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Influence of integrated application of NPK, Biofertilizers and zinc on the growth, yield and quality of potato (*Solanum tuberosum* L.) cv. Kufri Ganga

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Abstract
This present investigation entitled "Influence of Integrated Application of NPK, Biofertilizers, and Zinc on the Growth, Yield and Quality of Potato (*Solanum tuberosum*) cv. Kufri Ganga" was carried out in Kanpur, India, in the Research Field of the Vegetable Science Centre of Excellence during the Rabi season of 2024-2025. The experimental study was carried out using a Randomized Block Design (RBD) comprising three replications, each consisting of ten plots. Kufri Ganga. Treatments varied significantly in all observed parameters, with T_9 (150% RDF + 5.0 kg/ha Zn + foliar spray of $ZnSO_4$ 0.5% at 25 and 50 DAS) consistently recording the highest values. Plant emergence ranged from 85.35% to 97.68%, with T_9 showing maximum emergence. Growth attributes such as plant height, number of leaves, number of stems, and fresh and dry leaf weights were highest in T_9 at all growth stages, followed closely by T_3, T_4, and T_5. Yield parameters, including number of tubers per plant and per plot, tuber weight, yield per plant, yield per plot, and marketable yield per hectare, were significantly enhanced under T_9, achieving 36.24 t/ha, which was markedly higher than the control (12.80 t/ha). Biochemical traits also responded positively, with T_9 recording the highest total sugar (2.72%), reducing sugar (1.31%), starch (0.96%), total soluble solids (5.98 °Brix), and chlorophyll content (1.39 mg/g). Overall, integrated application of 150% RDF with soil-applied zinc and foliar $ZnSO_4$ sprays proved most effective in enhancing crop growth, yield, and quality attributes compared to other treatments and the control. This highlights the potential of combined nutrient management strategies for maximizing productivity and quality in the studied crop.

Keywords: Integrated nutrient management (INM), zinc sulphate, biofertilizer, growth parameters, yield, quality, biochemical traits.

Introduction
Potato (*Solanum tuberosum L.*) is a popular vegetable and major food crop worldwide. chromosome no. 2n=4x=48. It is the "future food." The United Nations designated 2008 as the "International Year of Potato" because it views potatoes as a key food that contributes to both food security and poverty reduction. Due to their high nutritional content and potential for large yields, potatoes rank third in importance among food crops, after rice and wheat Kumar *et al.*, (2015) [8, 17].

Solanum tuberosum is a herbaceous perennial species that can attain an approximate height of 1 m, characterized by elongated pinnate leaves and floral colors that range from pink to white, purple, or blue, with stamens exhibiting a yellow hue, which also yields fruit that bears resemblance to a green cherry tomato but is toxic to humans due to the presence of solanine, a notable alkaloid. Cultivated potato plants develop enlarged subterranean stems, commonly referred to as tubers, which constitute a significant economic asset. On the surface of the tubers, one can observe "eyes" or buds that are systematically arranged in a spiral configuration. Under optimal conditions, new plants and shoots are capable of emerging from these eyes.

Most potato crops are propagated from vegetative parts or tubers, which are clones of their parents. In contrast, plants grown from seeds exhibit wide variation, poor vigor, and lower yields. Additionally, propagation from seeds is a labor-intensive and time-consuming process; therefore, propagation from tubers is preferred over that from seeds in potato crops.

After rice and wheat, potatoes are the third most widely consumed food crop worldwide. Around the world, 300 million metric tons of agricultural products are produced and over a billion people use potatoes.

Compared with cereal crops, potatoes yield two to four times the amount of food per acre. Compared with other major crops, potatoes may use up to seven times more water than cereals and yield more water per unit of water. Since the early 1960s, the area planted with potatoes has increased more rapidly than that of any other crop in developing countries. It is an essential part of food security for many individuals in South America, Africa, Asia, and India. Currently, almost half of the world's potato production originates from developing countries.

According to Potato Nutrition - International Potato Centre, Lima, Peru (2011), "potato has a nutrient constituent of Carbohydrate 20.13 g, Protein 1.87 g, Fiber 1.8 g, Fat 0.1 g, Potassium 379 mg, Phosphorus 44 mg, Vitamin C 13 mg, Fe 0.4 mg, Zn 0.3 mg, Calcium 5 mg, Riboflavin 0.02 mg, Thiamine 0.10 mg, and Niacin 1.44 mg."

20.13 g of carbohydrates, 1.87 g of protein, 1.8 g of fiber, 0.1 g of fat, 379 mg of potassium, 44 mg of phosphorus, 13 mg of vitamin C, 0.4 mg of iron, 0.3 mg of zinc, 5 mg of calcium, 0.02 mg of riboflavin, 0.10 mg of thiamine, and 1.44 mg of niacin are among the nutrients found in potatoes. (Potato Nutrition International Potato Centre, Lima, Peru, 2011).

Potato is highly responsive to nutrient applications. Nitrogen is the primary limiting nutrient for potato cultivation. Potassium increased the size of the tubers. The recommended doses of nitrogen, phosphorus, and potassium are 180-200 kg, phosphorus 90-100 kg and potassium 120-150 kg per hectare, respectively. However, nutrient requirements depend on the type of soil and its nutrient status (Hazra and Som, 2015) [6]. The primary limiting nutrient in potato cultivation is nitrogen, which directly affects the tuber yield in all soil groups. For effective utilization by the crop, nitrogen should be applied in two split doses: half at the time of planting and the remaining half at earthing up.

Several high-yielding varieties have been developed, and a number of trials on planting time, spacing, manurial and fertilizer requirements, water management, and weed control have been conducted to increase potato production. Among these cultural practices, the optimum fertilizer dose is one of the most important. Furthermore, among the major nutrients, the roles of nitrogen, phosphorus, and potash have been well documented *with respect to* tuber development, yield, and quality. Inadequate fertilization leads to poor crop growth and yield, whereas excessive fertilization leads to delayed tuberization, poor quality, excessive nitrate leaching, and ultimately a reduction in tuber yield. Potato cultivars differ in their yield potential, response to NPK, and bulking rate, even if they are of the same maturity group. Nitrogen (N), an essential constituent of proteins and chlorophyll, plays a key role in crop growth and development. Phosphorus fertilization contributes to early crop development and tuberization and enhances tuber maturation, whereas potassium influences both yield and tuber quality and enhances plant resistance to drought and frost stress (Nizamuddin *et al.,* 2003) [13]. Biofertilizers show a positive response to growth and tuber yield and are useful in maximizing the uptake of fertilizers.

Biofertilizers are natural fertilizers containing microorganisms that enhance productivity by biological nitrogen fixation, solubilization of insoluble phosphate, or production of hormones, vitamins, and other growth regulators required for plant growth. *Azotobacter*, PSB, and *Bacillus* have been recognized as the cheapest fertilizer inputs for improving soil health and fertility for optimum crop production. However, their effects depend on the crop type, soil, and environmental conditions. The ability of *Azotobacter* and PSB to proliferate in the *rhizosphere* of crops suggests increased nutrient availability to plants. It is a matter of great interest to determine the best combination of organic compounds with or without biofertilizer treatment, which can induce better growth, yield, and quality of potatoes.

Material and Methods

This present investigation entitled "Influence of Integrated Application of NPK, Biofertilizers, and Zinc on the Growth, Yield and Quality of Potato (*Solanum tuberosum*) cv. Kufri Ganga" was carried out in Kanpur, India, in the Research Field of the Vegetable Science Centre of Excellence during the Rabi season of 2024-2025. The experimental study was carried out using a Randomized Block Design (RBD) comprising three replications, each consisting of ten plots. Kufri Ganga is a medium-duration, high-yielding, table-purpose potato variety developed by the ICAR-Central Potato Research Institute (CPRI), Modipuram, Meerut, U.P. through a cross between MS/82-638 and Kufri Gaurav. Released in 2018-19, this variety is especially suited for cultivation in the North Indian plains.

The parameters recorded viz., Plant emergence (%), Plant height (cm), Number of leaves plant^{-1}, Number of stems plant^{-1}, Fresh weight of leaves (g), Dry weight of leaves (g), Number of tubers/plants, Number of tubers/plots, Tuber weight (g), Tuber yield/plant (g), Tuber yield/plot (kg), Grade wise tuber yield (t ha^{-1}), Marketable tuber yield (t ha^{-1}), Total sugar (%), Reducing sugar (%), Starch (%), Total soluble solid (⁰Brix), Chlorophyll content (mg/g), Soil pH, Soil EC (ds m^{-1}), Organic carbon (%), Soil available N (Kg ha^{-1}), Soil available P (Kg ha^{-1}), Soil available K (Kg ha^{-1}), Soil available Zn (ppm), Concentration of Zn in Plant Samples (ppm), Cost of cultivation, Gross Return and Benefit cost ratio.

3. Result and Discussion

3.1 Growth parameters

3.1.1 Plant emergence (%)

The per cent emergence ranged (Table 1) from 90.35 to 97.68 per cent. Significantly maximum emergence per cent (97.68 %) was noticed among the plants which received T_9: 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days which was at par with T_3 (96.35 %), T_4 (95.26 %) and T_5 (94.23.5%). While minimum emergence (85.35 %) was recorded in the control. Similar results were reported by Singh *et al.* (2015) [17].

3.1.2 Plant Height

Significant differences in plant height were observed (Table 1) across treatments at all growth stages. At 30 DAS, the tallest plants (19.42 cm) were recorded in T_9 (150% RDF + 5.0 kg/ha Zn + foliar spray of $ZnSO_4$ 0.5% at 25 and 50 DAS), which was at par with T_3 (17.67 cm), T_4 (16.80 cm), and T_5 (16.70 cm), while the control recorded the lowest height (10 cm). At 60 DAS, T_9 again showed the highest height (36.33 cm), statistically similar to T_3 (35.33 cm), T_4 (34.87 cm), and T_5 (34.42 cm), with the control being minimum (25 cm). At harvest, T_9 maintained the maximum height (45.00 cm), at par with T_3 (43.00 cm), T_4 (42.60 cm), and T_5 (42.33 cm), whereas the control recorded the shortest plants (35 cm). Similar results were reported by Fouda (2021) [5].

3.1.3 Number of leaves plant^{-1}

The number of leaves varied significantly across treatments (Table 2) at all stages. At 30 DAS, T_9 (150% RDF + 5.0 kg/ha Zn + foliar spray of $ZnSO_4$ 0.5% at 25 and 50 DAS) recorded the maximum leaves (189.67), at par with T_3 (188.33), T_4 (187.12), and T_5 (186.32), while the control had the least (175.36). At 60 DAS, T_9 again showed the highest leaf count (221.67), statistically similar to T_3 (213), T_4 (210), and T_5 (196), with the control lowest (183.33). At harvest, T_9 maintained the maximum leaves (280), at par with T_3 (277), T_4 (275.80), and T_5 (275.47), whereas the control recorded the minimum (200). Similar results were reported by Sharma *et al.* (2015) [16].

3.1.4 Number of stems plant^{-1}

The number of stems varied significantly across treatments (Table 2) at all stages. At 30 DAS, T_9 (150% RDF + 5.0 kg/ha Zn + foliar spray of $ZnSO_4$ 0.5% at 25 and 50 DAS) recorded the highest stems (4.17), at par with T_3 (4.00), T_4 (3.97), and T_5 (3.93), while the control had the lowest (3.27). At 60 DAS, T_9 again showed the maximum stems (4.83), comparable to T_3 (4.50), T_4 (4.45), and T_5 (4.38), with the control minimum (3.93). At harvest, T_9 maintained the highest stem count (4.90), statistically similar to T_3 (4.89), T_4 (4.82), and T_5 (4.75), whereas the control recorded the least (4.00). Similar results were reported by Singh *et al.* (2015) [17].

3.1.5 Fresh weight of leaves (g)

The fresh weight of leaves varied significantly (Table 2) across treatments at all stages. At 30 DAS, T_9 (150% RDF + 5.0 kg/ha Zn + foliar spray of $ZnSO_4$ 0.5% at 25 and 50 DAS) recorded the highest fresh weight (12.35 g), at par with T_3 (9.38 g), T_4 (9.37 g), and T_5 (9.35 g), while the control had the lowest (8.68 g). At 60 DAS, T_9 again showed the maximum weight (28.02 g), comparable to T_3 (27.20 g), T_4 (26.67 g), and T_5 (26.75 g), with the control minimum (18.68 g). At harvest, T_9 maintained the highest weight (37.94 g), statistically similar to T_3 (35.16 g), T_4 (35.85 g), and T_5 (34.45 g), whereas the control recorded the least (24.83 g). Similar results were reported by Kumar *et al.* (2015) [8, 17].

3.1.6 Dry weight of leaves (g)

The dry weight of leaves differed significantly among (Table 3) treatments at all stages. At 30 DAS, T_9 (150% RDF + 5.0 kg/ha Zn + foliar spray of $ZnSO_4$ 0.5% at 25 and 50 DAS) recorded the highest dry weight (1.23 g), at par with T_3 (0.94 g), T_4 (0.94 g), and T_5 (0.94 g), while the control had the lowest (0.87 g). At 60 DAS, T_9 again showed the maximum (2.80 g), comparable to T_3 (2.72 g), T_4 (2.67 g), and T_5 (2.66 g), with the control minimum (1.87 g). At harvest, T_9 maintained the highest (3.79 g), statistically similar to T_3 (3.52 g), T_4 (3.49 g), and T_5 (3.44 g), whereas the control recorded the least (2.48 g). Similar results were reported by Mondal *et al.* (2007) [10].

3.2 Yield parameters

3.2.1 Number of tubers/plant

The number of tubers per plant were found (Table 3) maximum (3.80) in the treatment which received T_9: 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days which was statistically at par with T_3 (3.75), T_4 (3.65) and T_5 (3.45). The minimum number of tubers per plant (2.56) were found in the control. Similar results were reported by Lopez *et al.* (2014) [9], Narayan *et al.*, (2014) [12], Fasil *et al.*, (2016) [4].

3.2.2 Number of tubers/plot

The number of tubers per plot were found (Table 3) maximum (109.95) in the treatment T_9: 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days which was statistically at par with T_3 (108.32), T_4 (107.03) and T_5 (107.02). The minimum number of tubers per plot (92.36) were found in the control. Similar results were reported by Lopez *et al.* (2014) [9], Narayan *et al.*, (2014) [12], Fasil *et al.*, (2016) [4].

3.2.3 Tuber weight (g)

The maximum tuber weight was recorded (Table 3) in the treatment (75.44) supplied with the combination of T_9: 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days which was statistically at par with T_3 (73.41), T_4 (73.35) and T_5 (73.39). The minimum tuber weight (70.89 g) was found in the control. Similar results were reported by Ali *et al.* (2020) [2], Lopez *et al.*, (2014) [9].

3.2.4 Yield per plant

The maximum yield per plant was recorded (Table 3) in the treatment (248.66 g) supplied with the combination of T_9: 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days which was statistically at par with T_3 (246.99 g), T_4 (238.66 g) and T_5 (226.77 g). The minimum yield per plant (201.64 g) was found in the control. Similar results were reported by Banerjee *et al.*, (2016) [3], Mondal and Sarkar, (2005) [11], Lopez *et al.*, (2014) [9].

3.2.5 Yield per plot

The maximum yield per plot was recorded (Table 3) in the treatment (10.07 kg) supplied with the combination of T_9: 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days which was statistically at par with T_3 (9.87 kg), T_4 (9.81 kg kg) and T_5 (9.16 kg). The minimum yield per plot (8.97 kg) was found in the control. Similar results were reported by Singh and Kushwah (2006) [18], Yadav *et al.*, (2014) [19], Mondal and Sarkar, (2005) [11].

3.2.6 Marketable yield per hectare

The maximum yield per hectare was recorded (Table 4) in the treatment (36.24 t/ha) supplied with the combination of T_9: 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days which was statistically at par with T_6 (34.25 t ha), T_3 (33.21 t/ha) and T_8 (31.21 t/ha). The minimum yield per hectare (12.80 t / ha) was found in the control. Similar results were reported by Lopez *et al.* (2014) [9].

3.3 Biochemical parameters

3.3.1 Total sugar (%)

The total sugar content was recorded maximum (Table 4) in the treatment (T_9) supplied with the combination of 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days (2.72 %), which was at par with T_3 (1.98 %), T_4 (1.83 %) and T_5 (1.78 %). The minimum sugar content (1.01 %) was found in the control. Similar results were reported by Reddy *et al.*, (2024) [15].

3.3.2 Reducing sugar (%)

The maximum reducing sugar percentage was recorded (Table 4) in the treatment (T_9) supplied with the combination of 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days (1.31 %), which was at par with T_3 (1.06 %), T_4 (1.04 %) and T_5 (1.03 %). The minimum reducing sugar (0.22 %) was found in the control. Similar results were reported by Prasad (2010) [14].

3.3.3 Starch (%)
The maximum starch content was recorded (Table 4) in the treatment (T_9) supplied with the combination of 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days (0.96 %), which was at par with T_3 (0.87 %), T_4 (0.82 %) and T_5 (0.73 %). The minimum starch content (0.20 %) was found in the control. Similar results were reported by Abdel and Shams (2012) [1].

3.3.4 Total soluble solids (°Brix)
The maximum total soluble solids in the tuber were recorded (Table 4) in the treatment (T_9) supplied with the combination of 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days (5.98 °Brix), which was at par with T_3 (5.86 °Brix), T_4 (5.82 °Brix) and T_5 (5.81 °Brix). The minimum total soluble solid (5 °Brix) was found in the control. Similar results were reported by Reddy *et al.*, (2024) [15].

3.3.5 Chlorophyll content (mg/g)
Plants fertilized with 150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 days (T_9) produced highest (Table 4) total chlorophyll content (1.39 mg / g) which was statistically at par with T_3 (1.37 mg / g), T_4 (1.36 mg / g), T_5 (1.35 mg / g) and T_6 (1.25 mg / g). While minimum chlorophyll content (1.01 mg / g) was recorded in the control. Similar results were reported by Abdel and Shams (2012) [1].

Table 1: Growth parameters in potato

S. No.	Treatments	Emergence (%)	Plant height (cm)		
			30 DAS	60 DAS	At Harvest
T_1	50% RDF of NPK	92.35	12.67	27.00	37.33
T_2	100% RDF of NPK	93.65	14.67	29.33	39.67
T_3	150% RDF of NPK	96.35	17.67	35.33	43.00
T_4	50% RDF + Biofertilizer (Azotobacter + PSB)	95.26	16.80	34.87	42.60
T_5	100% RDF + Biofertilizer (Azotobacter + PSB)	94.35	16.70	34.42	42.33
T_6	150% RDF + Biofertilizer (Azotobacter + PSB)	94.26	16.13	32.33	42.29
T_7	50% RDF + 5.0 kg/ha zinc	91.25	14.82	32.27	42.41
T_8	100% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days	93.36	14.41	31.33	40.33
T_9	150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 Days	97.68	19.42	36.33	45.00
T_{10}	Absolute control	85.35	10.23	25.00	35.00
S.E m±		0.536	1.03	1.52	2.73
CD @ 5%		1.598	3.00	4.41	7.94

Table 2: Growth parameters in potato

S. No.	Treatments	Number of leaves			Number of stems			Fresh weight of leaves (gm)		
		30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest
T_1	50% RDF of NPK	182.00	192.33	216.67	3.29	3.95	4.02	8.78	20.02	26.35
T_2	100% RDF of NPK	185.35	197.33	250.00	3.32	3.99	4.05	8.88	25.04	28.35
T_3	150% RDF of NPK	188.33	213.00	277.90	4	4.5	4.89	9.38	27.2	35.16
T_4	50% RDF + Biofertilizer (Azotobacter + PSB)	187.12	210.00	275.80	3.97	4.45	4.82	9.37	26.67	34.85
T_5	100% RDF + Biofertilizer (Azotobacter + PSB)	186.32	196.67	275.47	3.93	4.38	4.75	9.36	26.57	33.45
T_6	150% RDF + Biofertilizer (Azotobacter + PSB)	181.25	195.67	273.00	3.96	4.33	4.4	9.35	25.02	32.35
T_7	50% RDF + 5.0 kg/ha zinc	183.65	195.00	273.48	3.97	4.49	4.59	9.34	25.03	31.95
T_8	100% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days	179.21	194.67	270.17	3.9	4.27	4.33	9.33	23.02	32.35
T_9	150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 Days	189.67	221.67	280.00	4.17	4.83	4.9	12.35	28.02	37.94
T_{10}	Absolute control	175.36	183.33	199.00	3.27	3.93	4	8.68	18.68	24.83
S.E m±		7.48	12.93	15.89	0.26	0.22	0.27	0.91	4.72	2.81
CD @ 5%		21.75	37.60	46.19	1.84	1.72	1.67	2.66	13.72	8.18

Table 3: Yield Parameters in Potato

S.No.	Treatments	Dry weight of leaves (gm) 30 DAS	60 DAS	At Harvest	Number of tubers/plants	Number of tubers/plots	Tuber weight (g)	Yield/plant (g)	Yield/plot (kg)	Marketable Yield/ha (t)
T_1	50% RDF of NPK	0.88	2.00	2.63	2.87	91.63	70.56	202.50	9.55	17.8
T_2	100% RDF of NPK	0.89	2.50	2.84	2.94	95.09	72.89	214.29	9.07	27.0
T_3	150% RDF of NPK	0.94	2.72	3.52	3.75	108.32	73.41	246.90	9.87	33.21
T_4	50% RDF + Biofertilizer (Azotobacter + PSB)	0.94	2.67	3.49	3.65	107.03	73.35	238.66	9.81	18.24
T_5	100% RDF + Biofertilizer (Azotobacter + PSB)	0.94	2.66	3.34	3.65	107.02	73.39	226.77	9.16	29.5
T_6	150% RDF + Biofertilizer (Azotobacter + PSB)	0.94	2.50	3.23	3.3	104.49	72.79	226.80	8.87	34.25
T_7	50% RDF + 5.0 kg/ha zinc	0.93	2.50	3.20	3.28	106.2	72.76	226.21	9.02	20.0
T_8	100% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days	0.93	2.30	3.23	3.17	104.76	72.23	228.96	9.01	31.21
T_9	150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 Days	1.23	2.80	3.79	3.80	109.95	75.44	248.66	10.07	36.24
T_{10}	Absolute control	0.87	1.87	2.48	2.56	92.36	70.89	201.64	8.87	12.80
S.E m±		0.91	4.72	2.81	0.10	4.16	4.16	14.47	0.57	1.21
CD @ 5%		2.66	13.72	8.18	0.30	12.10	12.10	42.05	1.65	3.51

Table 4: Biochemical Parameters in Potato

S.No.	Treatments	Total Sugar (%)	Reducing sugar (%)	Starch (%)	Total soluble solids (°Brix)	Chlorophyll content (mg/g)
T_1	50% RDF of NPK	1.03	0.73	0.45	5.69	1.20
T_2	100% RDF of NPK	1.23	0.65	0.56	5.60	1.26
T_3	150% RDF of NPK	1.98	1.06	1.07	5.86	1.36
T_4	50% RDF + Biofertilizer (Azotobacter + PSB)	1.83	1.04	1.02	5.82	1.35
T_5	100% RDF + Biofertilizer (Azotobacter + PSB)	1.78	1.03	0.93	5.81	1.25
T_6	150% RDF + Biofertilizer (Azotobacter + PSB)	1.32	0.66	0.84	5.74	1.21
T_7	50% RDF + 5.0 kg/ha zinc	1.22	0.54	0.72	5.70	1.16
T_8	100% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days	1.25	0.34	0.73	5.71	1.15
T_9	150% RDF + 5.0 kg/ha zinc + Foliar spray $ZnSO_4$ 0.5% @ 25 days and 50 Days	2.72	1.31	1.16	5.98	1.39
T_{10}	Absolute control	1.01	0.22	0.4	5	1.01
S.E m±		0.10	0.25	0.27	1.41	0.57
CD @ 5%		0.30	1.24	1.35	2.05	1.65

Conclusion

The study clearly demonstrated that integrated nutrient management practices significantly enhanced growth, yield, and biochemical quality of the crop. Among all treatments, T_9 (150% RDF + 5.0 kg/ha Zn + foliar spray of $ZnSO_4$ 0.5% at 25 and 50 DAS) consistently recorded superior performance in all parameters. Higher plant emergence, greater plant height, more leaves and stems, and increased fresh and dry leaf weights were achieved under T_9. Yield attributes such as number of tubers per plant, number of tubers per plot, tuber weight, yield per plant, and marketable yield per hectare were maximized in T_9, resulting in a substantial yield advantage over the control. Quality parameters, including total sugar, reducing sugar, starch, TSS, and chlorophyll content, were also significantly improved with this treatment. The combined application of higher RDF, soil-applied zinc, and foliar $ZnSO_4$ sprays enhanced nutrient availability and uptake, leading to better physiological growth and tuber development. The results highlight the importance of integrating macro and micronutrient management for sustainable crop production. Adoption of this nutrient management strategy could improve both productivity and profitability for farmers while maintaining soil health. This approach is particularly effective in zinc-deficient soils and areas requiring higher nutrient input efficiency.

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