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Effect of foliar application of nano zinc and nano copper on the growth, yield and economics of cowpea (*Vigna unguiculata* L.)

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Abstract

A field experiment was conducted during the Kharif season 2025 at the Vegetable Research Farm, Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, to evaluate the effect of foliar application of nano zinc and nano copper on growth, yield, post-harvest quality, and economics of cowpea (*Vigna unguiculata* L.). The experiment comprised eight treatments arranged in a Randomized Block Design with three replications. Results indicated that foliar application of nano zinc (50 ppm) + nano copper (50 ppm) significantly enhanced growth and yield attributes compared to other treatments. The combined application recorded the highest plant height, number of branches, pods per plant, pod length, pod width, pericarp weight, and seeds per pod. It also produced the maximum pod yield (428.66 g plant⁻¹ and 16.20 kg plot⁻¹), representing a 56.05% increase over the control. Post-harvest shelf life was significantly improved under the combined nano-nutrient treatment. Economic analysis revealed the highest net return (₹3,73,866.8 ha⁻¹) and benefit–cost ratio (1:6.83) with nano zinc + nano copper application. Nano-formulations consistently outperformed their conventional counterparts (ZnSO₄ and CuSO₄), highlighting the potential of nanotechnology for efficient micronutrient delivery and enhanced crop productivity. The study concludes that foliar application of nano zinc and nano copper at 50 ppm each is an effective and economically viable strategy for improving yield, yield attributes, shelf life, and profitability of cowpea cultivation.

Keywords: Cowpea, nano zinc, nano copper, foliar application, yield, shelf life, economic

Introduction

Agriculture sector is one of the most important sectors which plays a major role in ensuring food and nutritional security around the world. Green revolution was a major leap in meeting the food requirements of the rising population around the globe through the intensive use of irrigation, fertilizers, agrochemicals and short duration high yielding dwarf varieties etc. which ultimately led to an increase in world food production. However, the adverse impacts of green revolution became evident in the later years. Intensive use of chemical fertilizers led to the deterioration of soil health and the quality of underground water. Eutrophication, nutrient imbalances and other environmental hazards occurred as a result of improper and unscientific management of conventional fertilizers (Alshaal and El-Ramady, 2017) [3]. Cowpea is well-known for its ability to withstand dryness. It is also known as black-eyed pea or southern pea. The shadowing effect of its broad, drooping leaves preserves soil moisture. It can be used as a vegetable, food, feed, fodder, forage and green manuring. In the semi-arid tropical regions of Asia, Africa, Southern Europe, Central America, and South America, it is a vital food legume. Worldwide, the use of cowpeas as food, fodder, and a raw resource for numerous industries is increasing. Cowpea, also referred to as vegetable meat, is a valuable source of vitamins, minerals, and protein for a healthy diet. 4.3 g protein, 2.0 fibre, 8.0 g carbohydrate, 74 mg phosphorus, 2.5 mg iron, 13.0 mg vitamin C and 0.9 mg minerals, etc. are present in 100 g of green tender pods (Damoar K, Sharma RK, Maida P, 2020) [6]. India has low pulse production and productivity as pulses are cultivated mainly on marginal and submarginal soils with inadequate management techniques (Ponniya Vijay, Anil Choudhary K, 2015) [24]. India is the world's biggest importer and user of pulses. With 2,745.28 tonnes production, Uttar Pradesh is the top cowpea producer. India's productivity of pulses (764 kg ha⁻¹) is significantly lower than the global average (848 kg ha⁻¹). Overall area cultivated for

pulses remains almost unchanged at 22 to 24 million hectares, with a production that has remained relatively constant at 12 to 14 million tonnes. Legumes are crops that are fond of phosphorus, and is necessary for the development of seeds, nodules, and flower initiation. Zinc is a major micronutrient that is crucial to the growth and development of plants. In developing countries, Zn deficiency occurs due to inadequate supply of micronutrient. Several research findings also reported that, considerable increment in the yield of the crop is due to the application of Zn fertilizers. In India, despite the availability of high-yielding varieties such as 'Kashi Kanchan', cowpea productivity remains below its potential due to several production constraints, among which micronutrient deficiencies are particularly significant. Zinc and copper are essential micronutrients involved in numerous physiological and biochemical processes, including enzyme activation, photosynthesis, protein synthesis, reproductive development, and biological nitrogen fixation. Deficiencies of these nutrients are widespread in Indian soils and adversely affect crop growth, yield, and quality. Conventional micronutrient fertilizers often exhibit low nutrient use efficiency because of fixation, leaching, and limited plant availability. Recent advances in nanotechnology have opened new opportunities for improving nutrient management in agriculture. Nano-fertilizers possess unique properties such as high surface area, enhanced reactivity, and improved nutrient delivery, which can increase nutrient use efficiency while reducing environmental losses. Although positive effects of nano zinc and nano copper have been reported in several crops, information regarding their combined and individual effects on cowpea under the agro-climatic conditions of Uttar Pradesh remains limited. Considering the low productivity of cowpea, widespread zinc and copper deficiencies, and the potential benefits of nano-fertilizers, the present study was undertaken to evaluate the effect of foliar application of nano zinc and nano copper on the growth, yield, quality, and economics of cowpea cultivation.

Materials and Methods

A field experiment was conducted during the Kharif season 2025 at the Vegetable Research Farm, Department of Vegetable Science, Chandra Shekhar Azad University of Agriculture and Technology (CSAUA&T), Kanpur, Uttar Pradesh, India. The experimental site is situated at 26°49' N latitude, 80°30' E longitude, and an altitude of 133 m above mean sea level. The region experiences a humid subtropical climate with an average annual rainfall of 750–800 mm. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction (pH 7.7), low in organic carbon (0.45%) and available nitrogen (210.3 kg ha⁻¹), medium in available phosphorus (13.5 kg ha⁻¹), and rich in available potassium (251.6 kg ha⁻¹). The experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications using the vegetable cowpea variety 'Kashi Kanchan'. Seeds were sown on 23 July 2025 at a spacing of 45

cm × 15 cm using a seed rate of 25 kg ha⁻¹. A recommended basal fertilizer dose of 30:60:80 kg N:P₂O₅: K₂O ha⁻¹ was applied through urea, single superphosphate, and muriate of potash, respectively. Seeds were treated with carbendazim at 2.5 g kg⁻¹ seed before sowing. The treatments consisted of: T₁–100% RDF (control); T₂–RDF + Nano Zn (50 ppm); T₃–RDF + Nano Cu (50 ppm); T₄–RDF + Nano Zn (50 ppm) + Nano Cu (50 ppm); T₅–RDF + ZnSO₄ (1%); T₆–RDF + CuSO₄ (1%); T₇–RDF + ZnSO₄ (1%) + CuSO₄ (1%); and T₈–RDF + Kashi Sookshma Shakti micronutrient mixture (0.5%). Foliar sprays were applied twice, at 30 and 45 days after sowing (DAS), corresponding to the vegetative growth and flowering initiation stages, respectively. Standard agronomic practices were followed throughout the crop growth period. Gap filling, thinning, weeding, irrigation, and plant protection measures were carried out as required. Green pods were harvested manually in five pickings at weekly intervals from 48 to 70 DAS. Observations were recorded on growth, phenological, yield, shelf life, and economic parameters. Included plant population, plant height, and number of branches per plant, days to 50% flowering and days to first fruit initiation, number of pods per plant, pod length, pod girth, number of seeds per pod, pericarp weight, pod yield per plant, pod yield per plot, and green pod yield per hectare. Shelf life of pods at room temperature was recorded as a quality parameter. Economic analysis was carried out by estimating gross returns, net returns, and benefit–cost ratio for each treatment.

Results and Discussion

Growth Parameters

Foliar application of nano zinc and nano copper significantly influenced the growth of cowpea. Among all treatments, the combined application of nano zinc and nano copper (T₄) recorded the maximum plant height of 31.39 cm and 60.94 cm at 30 and 60 DAS, respectively, which was significantly higher than the control (23.89 cm and 54.22 cm). Similarly, T₄ produced the highest number of branches per plant (10.55) at 50 DAS. The superior growth performance under nano nutrient application may be attributed to enhanced nutrient absorption, enzyme activation, auxin synthesis, and improved photosynthetic activity. Nano-formulations exhibited greater effectiveness than conventional ZnSO₄ and CuSO₄ treatments owing to their higher bioavailability and efficient foliar uptake.

Phenological Characters

The foliar application of micronutrients significantly affected flowering and fruit initiation. Treatment T₄ recorded the earliest 50% flowering (43.10 days) and first fruit initiation (47.77 days), whereas the control required 52.88 and 58.10 days, respectively. The enhanced nutrient availability under nano treatments may have accelerated physiological and metabolic processes responsible for reproductive development, resulting in earlier flowering and fruit set.

Table 1: Effect of foliar application of nano zinc and nano copper on growth, phenological, parameters of cowpea.

Treatments	Plant Height 30 DAS	Plant Height 60 DAS	No. of Branches /Plant 50 DAS	Days to 50% Flowering	Days to 1 st Fruit Initiation
T ₁ - 100% RDF (150-60-80 kg NPK/ha)	26.18	1.73	118.63	18.21	68.50
T ₂ - Spray of nano Zinc (50 ppm) twice at 30 and 45 DAS	30.77	2.20	129.21	23.66	80.40
T ₃ - Spray of nano Copper (50 ppm) twice at 30 and 45 DAS	29.55	2.16	126.33	22.44	75.30
T ₄ - Spray of nano Zinc (50 ppm) and nano Copper (50 ppm) at 30 and 45 DAS	30.53	2.26	132.66	25.10	86.40
T ₅ - Spray of ZnSO ₄ @1% twice at 30 and 45 DAS	30.34	2.20	129.99	22.22	72.80
T ₆ - Spray of CuSO ₄ @1% twice at 30 and 45 DAS	29.12	2.16	124.33	21.44	79.60
T ₇ - Spray of ZnSO ₄ and CuSO ₄ @1% at 30 and 45 DAS	29.37	2.20	122.88	24.44	82.10
T ₈ - Spray of Kashi Sookshma micronutrient mixture @0.5%at 30 and 45 DAS	29.49	2.16	126.11	23.88	77.90
S.Em (±)	0.811	0.056	2.058	1.261	1.394
CD (0.05)	4.775	4.561	6.301	3.86	4.132

Yield Attributes

Significant improvements in yield-contributing characters were observed due to nano nutrient application. The combined nano zinc and nano copper treatment (T₄) recorded the highest number of pods per plant (25.10), pod length (30.53 cm), pod width (2.26 cm), pericarp weight (86.40 g per 10 pods), and number of seeds per pod (14.60). These values were significantly superior to the control treatment. Enhanced pollen viability, better fertilization, efficient assimilate partitioning, and improved sink strength under nano nutrient application might have contributed to the superior pod and seed characteristics.

Pod Yield

Pod yield was significantly influenced by the different treatments. The highest pod yield was recorded under T₄ (Nano Zn + Nano Cu), with 428.66 g plant⁻¹, 16.20 kg plot⁻¹, and 171.43 q ha⁻¹, representing a substantial increase over the control (278.75 g plant⁻¹, 10.50 kg plot⁻¹, and 111.11 q ha⁻¹). Among the individual nano treatments, nano zinc performed better than nano copper. The higher yield under combined nano application may be

attributed to improved vegetative growth, enhanced photosynthetic efficiency, greater nutrient use efficiency, and better translocation of assimilates towards developing pods. Pod weight was also significantly increased by nano nutrient application. The maximum pod weight of 132.66 g per 10 pods was recorded under T₄, followed by T₅ (129.99 g) and T₂ (129.21 g), whereas the control recorded the lowest value (118.63 g). The increase in pod weight reflects improved carbohydrate accumulation and efficient utilization of photosynthates during pod development.

Shelf Life

Shelf life of fresh cowpea pods was significantly improved by nano nutrient application. The combined foliar application of nano zinc and nano copper (T₄) recorded the longest shelf life (5.20 days), compared with 4.10 days in the control. Improved membrane stability, reduced moisture loss, and enhanced antioxidant enzyme activity under nano micronutrient treatments may have contributed to better post-harvest quality and prolonged shelf life.

Table 2: Effect of foliar application of nano zinc and nano copper on growth, yield, yield attributes and quality parameters of cowpea

Treatments	Pod length (cm)	Pod girth (cm)	Pod Weight (g/10 pods)	Number of pods per plant	Pericarp Weight (g/10 pods)	No. of Seeds/Pod	Shelf life of the Pods	Pod Yield/Plant	Pod Yield/Plot	Pod yield (q/ha)
T ₁ - 100% RDF (150-60-80 kg NPK/ha)	26.18	1.73	118.63	18.21	68.50	11.20	4.10	278.75	10.50	111.11
T ₂ - Spray of nano Zinc (50 ppm) twice at 30 and 45 DAS	30.77	2.20	129.21	23.66	80.40	12.80	4.90	358.84	13.60	143.92
T ₃ - Spray of nano Copper (50 ppm) twice at 30 and 45 DAS	29.55	2.16	126.33	22.44	75.30	13.90	4.55	331.54	12.50	132.28
T ₄ - Spray of nano Zinc (50 ppm) and nano Copper (50 ppm) at 30 and 45 DAS	30.53	2.26	132.66	25.10	86.40	14.60	5.20	428.66	16.20	171.43
T ₅ -Spray of ZnSO ₄ @1% twice at 30 and 45 DAS	30.34	2.20	129.99	22.22	72.80	12.50	4.40	348.21	13.00	137.57
T ₆ - Spray of CuSO ₄ @1% twice at 30 and 45 DAS	29.12	2.16	124.33	21.44	79.60	13.50	4.75	315.69	11.80	124.87
T ₇ - Spray of ZnSO ₄ and CuSO ₄ @1% at 30 and 45 DAS	29.37	2.20	122.88	24.44	82.10	13.20	4.65	414.00	15.60	165.08
T ₈ - Spray of Kashi Sookshma micronutrient mixture @0.5% at 30 and 45 DAS	29.49	2.16	126.11	23.88	77.90	13.60	4.80	394.92	14.90	157.67
S.Em (±)	0.811	0.056	2.058	1.261	1.394	0.346	0.096	6.465	0.451	2.399
CD (0.05)	4.775	4.561	6.301	3.86	4.132	1.059	0.212	19.773	1.382	7.347

Economics

Economic analysis revealed that T₄ (Nano Zn + Nano Cu) was the most profitable treatment, recording the highest gross return, net return, and benefit–cost ratio. The increased profitability was primarily due to higher marketable pod yield and improved

quality attributes. The economic superiority of nano-formulations over conventional micronutrient sources indicates their potential as an efficient and sustainable nutrient management strategy for vegetable cowpea cultivation.

S. No.	Yield per hectares (q/h)	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
T ₁ (control)	111.11	54672.2	277775	223102.8	1:4.08
T ₂ (Nano zinc)	143.92	54689.7	359800	305140.3	1:5.57
T ₃ (Nano copper)	132.28	54690.7	330700	276009.3	1:5.04
T ₄ (NZ + NC)	171.43	54708.2	428575	373866.8	1:6.83
T ₅ (ZnSO ₄)	137.57	54972.2	343925	288952.8	1:5.25
T ₆ (Cu SO ₄)	124.87	55072.2	312175	257102.8	1:4.66
T ₇ (ZnSO ₄ + Cu SO ₄)	165.08	55372.2	412700	357327.8	1:6.45
T ₈ (KASHISAKTI)	157.67	54782.2	394175	339392.8	1:6.19

Cowpea pod price @25 Rs. /Kg

Conclusion

The present study demonstrated that foliar application of nano zinc and nano copper significantly improved growth, yield

attributes, yield, quality, and economic returns of cowpea. Among the different treatments, the combined application of nano zinc (50 ppm) and nano copper (50 ppm) proved most effective,

recording the highest plant height, number of branches, pods per plant, pod dimensions, pericarp weight, seeds per pod, and pod yield. The treatment also enhanced post-harvest shelf life and resulted in the highest net returns and benefit–cost ratio. Nano-formulations consistently outperformed conventional zinc and copper sources, indicating superior nutrient use efficiency and bioavailability. Therefore, foliar application of nano zinc (50 ppm) and nano copper (50 ppm) at 30 and 45 DAS can be recommended as an efficient and economically viable micronutrient management strategy for enhancing productivity, quality, and profitability of cowpea cultivation in Central plains of Uttar Pradesh.

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