrients in soil, and degradation of underground and surface water resources etc. The demanding need of agriculture for more output with less input has made the agriculture dependent countries to adopt more advanced technologies with labor-saving practices and methods. Therefore, there is an urgent need to infuse nanotechnology into agricultural sciences for the transformation of traditional farming practices to precision agriculture so as to insure evergreen revolution and food security of the country. Imbalanced application of nitrogenous fertilizers and their low nutrient use efficiency (30-50%) ultimately cause soil, water and air pollution. Injudicious use of urea causes nutrient mining as well as N losses occurs through volatilization, leaching and denitrification. Zinc fertilizers may be toxic to plants if applied for several years. Therefore, the application of nano zinc and nano urea is being preferred to enhance agronomic effectiveness.

Nano-fertilizers intended to improve the nutrient use efficiencies by exploiting unique properties of nanoparticles. These fertilizer carriers which are used to develop nano-fertilizers have offered a possibility of developing nano-structured materials for improvement in nutrient usage and to minimize environmental degradation. These fertilizers are synthesized by fortifying nutrients singly or in combinations onto the adsorbents with nano dimensions. Nano-fertilizers are known to release nutrients slowly and steadily for more than 30 days, which can improve the nutrient use efficiency without any associated ill-effects. The nano-fertilizers are designed to deliver slowly over a long period of time; the loss of nutrients is substantially reduced vis-a-vis environmental safety (Subramanian *et al.*, 2015) [16]. However, there is a scarcity of research on how potatoes respond to fertilizer applications in the soil as well as foliar spraying of Nano fertilizer (Nano N, Zn & Cu). Considering the facts above, an experiment was planned to study the effect of Nano fertilizers on crop nutrient content, uptake and soil nutrient status in Potato.

Materials and Methods

The field experiment was conducted during the Rabi season 2021-22 at MES Vegetable Research Farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh. Geographically, the experimental site

was situated at 24°47' N latitude and 82.12° E longitude with an altitude of 113 meters above mean sea level. The experimental field was well levelled and had good irrigation and drainage facilities. The climate of this area is a sub-arid climate, receiving a mean annual rainfall of about 1000 mm. About 85% of the total rainfall is received from mid-June to the end of September. The experiment was laid out in a randomized block design with 9 treatments and 3 replications.

The treatments comprised of T₁- Control (Water spray); T₂- RDF (150:100:120 kg ha⁻¹ N:P₂O₅:K₂O); T₃- Recommended PK + 50% RDN + Two spray of Nano N; T₄- T₃ + Two spray of Nano Zn; T₅- T₃ + Two spray of Nano Cu; T₆- T₃ + One spray of Nano Zn + One spray of Nano Cu; T₇- Recommended PK + Two spray of Nano N; T₈- Recommended PK + Two spray of Nano N + Two spray of Nano Cu; T₉- Recommended PK + Two spray of Nano N + Two spray of Nano Zn. The potato crop was planted with seeds of cultivar Kufri Garima having uniform tubers of 25-30 g size at a spacing of 60 cm × 20 cm on the ridges at the rate of 25 q ha⁻¹. During the experiment, composite soil samples (0-15 cm) were taken before treatments application. The collected samples were air-dried, processed and analyzed for basic soil physical and chemical properties. The experimental site was slightly alkaline in soil pH (8.12), non-saline nature in EC (0.22 dS m⁻¹), low in organic carbon (3.4 g kg⁻¹), available nitrogen (147.2 kg ha⁻¹), available zinc (0.43 mg kg⁻¹); medium in available phosphorus (14.2 kg ha⁻¹), available potassium (267 kg ha⁻¹) and high in available copper (1.59 mg kg⁻¹), respectively. The predominant soil at the experimental site is classified as a silty-loam texture. The soil samples were collected after harvesting of the crop. Collected samples were air-dried, processed and analyzed through standard laboratory procedures viz. pH and EC (electrical conductivity) was determined with pH and EC meter (Jackson, 1973 and Jackson, 1967) [7,8], soil organic carbon (SOC) with rapid titration method (Walkley and Black, 1934) [17], Available nitrogen with Alkaline potassium permanganate method (Subbiah and Asija, 1956) [15], Available phosphorus with Olsen method (Olsen *et al.*, 1954) [13], Available potassium with ammonium acetate method (Hanway and Heidel, 1952) [6] and Available zinc and copper with DTPA Extractable method (Lindsey & Norvell 1978). Representative plant samples were taken from each net plot during the harvest of crop for the estimation of N, P, K, Zn and Cu. N content was determined with Micro Kjeldahl's method (Jackson, 1973) [7], phosphorus with Vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973) [7] and potassium with flame photometer method (Jackson, 1973) [7]. The N, P, K, Zn and Cu uptake by potato was estimated by using the following formula:

$$\text{Macronutrient Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Micronutrient Uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1}\text{)}}{1000}$$

Total nutrient uptake = Uptake in tuber + Uptake in Haulm

The statistical analysis of the data was performed using the standard procedure for "Analysis of Variance" (ANOVA), as described by Gomez and Gomez (1984) [5]. The standard error of the mean and the critical difference were calculated at the 5% level of probability.

Results and Discussion

Nutrient content in soil post-harvest of potato crop

The data presented in Table 1 clearly indicate the influence on

pH, EC, organic carbon and available nutrient status after harvesting of the potato crop. Compared to the control (T₁), all treatments improved soil nutrient status. The observed differences in pH, EC and organic carbon (OC) were statistically

non-significant, whereas available nitrogen, phosphorus, potassium, zinc and copper were statistically significant at the 5% level.

Table 1: Effect of different treatments of Nano Fertilizers on soil properties after harvest of potato crop

S. No.	Treatments	pH	EC (dS m ⁻¹)	OC (g kg ⁻¹)	Available N (kg ha ⁻¹)	Available P (kg ha ⁻¹)	Available K (kg ha ⁻¹)	Available Zn (mg kg ⁻¹)	Available Cu (mg kg ⁻¹)
T ₁	Control (Water spray)	8.60	0.26	3.30	150.20	12.35	243.50	0.40	0.41
T ₂	RDF (150:100:120 kg ha ⁻¹ N: P ₂ O ₅ :K ₂ O)	8.50	0.24	3.51	165.80	17.75	263.30	0.52	0.50
T ₃	Recommended PK + 50% RDN + Two spray of Nano N	8.51	0.25	3.48	160.30	15.10	255.54	0.48	0.46
T ₄	T ₃ + Two spray of Nano Zn	8.52	0.25	3.49	163.50	16.20	259.59	0.50	0.48
T ₅	T ₃ + Two spray of Nano Cu	8.53	0.25	3.49	162.45	15.80	257.38	0.46	0.47
T ₆	T ₃ + One spray of Nano Zn + One spray of Nano Cu	8.52	0.25	3.50	164.20	16.70	261.86	0.50	0.50
T ₇	Recommended PK + Two spray of Nano N	8.51	0.24	3.39	151.80	13.30	252.80	0.41	0.46
T ₈	Recommended PK + Two spray of Nano N + Two spray of Nano Cu	8.52	0.24	3.41	152.00	13.90	253.05	0.43	0.47
T ₉	Recommended PK + Two spray of Nano N + Two spray of Nano Zn	8.54	0.25	3.42	154.00	14.60	254.35	0.44	0.48
	SEm±	0.44	0.01	0.12	3.92	1.04	2.96	0.03	0.02
	CD (P= 0.05)	NS	NS	NS	11.78	3.13	8.90	0.11	0.08

Soil pH

The foliar application of nano fertilisers had no significant effect on soil pH. The lowest soil pH value (8.50) was recorded under the application of treatment T₂, followed by treatments T₃ and T₇. In contrast, treatment T₁ recorded the highest pH value in soil. These results are close conformity with the findings of Kumar *et al.*

Soil EC (dS m⁻¹)

The application of nano-fertiliser through foliar application had no significant effect on soil EC. Soil EC ranged from 0.26 to 0.24 dSm⁻¹. The minimum value of soil EC was observed in treatments applying T₂, T₇ and T₈, and the maximum value of soil EC was observed in control (T₁) treatment.

Soil Organic Carbon (g kg⁻¹)

The application of nano fertilizer through foliar application had no significant effect on soil organic carbon. The organic carbon in soil under different treatments varied from 3.30 to 3.51 g kg⁻¹. The maximum soil organic carbon content (3.51 g kg⁻¹) was observed with the application of T₂, which was closely followed by T₆ and statistically at par with all other treatments.

Available Nitrogen (kg ha⁻¹)

The available nitrogen content in soil was found to be significantly effect of different treatments. The available nitrogen ranged from 150.20 to 165.80 kg ha⁻¹. The maximum available nitrogen (165.80 kg ha⁻¹) was recorded under T₂, which was significantly superior to control (T₁). However, T₂ was statistically at par with T₄, T₅ and T₆. The improvement in available nitrogen under these treatments may be attributed to enhanced nutrient use efficiency and reduced nitrogen losses, leading to improved soil fertility status after harvest.

Available Phosphorus (kg ha⁻¹)

The available phosphorus in soil was found to be significantly influenced of different treatments. The available phosphorus ranged from 12.35 to 17.75 kg ha⁻¹. The maximum available phosphorus (17.75 kg ha⁻¹) was recorded under T₂, which was significantly superior to control (T₁). However, T₂ was statistically at par with T₃, T₄, T₅ and T₆. There was appreciable improvement in the availability of phosphorus due to the sole

application of RDF as compared to treatments containing combined application of soil and foliar applied treatments.

Available Potassium (kg ha⁻¹)

The available potassium in soil was found to be significantly influenced of different treatments. The available potassium ranged from 243.50 to 263.30 kg ha⁻¹. The maximum available potassium (263.30 kg ha⁻¹) was recorded under T₂, which was significantly superior to control (T₁). However, T₂ was statistically at par with T₃, T₄, T₅ and T₆. It was observed that foliar application of nutrients did not result in any significant change in the available potassium content of the soil. There was appreciable improvement in the availability of potassium due to the sole application of RDF as compared to treatments containing combined application of soil and foliar applied treatments.

Available Zinc (mg kg⁻¹)

The available zinc content in soil after harvest of potato crop varied from 0.40 to 0.52 mg kg⁻¹ under different treatments. The highest available zinc (0.52 mg kg⁻¹) was recorded under T₂, which was statistically at par with T₄ and T₆.

Available Copper (mg kg⁻¹)

The fertilizer treatment influenced the available copper content in soil. It was observed that the foliar application of nano fertilizers did not result in any significant changes in the available copper content in the soil. The available copper ranged from 0.41 to 0.50 mg kg⁻¹. The maximum available copper (0.50 mg kg⁻¹) observed in treatment applying T₂ was significantly superior to the control, statistically at par with the rest of the treatments. The minimum available copper (0.41 mg kg⁻¹) was found in the control (T₁).

Overall results revealed that the maximum build-up of available nutrients viz. N, P, K, Zn and Cu were registered with the treatment having soil application of nutrients viz. (T₂) RDF 150:100:120 kg ha⁻¹ N:P₂O₅:K₂O. This might be due to the addition of chemical fertilizers, which help to re-establish the soil fertility very quickly and the nutrients are available to the plants as soon as the fertilizers are dissolved in the soil. This result corroborates the findings of Miah, 1994. Inorganic fertilizers also increase plant residues, which indirectly increase organic matter (Debele, 2021) [3].

Nutrient content and uptake

Nitrogen content and uptake

Data concerning nitrogen content and uptake are presented in Table 2. The application of different treatments was significantly influenced by N content and uptake in tuber and haulm in Potato crop. The nitrogen content in tuber ranged from 1.60 to 1.79%, while in haulm it varied between 2.21 to 2.33%. The highest nitrogen content in tuber (1.79%) and haulm (2.33%) was recorded under T₂. Nitrogen uptake by tuber exhibited a range from 57.13 kg ha⁻¹ (T₁) to 104.48 kg ha⁻¹ (T₂), while haulm varied from 37.87 kg ha⁻¹ (T₁) to 71.40 kg ha⁻¹ (T₂). Consequently, the total nitrogen uptake varied from 95.00 kg ha⁻¹ (T₁) to 175.88 kg ha⁻¹ (T₂), indicating a substantial improvement of more than 85% over the control (T₁).

Phosphorus content and uptake

Phosphorus content and uptake in tubers and haulm of Potato as influenced by various nutrient management treatments are summarized in Table 3. The phosphorus content in tubers ranged from 0.20% (T₁) to 0.27% (T₂, T₄, T₆) and in haulm varied from 0.24% (T₁) to 0.28% (T₂, T₃, T₄, T₅, T₆). Phosphorus uptake by tubers exhibited a range from 7.14 kg ha⁻¹ (T₁) to 15.76 kg ha⁻¹ (T₂), while haulm varied from 4.11 kg ha⁻¹ (T₁) to 8.58 kg ha⁻¹ (T₂). Consequently, the total phosphorus uptake varied from 11.25 kg ha⁻¹ (T₁) to 24.34 kg ha⁻¹ (T₂), indicating a substantial improvement of more than 116.36% over the control (T₁). The data indicated that application of different management practices (T₂) recorded the highest phosphorus content & uptake and was significantly influenced by all other treatment combinations.

Potassium content and uptake

Potassium content and uptake in tubers and haulm of Potato as influenced by various nutrient management treatments are summarized in Table 3. The potassium content in tubers ranged from 1.37% (T₁) to 1.43% (T₂) and in haulm varied from 1.88% (T₁) to 1.97% (T₂). Potassium uptake by tubers exhibited a range from 48.92 kg ha⁻¹ (T₁) to 83.47 kg ha⁻¹ (T₂), while haulm

varied from 32.22 kg ha⁻¹ (T₁) to 60.37 kg ha⁻¹ (T₂). Consequently, the total potassium uptake varied from 81.13 kg ha⁻¹ (T₁) to 143.84 kg ha⁻¹ (T₂), indicating a substantial improvement of more than 116.36% over the control (T₁). The data indicated that application of different management practices (T₂) recorded the highest potassium content & uptake and was significantly influenced by all other treatment combinations.

Zinc content and uptake

Zinc content and uptake in tubers and haulm of Potato as influenced by various nutrient management treatments are summarized in Table 3. The zinc content in tubers ranged from 27.50% (T₁) to 29.90% (T₂) and in haulm varied from 6.88% (T₁) to 7.48% (T₂). Zinc uptake by tubers exhibited a range from 981.92 kg ha⁻¹ (T₁) to 1745.20 kg ha⁻¹ (T₂), while haulm varied from 117.90 kg ha⁻¹ (T₁) to 229.22 kg ha⁻¹ (T₂). Consequently, the total zinc uptake varied from 1099.81 kg ha⁻¹ (T₁) to 1974.42 kg ha⁻¹ (T₂), indicating a substantial improvement of more than 79.52% over the control (T₁). The data indicated that application of different management practices (T₂) recorded the highest zinc content & uptake and was significantly influenced by all other treatment combinations.

Copper content and uptake

Copper content and uptake in tubers and haulm of Potato as influenced by various nutrient management treatments are summarized in Table 4. The copper content in tubers ranged from 5.84% (T₁) to 5.92% (T₂) and in haulm varied from 3.50% (T₁) to 3.55% (T₂). Copper uptake by tubers exhibited a range from 208.52 kg ha⁻¹ (T₁) to 345.54 kg ha⁻¹ (T₂), while haulm varied from 59.98 kg ha⁻¹ (T₁) to 108.79 kg ha⁻¹ (T₂). Consequently, the total copper uptake varied from 268.50 kg ha⁻¹ (T₁) to 454.33 kg ha⁻¹ (T₂), indicating a substantial improvement of more than 69.21% over the control (T₁). The data indicated that application of different management practices (T₂) recorded the highest copper content & uptake and was significantly influenced by all other treatment combinations.

Table 2: Effect of different treatments of Nano Fertilizers on nitrogen & phosphorous content and uptake in tuber & haulam of potato crop

Treatments	Nitrogen content (%)		Nitrogen uptake (kg ha ⁻¹)			Phosphorus content (%)		Phosphorus uptake (kg ha ⁻¹)		
	Tuber	Haulm	Tuber	Haulm	Total uptake	Tuber	Haulm	Tuber	Haulm	Total uptake
T ₁	1.60	2.21	57.13	37.87	95.00	0.20	0.24	7.14	4.11	11.25
T ₂	1.79	2.33	104.48	71.40	175.88	0.27	0.28	15.76	8.58	24.34
T ₃	1.76	2.29	95.91	65.10	161.01	0.26	0.28	14.17	7.96	22.13
T ₄	1.78	2.31	100.38	68.48	168.86	0.27	0.28	15.23	8.30	23.53
T ₅	1.77	2.30	96.82	66.02	162.84	0.26	0.28	14.22	8.04	22.26
T ₆	1.78	2.31	101.16	69.16	170.32	0.27	0.28	15.34	8.38	23.73
T ₇	1.72	2.24	83.71	57.39	141.10	0.25	0.26	12.17	6.66	18.83
T ₈	1.73	2.25	87.68	59.94	147.61	0.26	0.26	13.18	6.93	20.10
T ₉	1.73	2.26	90.16	60.37	150.53	0.26	0.27	13.55	7.21	20.76
SEm±	0.06	0.03	1.19	0.68		0.01	0.01	0.17	0.09	
CD (P= 0.05)	0.18	0.11	3.60	2.07		0.04	0.03	0.52	0.29	

Table 3: Effect of different treatments of Nano Fertilizers on potassium & zinc content and uptake in tuber & haulam of potato crop

Treatments	Potassium content (%)		Potassium uptake (kg ha ⁻¹)			Zinc content (mg kg ⁻¹)		Zinc uptake (g ha ⁻¹)		
	Tuber	Haulm	Tuber	Haulm	Total uptake	Tuber	Haulm	Tuber	Haulm	Total uptake
T ₁	1.37	1.88	48.92	32.22	81.13	27.50	6.88	981.92	117.90	1099.81
T ₂	1.43	1.97	83.47	60.37	143.84	29.90	7.48	1745.20	229.22	1974.42
T ₃	1.41	1.94	76.84	55.15	131.99	28.70	7.18	1563.98	204.12	1768.10
T ₄	1.42	1.96	80.08	58.10	138.18	29.50	7.38	1663.56	218.78	1882.34
T ₅	1.42	1.95	77.68	55.97	133.65	28.80	7.20	1575.42	206.67	1782.09
T ₆	1.42	1.96	80.70	58.68	139.38	29.60	7.40	1682.17	221.56	1903.73
T ₇	1.38	1.90	67.16	48.68	115.84	28.50	7.13	1387.10	182.66	1569.76
T ₈	1.39	1.91	70.45	50.88	121.33	28.60	7.15	1449.45	190.47	1639.92
T ₉	1.39	1.91	72.44	51.02	123.46	28.70	7.18	1495.73	191.78	1687.51
SEm±	0.01	0.02	0.75	0.64		0.79	0.19	26.89	2.87	
CD (P= 0.05)	0.05	0.08	2.26	1.93		2.38	0.59	81.31	8.68	

Table 4: Effect of different treatments of Nano Fertilizers on copper content and uptake in tuber & haulm of potato crop

Treatments	Treatments	Copper content (mg kg ⁻¹)		Copper uptake (g ha ⁻¹)		
		Tuber	Haulm	Tuber	Haulm	Total uptake
T ₁	Control (Water spray)	5.84	3.50	208.52	59.98	268.50
T ₂	RDF (150:100:120 kg ha ⁻¹ N:P ₂ O ₅ :K ₂ O)	5.92	3.55	345.54	108.79	454.33
T ₃	Recommended PK + 50% RDN+ Two spray of Nano N	5.82	3.52	317.16	100.07	417.23
T ₄	T ₃ + Two spray of Nano Zn	5.90	3.54	332.71	104.94	437.65
T ₅	T ₃ + Two spray of Nano Cu	5.86	3.52	320.55	101.04	421.59
T ₆	T ₃ + One spray of Nano Zn + One spray of Nano Cu	5.91	3.55	335.87	106.29	442.15
T ₇	Recommended PK + Two spray of Nano N	5.85	3.50	284.72	89.67	374.39
T ₈	Recommended PK + Two spray of Nano N + Two spray of Nano Cu	5.85	3.51	296.48	93.50	389.98
T ₉	Recommended PK + Two spray of Nano N + Two spray of Nano Zn	5.85	3.51	304.88	93.75	398.63
	SEM±	0.03	0.01	3.59	0.898	

Uptake of nutrients depends on the available nutrient status of the soil, the health of both the vegetative and reproductive parts of the plant, the metabolic activity of the crop, and the type of fertilizer used, among other factors. The data obtained for the uptake of N, P, K, Zn, and Cu by tuber, haulm, and total uptake showed significant effects and differences among the different treatments. Maximum uptake of N, P, K, Zn and Cu was obtained under treatment T₂ (100% RDF of NPK). Higher nutrient content at higher levels of fertilizer application, together with higher dry matter production, resulted in higher nutrient uptake by the potato crop. Similar results were reported by Kumar *et al.*, (2021), who also recorded higher agronomic use efficiency (N, P, K, Zn and Cu) under the treatment of 100% RDF to the potato crop. Thus, the experimental results revealed that application of T₂ was found suitable for optimum production of potato for a medium-duration variety. Among the foliar applications, treatment applying T₃ + One spray of Nano Zn + One spray of Nano Cu (T₆) observed maximum nutrient uptake after RDF (T₂). This was due to increased availability of the nutrients viz. N, P, K, Zn and Cu are in readily available form for quick absorption by the crop. These findings were closely related to the results of Adhikari *et al.*, (2014) ^[1] and Merghany *et al.*, (2019) ^[11].

Conclusion

Based on the research, it may be concluded that RDF recorded the highest nutrient content and uptake in potatoes. Among all treatments, treatment T₂ RDF (150:100:120 kg ha⁻¹ N:P₂O₅:K₂O) recorded the highest nutrient content in soil. It also resulted in higher nutrient content and uptake in tuber and haulm of Potato. However, nano-fertilizer treatments integrated with reduced nitrogen levels produced comparable results, indicating their potential to improve nutrient use efficiency. Among nano treatments, the combined application of nano Zn and nano Cu (T₆) was found to be the most effective. Thus, nano-fertilizers can be used as a supplementary strategy to reduce dependence on conventional fertilizers without significant loss in nutrient uptake.

References

- Adhikari T, Ramana S. Nano fertilizer: Its impact on crop growth and soil health. J Res PJTSAU. 2019;47(3):1-11.
- AGRISTAT. AGRISTAT statistical database. Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture and Farmers Welfare, Economics, Statistics and Evaluation Division; 2026.
- Debele RD. The effect of integrated organic and inorganic fertilizer on soil fertility and productivity. Journal of Ecology and Natural Resources. 2021;5(3):1-6.
- FAOSTAT. FAOSTAT statistical database. Food and

Agriculture Organization of the United Nations; 2024. <https://www.fao.org/faostat/en/#data>

- Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984. p. 1-680.
- Hanway JJ. Soil analysis methods as used in the Iowa State College soil testing laboratory. Iowa Agriculture. 1952;57:1-131.
- Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt Ltd; 1973. p. 67-214.
- Jackson TL, Hay J, Moore DP. The effect of Zn on yield and chemical composition of sweet corn in the Willamette Valley. Proc Am Soc Hort Sci. 1967;91:462-471.
- Kennedy G, Raneri JE, Stoian D, Attwood S, Burgos G, Ceballos H, *et al.* Roots, tubers and bananas contributions to food security. Food Security and Sustainability. 2019:231-256.
- Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci Soc Am J. 1978;42:421-428.
- Merghany MM, Shahein MM, Mahmoud Sliem MA, Abdelgawad KF, Radwan AF. Effect of nano fertilizers on cucumber plant growth, fruit yield and its quality. Plant Archives. 2019;19(2):165-172.
- Ojha S, Karki LB, Ali M. A comprehensive analysis of potato production and trade: Global trends and US production forecasting. American Journal of Economics and Business Innovation. 2025;4(2):42-48.
- Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington DC: US Department of Agriculture; 1954. (No. 939).
- Singh B, Rana RK, Govindakrishnan PM. Vision 2050. Shimla: Central Potato Research Institute (ICAR); 2014. p. 1-26.
- Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. 1956.
- Subramanian KS, Manikandan A, Thirunavukkarasu M, Rahale CS. Nano fertilizers for balanced crop nutrition. In: Nanotechnologies in food and agriculture. 2015. p. 69-80.
- Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934;37:29-38.