



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(4): 524-531
Received: 05-02-2026
Accepted: 09-03-2026

Krishna G Choli
College of Horticulture, UHS
Campus, Bengaluru, University of
Horticultural Sciences, Karnataka,
India

Manjunath R
College of Horticulture, UHS
Campus, Bengaluru, University of
Horticultural Sciences, Karnataka,
India

B Doddabasappa
Regional Horticultural Research
and Extension Centre, UHS
Campus, Bengaluru, Karnataka,
India

Shivanna M
College of Horticulture, UHS
Campus, Bengaluru, University of
Horticultural Sciences, Karnataka,
India

Anil Kumar S
Krishi Vigyan Kendra, Kolar,
Karnataka, India

Premalatha BR
College of Horticulture, UHS
Campus, Bengaluru, University of
Horticultural Sciences, Karnataka,
India

Shankarappa TH
College of Horticulture, UHS
Campus, Bengaluru, University of
Horticultural Sciences, Karnataka,
India

Corresponding Author:
Manjunath R
College of Horticulture, UHS
Campus, Bengaluru, University of
Horticultural Sciences, Karnataka,
India

Standardization of nutrients in apical rooted cuttings (ARC) potato (*Solanum tuberosum* L.) for soil chemical parameters and plant & tuber nutrients

Krishna G Choli, Manjunath R, B. Doddabasappa, Shivanna M, Anil Kumar S, Premalatha BR and Shankarappa T H

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i4g.5415>

Abstract

Potato (*Solanum tuberosum* L.) is a major global food crop valued for its high productivity, nutritional significance, and adaptability to diverse agro-ecological conditions. Apical Rooted Cuttings (ARC) have recently gained prominence as a rapid, disease-free multiplication technique for quality seed potato production. ARC-derived plants exhibit vigorous early growth and greater uniformity compared with conventional seed tubers; however, their nutrient demands may differ substantially, necessitating the development of standardized nutrient management protocols. The present study evaluated the effects of graded nutrient doses on soil chemical properties and nutrient uptake in ARC-derived potato plants and tubers. Application of inorganic fertilizers and Farmyard Manure (FYM) resulted in a reduction in soil pH from the initial level, while Electrical Conductivity (EC) and Organic Carbon (OC) remained statistically non-significant across treatments. Significant differences were observed in total nutrient uptake, including N, P, K, Ca, Mg, S, Fe, Cu, Mn, and Zn. Treatments T3, T4, and T10 recorded higher macronutrient concentrations in plant tissue, whereas micronutrient accumulation was greatest under T8, T9, and T3. In tubers, macronutrient enrichment was highest in T3, T4, T9, T10, and T1, while micronutrient levels were maximized under T2, T3, T9, and T4. Soil nutrient availability also varied significantly among treatments. T3 showed the highest availability of primary nutrients, while T6, T3, and T1 were superior for secondary nutrients. For micronutrient availability, T3, T4, and T7 were most effective. These findings emphasize the importance of nutrient standardization in ARC-based potato production systems and provide a basis for optimizing nutrient supply to enhance plant growth and tuber nutritional quality.

Keywords: Potato, apical rooted cuttings, nutrient standardization, soil chemical properties, nutrient uptake, tuber quality, fertigation

Introduction

Potato (*Solanum tuberosum* L.) is one of the world's most important food crops, originating from the Andean region of South America and now cultivated globally due to its high productivity, nutritional value, and adaptability (Thamburaj and Singh, 2016; FAO, 2008) ^[10, 31]. India is the second-largest potato producer after China, contributing nearly 360 million tonnes annually, with Karnataka ranking eleventh in national production (Anonymous, 2013; Anonymous, 2019) ^[2, 3]. Owing to its rich composition of carbohydrates, proteins, dietary fiber, vitamins, minerals, and bioactive compounds, potato plays a critical role in food and nutritional security (Burlingame et al., 2009; Fernandez-Lopez et al., 2020) ^[8, 11].

Despite its importance, potato productivity in India remains constrained by multiple factors, including abiotic stresses, pest and disease incidence, declining soil fertility, and limited access to high-quality seed tubers (FAO, 2008; Gildemacher et al., 2009) ^[10, 13]. Seed tubers account for 40–50% of production costs, and improved seed quality can enhance yields by 15–25% (Roy, 2014; Chindi et al., 2017) ^[9, 38]. However, because of slow multiplication rates, dependence on northern seed production zones, and high transportation costs, access to quality seed remains a major bottleneck.

Soil fertility and nutrient management play a central role in determining potato growth, nutrient use efficiency, and tuber yield. The crop is highly responsive to variations in soil chemical

Properties such as pH, organic matter, and macro- and micronutrient availability. Imbalanced nutrient supply can restrict root growth, impair canopy development, and reduce tuber formation. Nitrogen is essential for vegetative growth, chlorophyll synthesis, protein and enzyme formation, and metabolic processes (Biswas and Dutta, 2020) [39]. Combined N and K application enhances canopy duration, tuber bulking, and size distribution (Allen et al., 1972; Harris et al., 1978; Blumenthal et al., 2008) [6, 14, 40]. Phosphorus supports early growth, root proliferation, and energy transfer (Babaji et al., 2007; Harris, 2012) [4, 15], while potassium influences sugar translocation, tuber quality, and vitamin C content (Abdel-Latif et al., 2011) [1]. Micronutrient deficiencies particularly Zn, Mn, Fe, and B are widespread in Indian soils and influence photosynthesis, chlorophyll formation, enzyme activation, and tuber development (Patel et al., 2015; Tripathi et al., 2015) [32, 41]. Foliar application of micronutrients improves nutrient uptake and enhances tuber yield and quality (Singh et al., 2018) [42]. To overcome seed production constraints, the International Potato Centre (CIP) and the University of Horticultural Sciences, Bagalkot, introduced Apical Rooted Cuttings (ARC) technology through an RKVY-supported initiative (2017–2020). ARC combines the advantages of tissue culture-based mother plants with nursery propagation, producing disease-free, genetically uniform, and rapidly multiplying planting material (Sharma and Pandey, 2013) [27]. ARC-derived plants exhibit vigorous early growth and uniformity, making them highly suitable for seed production systems in regions such as Karnataka where seed availability is limited. However, ARC plants may differ in nutrient acquisition and physiological behavior from conventionally propagated tuber plants, necessitating the development of standardized nutrient management protocols. Integrating soil chemical analysis with nutrient profiling of plant tissues and tubers allows identification of nutrient requirements, uptake patterns, and potential deficiencies or toxicities. Such information is essential for formulating balanced fertilizer recommendations that improve nutrient-use efficiency and reduce environmental risks.

Therefore, this study was undertaken to standardize nutrient regimes for ARC-propagated potato by evaluating soil chemical parameters and nutrient dynamics in plant tissues and tubers. The outcomes aim to support the development of efficient, site-specific nutrient management practices to enhance seed quality, productivity, and sustainability in ARC-based potato production systems.

Materials and Methods

The study was conducted at the Regional Horticultural Research and Extension Centre (RHREC) on the UHS campus at GKVK, Bengaluru in the Rabi season of 2023. Apical Rooted Cuttings ((ARC) of Kufri Karan potato produced at RHREC Bengaluru tissue cultured planting material was used under RCBD experimental design with the following 10 treatments and 03 replications with spacing of 60 cm x 20 cm and plot size of 2.4 m x 2m.

Treatment details

T1: 125:100:125 kg ha⁻¹ N:P:K + Potato special (UHSB Package)
T2: 125:100:125 kg ha⁻¹ N:P: K
T3: 156: 125:156 kg ha⁻¹ N: P: K+ Potato special
T4: 156: 125: 156 kg ha⁻¹ N: P: K
T5: 93.5: 75: 93.5 kg ha⁻¹ N: P: K+ Potato special
T6: 93.5: 75: 93.5 kg ha⁻¹ N: P: K
T7: 93.5: 100: 125 kg ha⁻¹ N: P: K + Potato special
T8: 125: 100: 93.5 kg ha⁻¹ N: P: K + Potato special
T9: 156: 100: 125 kg ha⁻¹ N: P: K + Potato special
T10: 125: 100: 156 kg ha⁻¹ N: P: K + Potato special

The potato special of UHSB-3 formulation for foliar at spray 3 g L⁻¹ it contains zinc, manganese, iron, boron, and copper in the ppm of 200, 75, 100, 75, and 25 respectively.

Prior to the experiment, the chemical properties of the red sandy loam soil at the experimental site were analyzed using a composite soil sample collected from a depth of 0-15 cm. The findings of this analysis are presented in Table 1.

Table 1: Initial soil physical and chemical properties of the experimental field

	Soil physical properties	Value
1	Bulk density (g/cm ³)	1.55
2	Water holding capacity (%)	44.65
3	Porosity (%)	41.60
4	Texture	Sandy loam
	Soil chemical properties	Value
1	pH	4.90
2	EC (dS/m)	0.57
3	Organic carbon (%)	0.60
4	Available Nitrogen (kg ha ⁻¹)	125.44
5	Available Phosphorous (P ₂ O ₅) (kg ha ⁻¹)	16.59
6	Available Potassium (K ₂ O) (kg ha ⁻¹)	205.20
7	Exchangeable Calcium (Ca)[cmol(p ⁺) kg ⁻¹ soil]	1.21
8	Exchangeable Magnesium (Mg)[cmol(p ⁺) kg ⁻¹ soil]	0.83
9	Available Sulphur (S) (ppm)	19.37
10	DTPA – Iron (Fe) (ppm)	0.48
11	DTPA – Manganese (Mn) (ppm)	2.54
12	DTPA – Zinc (Zn) (ppm)	1.26
13	DTPA – Copper (Cu) (ppm)	0.96

The experimental field was initially tilled using a disc plough followed by two successive cultivator operations to achieve a fine tilth. Weeds, crop residues, and stubbles were removed, and

the field surface was leveled. The area was then divided into 30 plots measuring 2.4 m × 2.0 m each. Well-decomposed Farmyard Manure (FYM) was incorporated into the soil

according to Treatment requirements. Furrows were prepared at the designated spacing prior to transplanting.

Potato tissue culture plantlets were initially raised under sterile laboratory conditions. After 12–15 days, they were transferred to raised beds (1 m width) in a polyhouse and spaced at 10 cm × 7.5 cm. Cocopeat served as the rooting medium. Apical shoots bearing 3–4 leaves emerged approximately 22 days after planting and were clipped as cuttings. These were immediately placed into 98-cell trays containing decomposed cocopeat and allowed to root for 18–20 days before transplanting to the field.

Healthy and uniform ARC plantlets produced at RHREC were transplanted on 11 November 2023. Plantlets were placed at a depth of 20–30 cm, maintaining 60 cm row spacing and 20 cm intra-row spacing. Well-decomposed FYM was applied at 25 t ha⁻¹ during land preparation. The standard nutrient dose (125:100:125 kg ha⁻¹ N: P: K) served as the control. Nutrient treatments were applied as per the experimental structure. Half of the nitrogen, along with the entire P and K, was applied at planting. The remaining 50% N was applied 45 days later in a

ring 10 cm away from the plant base at a depth of 3–4 cm. Harvesting was performed after tubers reached physiological maturity. Plants from each plot were carefully uprooted, and tubers were collected and processed for further analysis according to the assigned treatments. The soil samples were collected from the experimental site both before and after harvest at a depth of 0–15 cm. It was air-dried in the laboratory shade for about 4–5 days. Then, it was further ground by a wooden pestle and mortar and then sieved through 2 mm mesh. The soil samples were then mixed well and stored in polythene bags for further analysis. These were determined for some of the physical properties: bulk density, water-holding capacity, porosity, and texture. Apart from the aforementioned chemical properties, initial and final analyses included the following: pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), available phosphorus (P₂O₅), available potassium (K₂O), exchangeable calcium (Ca), exchangeable magnesium (Mg), available sulfur (S), and available micronutrients including iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu).

Table 2: Methods followed for analysis of physical and chemical properties

Parameters	Methods	Reference
Bulk density (g cm ⁻³)	Keen's cup method	Piper, 1966 ^[23]
WHC (%)	Keen's cup method	Piper, 1966 ^[23]
Porosity (%)	Keen's cup method	Piper, 1966 ^[23]
Texture	Hydrometer method	Bouyoucos, 1962 ^[7]
pH	Potentiometric method	Jackson, 1973 ^[17]
EC (dS/m)	Conductometric method	Jackson, 1973 ^[17]
OC (%)	Wet oxidation method	Walkey and Black, 1934 ^[33]
Available N (kg ha ⁻¹)	Alkaline potassium permanganate distillation method	Subbiah and Asija, 1956 ^[29]
Available P ₂ O ₅ (kg ha ⁻¹)	Calorimetric method	Jackson, 1973 ^[17]
Available K ₂ O (kg ha ⁻¹)	Flame photometric method	Jackson, 1973 ^[17]
Exchangeable Ca [cmol(p ⁺) kg ⁻¹]	Versenate titration method	Hesse, 1971 ^[43]
Exchangeable Mg [cmol(p ⁺) kg ⁻¹]	Versenate titration method	Hesse, 1971 ^[43]
Available S (ppm)	Turbidometry method	Black, 1965 ^[5]
DTPA extractable micronutrients (ppm)	Atomic Absorption Spectrophotometric method	Lindsay and Norvel, 1978 ^[20]
Total Nitrogen (%)	Kjeldah's digestion and distillation method	Piper (1966) ^[23]
Total Phosphorous (%)	Vanadomolybdate yellow color method	Piper (1966) ^[23]
Total Potassium (%)	Flame photometric method	Piper (1966) ^[23]
Total Calcium and Magnesium (%)	Complexometric titration method	Hesse (1971) ^[43]
Total Sulphur (%)	Turbidimetric method	Black (1965) ^[5]
Total Iron, Manganese, Zinc and Copper (ppm)	Atomic Absorption Spectrophotometric method	Lindsay and Norvell (1978) ^[20]

Results and Discussion

Soil chemical parameters

The pH of the soil varied significantly (Table 3); T8 had the highest pH, 5.68, of all of the samples. On the other hand, T3 had the lowest pH of all of the soil samples, at 4.89. This difference suggests that soil acidity may be influenced by fertilizer concentration. Nitrogen-containing fertilizers, especially those containing ammonium, have a tendency to lower soil pH by raising the concentration of hydrogen ions in the soil. For instance, T3, a treatment with a greater nitrogen content, produced a lower pH of 4.89, indicating a more acidic soil environment. These data are consistent with the findings of Youssef et al. (2017)^[35], who found that increased nitrification and the accompanying release of hydrogen ions might lead to soil acidification as a result of high nitrogen fertilization levels. Table 3 indicates that there was no discernible variation in EC among the treatments. T1, T2, and T10 had the greatest EC values, measuring 0.70, 0.70, and 0.70 dS m⁻¹, respectively. On the other hand, T6 and T8 showed the lowest EC, measuring

0.51 and 0.51 dS m⁻¹, respectively. Between the treatments, there was no apparent difference in OC (Table 3). Between treatments, there is no discernible change in the OC level. At 0.64%, T6 had the highest OC ever recorded. In contrast, T4 had the lowest OC, at 0.51%.

Table 4 shows that T3 had the largest amount of accessible soil nitrogen, 391.21 kg ha⁻¹. On the other hand, treatment T6 had the least amount of accessible soil nitrogen, at 218.25 kg ha⁻¹. T3 had the most quantity of accessible phosphorus, measuring 34.89 kg ha⁻¹. On the other hand, treatment T6 had the lowest amount of accessible phosphorus (18.21 kg ha⁻¹). The maximum potassium level that was detected was 339.33 kg ha⁻¹ in treatment T3. The treatment T6 exhibited the lowest amount of accessible soil potassium, measuring 148.44 kg ha⁻¹. In contrast. Similar to these studies, higher levels of applied fertilizer increase available nitrogen and phosphorous because these nutrients are more readily soluble and aid in the uptake of nutrients by plant roots. However, higher levels of phosphorus also cause potassium levels to decrease because they can react

with calcium, iron, and aluminum in the soil to form compounds that are not easily absorbed by plants. The findings of Setu (2000) and Kumar et al. (2017) ^[26] are similar to those studies.

Table 4 shows that there is no discernible variation in calcium, magnesium, or sulfur. At 3.91 cmol(p+) kg⁻¹ soil, treatment T7 exhibited the maximum exchangeable calcium. Conversely, T1 soil had the lowest exchangeable calcium, measuring 2.71 c mol (p+) kg⁻¹. T7 has the most exchangeable magnesium, 1.95 cmol(p+) kg⁻¹ soil. T4 had the lowest exchangeable magnesium, however, measuring 1.41 cmol(p+) kg⁻¹ of soil. The greatest accessible sulphur, at 19.42 ppm in soil was recorded in T2. On the other hand, T6 had the lowest exchangeable magnesium level in the soil, at 9.75 ppm.

The findings on DTPA-extractable micronutrients in Table 5 indicate a considerable variation between the treatments. T4 and T10 had the highest DTPA extractable iron levels, at 16.90 and 16.90 ppm, respectively. On the other hand, T1 had the lowest amount of DTPA extractable iron 12.13 ppm. Treatment T4 had the greatest concentration of DTPA-extractable manganese (36.66 ppm). On the other hand, treatment T7 had the lowest amount of DTPA-extractable iron (25.90 ppm). Treatment T7 had the most amount of DTPA-extractable copper (1.29 ppm). On the other hand, treatment T1 had the lowest amount of DTPA-extractable copper, at 0.81 ppm. Treatment T3 had the greatest concentration of DTPA-extractable zinc (2.57 ppm). In comparison, treatment T10 had the lowest amount, 1.70 ppm. Higher concentrations of N, P, and K fertilizers raise the concentration of micronutrients while providing these nutrients in the short term, according to.

Plant and tuber nutrient content

Plant nutrient content

Table 6 shows how different nutrient dosages affect plants levels of potassium, phosphorus, and nitrogen. Treatment T3 had the maximum nitrogen level, 233.36 kg ha⁻¹. In contrast, treatment T-1 had the lowest nitrogen level, measuring 90.18 kg ha⁻¹. Treatment T10 had the maximum phosphorus level, 4.09 kg ha⁻¹. Treatment T6 had the lowest phosphorus concentration, 2.29 kg ha⁻¹. Treatment T4 had the greatest potassium level, 73.87 kg ha⁻¹. On the other hand, treatment T6 showed the lowest potassium level, 34.05 kg ha⁻¹. The reason for this improvement is that when plants were given a combination of inorganic and organic inputs, there was an increased availability of nutrients. Applying farmyard manure, or FYM, probably enhanced the physical and chemical characteristics of the soil, making it easier for potassium, phosphate, and nitrogen to be absorbed. A larger tuber production might result from improved nutrient availability and an enlarged absorptive area, which would explain the enhanced nutrient absorption. Similar results for potatoes, taro, and cassava have been reported by Parmar et al. (2007) ^[22].

Table 7 illustrates the effects of several nutritional treatments on plant levels of calcium, magnesium, and sulfur, demonstrating a non-significant variation between treatments. 37.05 kg ha⁻¹ was the maximum amount recorded in treatment T1. On the other hand, treatment T8 had the lowest calcium content, measuring 21.25 kg ha⁻¹. With a level of 19.71 kg ha⁻¹, treatment T1 had the highest magnesium content. Treatment T6 had the lowest magnesium level, 14.50 kg ha⁻¹. Treatment T4 had the greatest sulfur level, measuring 27.92 kg ha⁻¹. Treatment T1 had the lowest sulfur concentration, measuring 22.51 kg ha⁻¹.

The iron, copper, manganese, and zinc content of plants as influenced by different nutritional dosages are summarized in Table 8. T8 had the plant's greatest iron content, measuring 91.83 g ha⁻¹. On the other hand, T2 had the lowest iron level,

measuring 26.51 g ha⁻¹. T3 has the greatest concentration of copper (20.69 g ha⁻¹). T6 has the lowest copper concentration, measuring 28.89 g ha⁻¹. T3 has the greatest manganese levels, measuring 84.18 g ha⁻¹. T6 has the lowest manganese level of any sample, 15.86 g ha⁻¹. T9 had the greatest zinc content, measuring 38.51 g ha⁻¹. T6, on the other hand, has the lowest zinc level, weighing 7.67 g ha⁻¹. This result may be explained by the plant's improved ability to photosynthesize, which raised the amount of dry matter that accumulated and, in turn, increased the availability of nutrients to the plant's aerial parts from the soil. The increased nitrogen delivery as well as the crop's beneficial interactions with boron and zinc increased this even further. These results align with the findings of Karubakee et al. (2024) ^[18] as well as Singh and Lenka and Das (2019) ^[19].

Tuber nutrient content

Treatment T3 had the greatest nitrogen level, 359.26 kg ha⁻¹, as seen in Table 6 and Figure 1. Treatment T6 had the lowest nitrogen level, measuring 59.44 kg ha⁻¹. Treatment T9 had the maximum phosphorus level, 21.11 kg ha⁻¹. Treatment T6 had the lowest phosphorus concentration, 9.62 kg ha⁻¹. Treatment T4 had the maximum potassium level, 74.79 kg ha⁻¹. Treatment T5 had the lowest potassium concentration, 29.57 kg ha⁻¹. The combination application of NPK fertilizers and organic waste is probably what caused the increased potassium, phosphorus, and nitrogen buildup in the potato tubers. These results corroborate those of Nyamangara et al. (2000) ^[21], who found that farmyard manure promotes soil carbon mineralization by offering easily accessible carbon for microbial respiration, which raises nitrogen and phosphorus availability. Similar observations were observed by Zahoor et al. in 2021 ^[36].

There was no discernible variation in the levels of calcium, magnesium, and sulfur (Table 7). Treatment T4 had the highest calcium concentration, measuring 13.90 kg ha⁻¹, whereas treatment T5 had the lowest calcium content, measuring 4.93 kg ha⁻¹. With a value of 6.24 kg ha⁻¹, treatment T9 had the highest magnesium content. Treatment T2 had the lowest magnesium level, 1.82 kg ha⁻¹. Treatment T4 had the maximum sulfur level, 8.33 kg ha⁻¹. Treatment T2 had the lowest sulfur concentration, 3.40 kg ha⁻¹.

The micronutrient levels showed considerable variation (Table 8); T2 had the maximum iron concentration, measuring 84.19 g ha⁻¹. On the other hand, T5 had the lowest iron concentration, measuring 32.24 g ha⁻¹. T9 has the greatest copper content, measuring 22.24 g ha⁻¹. T4 has the lowest copper concentration, measuring 11.48 g ha⁻¹. T10 had the greatest manganese content, measuring 50.73 g ha⁻¹. T6 exhibited the lowest manganese concentration, 24.64 g ha⁻¹. T4 had the greatest zinc content, measuring 137.13 g ha⁻¹. Conversely, T5 showed the lowest zinc concentration, at 19.43 g ha⁻¹. Fertilizers high in nitrogen usually have little effect on the potassium, calcium, and magnesium contents of tubers. But it can cause the tubers' levels of iron and phosphorus to drop. Applying fertilizers containing phosphorus, on the other hand, can raise the concentrations of nitrogen and magnesium while simultaneously lowering manganese levels. Potassium fertilizers frequently, but not always, increase the amount of magnesium in tubers while lowering the amounts of calcium and phosphorus. These alterations are brought about by the intricate relationships between soil minerals and how they affect plant absorption, as well as the impact of tissue mineral composition on how elements are redistributed throughout the plant. All things considered; these investigations indicate that the availability of various minerals to the crop has a significant impact on the mineral content of tubers. As White et al. (2009) ^[34] point out,

the concentration of tuber minerals might really differ greatly depending on the area.

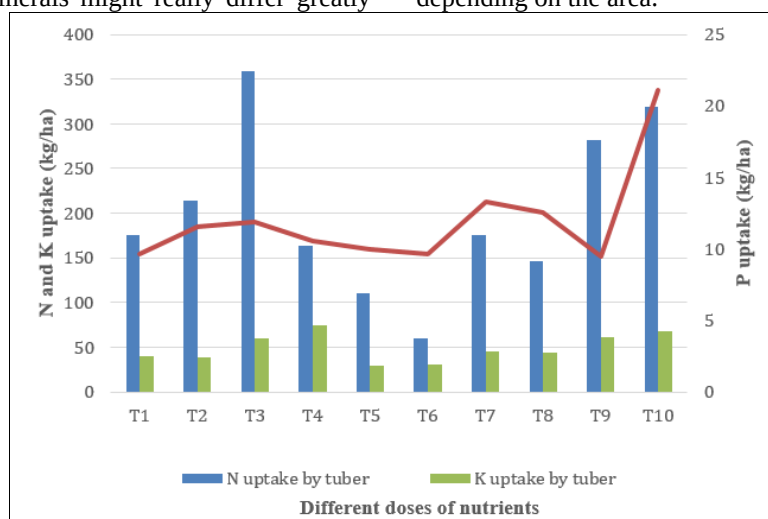


Fig 1: Performance of Apical rooted cuttings with different doses of nutrients on primary nutrient uptake by potato tubers

Table 3: Effect of different doses of nutrients on soil pH, EC, and Organic carbon (%) after harvesting

Treatments	pH	EC (dS m ⁻¹)	Organic carbon (%)
T ₁	5.12	0.70	0.60
T ₂	5.27	0.70	0.61
T ₃	4.89	0.63	0.53
T ₄	4.98	0.64	0.51
T ₅	5.27	0.61	0.59
T ₆	5.42	0.55	0.62
T ₇	5.11	0.60	0.60
T ₈	5.68	0.55	0.56
T ₉	4.98	0.60	0.54
T ₁₀	5.33	0.70	0.64
S.Em±	0.11	0.05	0.07
C.D at 5%	0.34	0.16	0.22

Table 4: Effect of different doses of nutrients on soil primary and secondary nutrients after harvesting

Treatments	Iron (ppm)	Copper (ppm)	Manganese (ppm)	Zinc (ppm)
T ₁	12.13	0.78	32.74	2.02
T ₂	14.14	1.14	31.14	2.22
T ₃	13.20	1.17	36.43	2.57
T ₄	16.90	1.12	36.66	2.44
T ₅	14.40	1.23	30.41	2.11
T ₆	15.83	1.14	30.69	1.87
T ₇	13.01	1.29	25.90	1.94
T ₈	14.55	1.23	32.32	2.54
T ₉	16.75	1.15	36.37	2.32
T ₁₀	16.90	0.81	29.61	1.70
S.Em±	2.05	0.01	0.53	0.03
C.D at 5%	6.11	0.04	1.60	0.10

Table 5: Effect of different doses of nutrients on soil micronutrients after harvesting

Treatments	Available Nitrogen (kg ha ⁻¹)	Available P ₂ O ₅ (kg ha ⁻¹)	Available K ₂ O (kg ha ⁻¹)	Exchangeable Calcium [cmol(p+) kg ⁻¹]	Exchangeable Magnesium [cmol(p+) kg ⁻¹]	Available Sulphur (ppm)
T ₁	324.84	29.31	265.31	2.71	1.60	19.79
T ₂	233.74	20.41	291.31	3.83	1.41	18.42
T ₃	391.21	34.89	300.70	2.80	1.90	11.27
T ₄	387.44	30.24	304.11	3.70	1.55	16.38
T ₅	220.41	19.59	241.60	3.23	1.65	13.16
T ₆	218.25	18.21	196.80	3.00	1.60	11.09
T ₇	265.21	25.91	209.31	3.91	1.95	12.05
T ₈	243.52	24.31	287.11	3.73	1.75	11.75
T ₉	285.95	28.46	265.11	3.75	1.90	12.68
T ₁₀	288.44	29.11	293.22	3.63	1.93	19.16
S.Em±	6.15	1.16	6.05	0.57	0.51	3.06

C.D at 5%	18.28	3.46	17.98	1.71	1.53	9.09
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Table 6: Effect of different doses of nutrients on primary nutrients uptake by plants and tuber nutrients

Treatments	Total Nitrogen (kg ha ⁻¹)			Total Phosphorus (kg ha ⁻¹)			Total Potassium (kg ha ⁻¹)		
	Plant	Tuber	Total	Plant	Tuber	Total	Plant	Tuber	Total
T ₁	128.44	175.34	303.78	3.35	9.63	12.98	61.48	39.79	101.27
T ₂	143.42	213.68	357.1	2.81	11.54	14.35	50.35	39.02	89.37
T ₃	233.36	359.26	592.62	3.71	11.88	15.59	70.87	59.91	130.78
T ₄	223.82	163.46	387.28	3.21	10.59	13.80	73.87	74.79	148.66
T ₅	132.31	110.25	242.56	2.91	9.99	12.90	57.18	29.57	86.75
T ₆	90.18	59.44	149.62	2.29	9.62	11.91	34.05	30.58	64.63
T ₇	132.55	175.83	308.38	2.86	13.29	16.15	56.28	45.86	102.14
T ₈	148.17	146.98	295.15	3.73	12.54	16.27	52.01	44.14	96.15
T ₉	170.7	281.53	452.23	2.91	9.45	12.36	51.92	61.34	113.26
T ₁₀	174.27	319.21	493.48	4.09	21.11	25.20	58.6	68.10	126.70
S.Em±	8.08	12.52	-	0.34	0.87	-	2.37	2.78	-
C.D at 5%	24.02	37.20	-	1.01	2.59	-	7.04	8.28	-

Table 7: Effect of different doses of nutrients on the secondary nutrient uptake by plants and tubers same as earlier

Treatments	Calcium (kg ha ⁻¹)			Magnesium (kg ha ⁻¹)			Sulphur (kg ha ⁻¹)		
	Plant	Tuber	Total	Plant	Tuber	Total	Plant	Tuber	Total
T ₁	Plant	Tuber	Total	Plant	Tuber	Total	Plant	Tuber	Total
T ₂	37.05	12.73	49.78	19.71	2.09	21.8	22.51	6.50	29.01
T ₃	24.60	10.24	34.84	15.43	1.82	17.25	24.00	3.40	27.40
T ₄	31.22	7.70	38.92	19.34	5.52	24.86	25.10	5.94	31.04
T ₅	29.06	13.9	42.96	19.60	2.52	22.12	27.92	8.33	36.25
T ₆	28.40	4.93	33.33	15.60	2.27	17.87	27.60	5.73	33.33
T ₇	25.32	7.11	32.43	14.50	2.56	17.06	26.80	3.90	30.70
T ₈	26.90	9.20	36.10	18.15	3.00	21.15	24.11	6.80	30.91
T ₉	21.25	7.80	29.05	16.30	4.30	20.60	26.60	2.97	29.57
T ₁₀	30.33	6.53	36.86	19.11	6.24	25.35	24.64	7.90	32.54
S.Em±	35.96	5.80	41.76	15.12	6.01	21.13	26.90	7.90	34.80
C.D at 5%	3.20	1.99	-	2.07	1.20	-	1.41	1.32	-
	9.52	5.91	-	6.17	3.51	-	4.19	3.92	-

Table 8: Effect of different doses of nutrients on micronutrients uptake of plants and tubers

Treatments	Iron (g ha ⁻¹)			Copper (g ha ⁻¹)			Manganese (g ha ⁻¹)			Zinc (g ha ⁻¹)		
	Plant	Tuber	Total	Plant	Tuber	Total	Plant	Tuber	Total	Plant	Tuber	Total
T ₁	37.50	40.50	78.00	13.91	15.10	29.01	52.91	39.23	92.14	29.80	123.60	153.4
T ₂	26.51	84.20	110.71	11.29	13.71	25.00	34.43	26.06	60.49	11.10	68.74	79.84
T ₃	76.52	56.42	132.94	20.70	18.24	38.94	84.20	49.42	133.62	32.00	128.92	160.92
T ₄	56.34	70.54	126.88	13.05	11.50	24.55	62.12	40.13	102.25	18.80	137.13	155.93
T ₅	84.98	32.24	117.22	6.64	20.60	27.24	43.94	26.60	70.54	28.02	19.43	47.45
T ₆	29.73	36.25	65.98	2.90	13.23	16.13	15.9	24.64	40.54	7.70	98.65	106.35
T ₇	69.96	47.05	117.01	8.51	18.70	27.21	48.32	36.32	84.64	30.40	32.47	62.87
T ₈	91.81	40.06	131.87	9.22	18.21	27.43	63.20	36.33	99.53	23.63	84.44	108.07
T ₉	47.23	50.11	97.34	7.96	22.24	30.20	60.11	45.47	105.58	38.51	35.21	73.72
T ₁₀	36.34	65.50	101.84	5.21	19.03	24.24	59.64	50.73	110.37	35.20	39.52	74.72
S.Em±	5.14	3.77	-	0.39	1.02	-	3.00	2.07	-	1.27	4.64	-
C.D at 5%	15.29	11.20	-	1.15	3.04	-	8.93	6.16	-	3.79	13.79	-

Conclusion

The present study demonstrates that nutrient standardization in Apical Rooted Cutting (ARC)-based potato production exerts a substantial influence on soil chemical properties, nutrient availability, and the subsequent nutrient accumulation in plant tissues and tubers. Among the ten nutrient regimes evaluated, T₃ (156:125:156 NPK + Potato Special) consistently enhanced the availability of primary nutrients in soil and resulted in superior uptake of both macro- and micronutrients by the crop. Although soil EC and organic carbon remained largely unaffected, higher Nitrogen applications were associated with reduced soil pH, reflecting increased acidification through nitrification.

Secondary nutrients exhibited limited variation, whereas micronutrient concentrations responded significantly to treatment effects, indicating strong interactions between applied fertilizers and soil mineral dynamics. Enhanced nutrient uptake and tuber enrichment under integrated nutrient management treatments, particularly those combining inorganic fertilizers with Potato Special, highlight the importance of balanced and supplemental nutrient inputs for optimizing the performance of ARC-derived potatoes. Overall, the findings underscore the value of optimized NPK regimes in improving nutrient-use efficiency, sustaining plant physiological functioning, and enhancing tuber nutritional quality. These results provide a

scientific basis for developing site-specific and sustainable nutrient management protocols tailored to ARC-based seed potato production systems.

Acknowledgement

Authors sincerely acknowledge the facilities provided by Regional Horticultural Research and Extension Centre and Department of Natural Resources management, College of Horticulture, UHS campus, Bengaluru

References

1. Abdel-Latif KM, Osman EAM, Abdullah R, Abdel-Kader N. Response of potato plants to potassium fertilizer rates and soil moisture deficit. *Adv Appl Sci Res.* 2011;2:388–397.
2. Anonymous. Estimates of potato production. New Delhi: Directorate of Economics, Ministry of Agriculture; 2013.
3. Anonymous. Indian horticulture database. Gurgaon: National Horticulture Board; 2019.
4. Babaji BA, Amanas EB, Falaki AM, Chiezey UF, Mahmud M, Mahadi MA, et al. *Niger J Agric Biol Sci.* 2007;2(4–5):21–25.
5. Black CA. Methods of soil analysis. Part 2. Madison (WI): American Society of Agronomy; 1965.
6. Blumenthal JM, Baltensperger DD, Cassman KG, Mason SC, Pavlista AD. Importance and effect of nitrogen on crop quality and health. In: Hatfield JL, Follett RF, editors. *Nitrogen in the environment.* Elsevier; 2008. p. 51–70.
7. Bouyoucos GJ. Hydrometer method improved for making particle size analysis of soils. *J Agron.* 1962;54:464–465.
8. Burlingame B, Mouillé B, Charrondière R. Nutrients, bioactive non-nutrients and anti-nutrients in potatoes. *J Food Compos Anal.* 2009;22:494–502.
9. Chindi A, Shunka E, Solomon A, Gebremedhin WG, Seid E, Tessema L. Participatory potato seed production in the central highlands of Ethiopia. *Open Agric.* 2017;2:205–212.
10. Food and Agriculture Organization. International year of the potato. Rome: FAO; 2008.
11. Fernandez-Lopez J, Botella-Martínez C, de Vera CNR, Sayas-Barberá ME, Viuda-Martos M, Sánchez-Zapata E, et al. Vegetable soups and creams: raw materials, processing, health benefits and innovation trends. *Plants.* 2020;9:1769–1769.
12. Fisher RA, Yates F. Statistical tables for biological, agricultural and medical research. Edinburgh: Oliver and Boyd; 1938.
13. Gildemacher PR, Kaguongo W, Ortiz O, Tesfaye A, Woldegiorgis G, Wagoire WW, et al. Improving potato production in Kenya, Uganda and Ethiopia: a system diagnosis. *Potato Res.* 2009;52:173–206.
14. Harris PM. Mineral nutrition. In: Harris PM, editor. *The potato crop: the scientific basis for improvement.* London: Chapman and Hall; 1978. p. 195–243.
15. Harris PM. *The potato crop: the scientific basis for improvement.* Springer; 2012.
16. Hensh S, Malik GC, Banerjee M, Shankar T. Studies on integrated nutrient management on productivity and economics of potato. *Pharma Innov J.* 2020;9(12):15–18.
17. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt Ltd; 1973.
18. Karubakee S, Rath BS, Satapathy M, Mishra A. Effect on yield, nutrient uptake and quality of potato under integrated nutrient management. *Not Bot Horti Agrobot Cluj-Napoca.* 2024;52(2):13288–13288.
19. Lenka B, Divya RK, Das SK. Effect of zinc and boron nutrition on nutrient use efficiency and economics of potato. *Int J Chem Stud.* 2019;8(3):10–17.
20. Lindsay WL, Norvell WA. Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Sci Soc Am J.* 1978;42:421–428.
21. Nyamangara J, Mugwira LM, Mpofu SE. Soil fertility status in communal areas of Zimbabwe. *J Sustain Agric.* 2000;16:15–29.
22. Parmar DK, Sharma AS, Chaddha SC, Sharma VS, Vermani AV, Mishra AM, et al. Integrated plant nutrient system to improve productivity and profitability of potato. *Potato J.* 2007;34:209–215.
23. Piper CS. Soil and plant analysis. Bombay: Hans Publishers; 1966.
24. Satognon F, Lelei JJ, Owido SF. Performance of apical rooted cuttings of potato under nitrogen and irrigation regimes. *Heliyon.* 2021;7(9):e07842–e07842.
25. Sahair R, Sneha S, Raghu N, Gopenath T, Karthikeyan M, Gnanasekaran A, et al. *Solanum tuberosum* L.: Botanical, phytochemical and nutritional significance. *Int J Phytomedicine.* 2018;10:115–124.
26. Setu H, Mitiku T. Response of potato to nitrogen and phosphorus fertilizers at Assosa, Ethiopia. *J Agron.* 2020;112:1227–1237.
27. Sharma AK, Pandey KK. Mini-tuber production through direct transplanting of *in vitro* plantlets. *Am Potato J.* 2013;40:95–103.
28. Sood S. Kufri Karan: a multiple disease-resistant potato variety for hills and plateau regions. *Potato J.* 2021;47(2):1–10.
29. Subbiah BV, Asija GL. A rapid procedure for the estimation of available N in soils. *Curr Sci.* 1956;25:259–260.
30. Tadesse M, Lommen WJM, Struik PC. Temperature pre-treatment and transplant growth of potato plantlets. *Potato Res.* 2001;44:173–185.
31. Thamburaj S, Singh N. Vegetables, tuber crops and spices. New Delhi: ICAR; 2016.
32. Tripathi DK, Singh S, Singh S, Mishra S, Chauhan DK, Dubey NK. Micronutrients and their role in agricultural crops. *Acta Physiol Plant.* 2015;37:1–14.
33. Walkley AJ, Black CA. Examination of methods for determining soil organic matter. *Soil Sci.* 1934;37:29–38.
34. White PJ, Bradshaw JE, Finlay M, Dale B, Ramsay G, Hammond JP, et al. Relationships between yield and mineral concentration in potato tubers. *HortScience.* 2009;44:6–11.
35. Youssef RA, Mohamed AA, El-Sayed MA. Effects of nitrogen fertilizers on soil properties and plant growth. *J Soil Sci Agric Eng.* 2017;8(2):45–52.
36. Zahoor M, Afzal M, Ali M, Mohammad W, Khan N. Effect of organic waste and NPK fertilizer on potato yield and soil fertility. *Pure Appl Biol.* 2021;5:439–445.
37. Zelalem A, Tekalign T, Nigussie D. Response of potato to nitrogen and phosphorus on vertisols. *Afr J Plant Sci.* 2009;3:16–24.
38. Roy DP, Wulder MA, Loveland TR, Ce W, Allen RG, Anderson MC, Helder D, Irons JR, Johnson DM, Kennedy R, Scambos TA. Landsat-8: Science and product vision for terrestrial global change research. *Remote sensing of Environment.* 2014 Apr 5;145:154–72.
39. Biswas A, Bhattacharjee U, Chakrabarti AK, Tewari DN, Banu H, Dutta S. Emergence of Novel Coronavirus and COVID-19: whether to stay or die out?. *Critical reviews in*

- microbiology. 2020 Mar 3;46(2):182-93.
40. Allen PB. Neutron spectroscopy of superconductors. *Physical Review B*. 1972 Oct 1;6(7):2577.
41. Patel A, Sindhu DK, Arora N, Singh RP, Pruthi V, Pruthi PA. Biodiesel production from non-edible lignocellulosic biomass of *Cassia fistula* L. fruit pulp using oleaginous yeast *Rhodospiridium kratochvilovae* HIMPA1. *Bioresource Technology*. 2015 Dec 1;197:91-8.
42. Singh A, Singh NA, Afzal S, Singh T, Hussain I. Zinc oxide nanoparticles: a review of their biological synthesis, antimicrobial activity, uptake, translocation and biotransformation in plants. *Journal of materials science*. 2018 Jan;53(1):185-201.
43. Hesse CO. Monoploid Peaches, *Prunus persica* Batch: Description and Meiotic Analysis1. *Journal of the American Society for Horticultural Science*. 1971 May 1;96(3):326-30.