Response of growth and yield traits of *Vigna radiata* L. to organic fertilization and foliar application of nano copper

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Abstract

A study was conducted in the spring of 2023 in Karbala Governorate to examine the effects of liquid organic fertilizer and nano copper spray on the growth and yield mung beans in clay loam soil. The experiment used a randomized complete block design (RCBD) with treatments distributed in three replicates. The study looked at two factors: levels of liquid organic fertilizer (0, 10, and 2 L ha^{-1}) and concentrations of nano copper (0, 15, 30, and 45 mg L^{-1}). The results showed that using liquid organic fertilizer and nano copper spray, either alone or in combination, significantly impacted the growth and yield characteristics of the mung beans. The combination of liquid organic fertilizer (10 L ha^{-1}) and nano copper spray (45 mg L^{-1}) resulted in significant increase in the number of branches in a plant, number of leaves in a plant, leaf chlorophyll index (SPAD), plant biological yield, harvest index, and protein yield by 68.70%, 62.85%, 39.44%, 93.28%, 38.51% and 454.78% respectively, compared to the treatment without these additions.

Keywords: *Vigna radiate* L., nano copper, liquid organic fertilizer, spraying.

Introduction

Mung beans *Vigna radiata* L. are a type of legume used as a food source. It plays an important role in human nutrition due to its high protein content and richness in lysine, an essential amino acid lacking in many grains. In addition to carbohydrates, it also contains vitamins, calcium, iron, and zinc. This crop helps to increase soil fertility and improve its properties [1]. The current productivity of crops in Iraq is lower than the global mean. Despite the importance of these crops, they have not received enough attention, therefore, it is necessary to improve production by using modern agricultural techniques. This would help achieve optimal vegetative growth and a higher grain yield with good quality. To achieve this, it is important to have fertile soil, which contributes to increased crop productivity [2]. When it comes to giving plants the vital nutrients they need, liquid organic fertilizers are a significant and sustainable choice. They contain amino acids, humic and fulvic acids, and other elements that are good for the soil and help grow and produce a range of crops. These fertilizers produce little pollution, are inexpensive, and are simple to use. They enhance the soil's biological,

chemical, and physical characteristics, which promotes healthier plant growth. Furthermore, they are quickly released from the plant for use in physiological functions and are readily absorbed by plants. This gives plants the energy they require to absorb, particularly in key growth stages [3] Applying organic acids to soil offers several advantages, organic acids improve the soil's chemical characteristics by chelating ions and making them more available to plants. They also improve the plant's ability to survive environmental stresses like drought and high temperatures.

Additionally, organic acids boost the number of microorganisms in the soil and plant protein content [4]. Organic acids are also crucial for regulating soil pH, ion exchange, and water retention, all of which contribute to better absorption of nutrients and water by plants. Moreover, they promote higher crop yields by improving mineral nutrition in the soil, leading to better leaf and root development and enhanced physiological and biochemical functions in plants [5]. Notably, humic acid, a type of organic acid, is particularly effective at stimulating the activity of hormones like auxin, which is responsible for cell elongation. This leads to increased plant mass, enhanced nutrient uptake, and promotion of seed germination, seedling growth, and root elongation [6,7]. Furthermore, organic acids help plants withstand the negative effects of drought, high temperatures, and salt stress. They directly affect the ease with which nutrients are absorbed by the cell membranes of roots and leaves [8]. Using excessive amounts of fertilizers may increase production, but it also raises the cost of production and often leads to inefficient fertilizer use, causing soil degradation and decreased crop productivity, especially in alkaline soils, this diminishes the plants' ability to absorb nutrients added to the soil, with trace elements like copper particularly affected. Copper is essential for plant growth, nutritional balance, and vital functions. Foliar feeding, which involves applying nutrients to plants through their leaves, is an effective and cost-efficient technique for enhancing plant growth.

Copper is crucial for pollen production and seed formation, and its deficiency can result in reduced grain and seed production. Therefore, "It plays a significant role in improving agricultural crop production" [9, 10]. The use of nano copper fertilizer in fertilization presents an effective alternative to traditional fertilizers, as it offers several advantages such as requiring smaller quantities and displaying high stability under different conditions. Nano fertilizers are known for their extremely small size. This means they do not require large spaces and are rapidly absorbed by plants, allowing for their use at the required times based on the actual needs of the plant. They can be applied as sprays on the green group, enabling plants to benefit from them more quickly. This provides a larger area for various metabolic reactions in the plant, enhancing the activity of photosynthesis and increasing the production of dry matter and crop productivity [11,12].

Given the significance of the mung bean crop and the growing demand for high-quality food both in terms of quantity and quality, this study aims to determine the optimal addition level of liquid organic fertilizer and nano copper concentration, as well as their combined impact on the growth and productivity of mung bean plants.

Materials and Methods

Executing the experiment

Field research was carried out on clay loam soil in Kerbala Governorate, which is located at longitudes 44.16, and latitude 32.67, during the spring season of 2023. The aim of the research was to investigate the effects of adding liquid organic fertilizer and spraying with nano copper on the growth, yield, and quality of mung beans. A Randomized Complete Block Design was used for the experiment, with treatments applied in a split-plot configuration and three replicates [13]. The experiment involved two factors: levels of liquid organic fertilizer (0, 10, and 20) L ha^{-1}, represented by (O_0, O_1, and O_2) in sequence; and concentrations of nano copper (Cu%15) at (0, 15, 30, and 45) mg L^{-1}, represented by (F_0, F_1, F_2, and F_3) in sequence.

Field preparation and agricultural operations

The field soil was leveled, smoothed, and divided into (3m x 3m) panels to prepare it for planting. Spaces were left between sectors and treatments within the same industry to avoid the transfer of fertilizers between treatments. In each experimental unit, four rows spanned a length of 3 meters. The spacing between lines was set at 75 cm, while the distance between each seed hole was 25 cm. The seeds, which belonged to a local variety of mung beans, were sown on 15/03/2024.

Table (1): Soil chemical and physical properties at a 0–30 cm depth before mung bean planting.

Properties		Values
pH		7.40
EC (1:1)		2.12 ds m^{-1}
OM		1.18 g kg^{-1}
N available		30.54 mg kg^{-1}
P available		12.34 mg kg^{-1}
K available		68.27mg kg^{-1}
Soil separators	Sand	265 G kg^{-1}
	Silt	355 G kg^{-1}
	Clay	380 G kg^{-1}
Texture		Clay loam

Following the planting, the crop received immediate irrigation and was subsequently irrigated as required during the entire duration of the growing season. The liquid organic fertilizer, known as Humizone and produced by Al-Joud Company for Modern Industrial and Agricultural Technology in Kerbala Governorate, was applied in two separate doses. The first dose was administered during the initial irrigation after planting, while the second dose was given before the plant's flowering stage. Comprised of 14% humic acid, 3% fulvic acid, and a variety of essential nutrients, this fertilizer provides optimal nourishment for the plants. In addition to the fertilizer, nano copper was applied in three stages using a spraying technique. The first application occurred 30

days after planting, followed by a second spray two weeks later, and a third spray at the onset of pod formation. To ensure thorough coverage of the leaves, a 16-liter hand sprayer was utilized for the spraying process, which took place early in the morning to avoid high temperatures. Adding ($1cm^3$) of the bright cleaning solution with each spray as a spreading agent increases the surface tension, facilitating the absorption of the foliar fertilizer by the plant tissues. The control treatment was sprayed with distilled water only. All experimental units were given mineral fertilizers. Urea fertilizer containing 46% nitrogen was applied at a rate of 60 kg of nitrogen ha^{-1}, in two applications. The first application took place right after the complete emergence of seedlings, and the second was applied 30 days after the first. A single superphosphate fertilizer with 20% P_2O_5 was applied at a rate of 80 kg P_2O_5 ha^{-1} in a single application, mixed with the soil before planting. Potassium sulfate fertilizer with 50% K_2O was applied at a rate of 80 kg K_2O ha^{-1}, in two applications. The first application was performed 30 days after planting, and the second was at the beginning of the flowering stage [9]. The plants were harvested at full maturity on July 5, 2023. The studied plant traits were determined by averaging the values of ten randomly selected plants from each experimental unit.

Statistical analysis

The data was analyzed using analysis of variance (ANOVA) by the method of a randomized complete block design with a split plot, to compare and differentiate the mean differences the least significant difference ($LSD_{0.05}$) test was conducted [10]. The analysis was done using GenStat 12, a statistical analytical software.

Results and Discussion

Number of branches (branch $plant^{-1}$

The results from Table 2. demonstrate the significant effect of using liquid organic fertilizer on the number of plant branches. The addition level (O_2) resulted in the highest number of branches, with a mean of 8.19 branches $plant^{-1}$, marking a 46.51% increase compared to the comparison level (O_0), which had a mean of 5.59 branches $plant^{-1}$. Furthermore, the results indicate a notable difference in the number of plant branches when applying nano-copper. The highest mean of 7.32 branches $plant^{-1}$, was achieved with concentration (F_3), showing a 16.00% increase compared to concentration (F_0), which had a mean of 6.31 branches $plant^{-1}$. The interaction results revealed a significant effect of the combined treatments. Treatment (O_2 F_3) resulted in the highest number of branches, with a mean of 8.72 branches $plant^{-1}$, while the comparison treatment (O_0 F_0) had the lowest number of branches, averaging 5.16 branches $plant^{-1}$, marking a 68.70% increase.

Table (2): Effect of liquid organic fertilizer, nano copper, and their interaction on Number of branches (branch plant^{-1})

Nano copper (mg L^{-1})	Liquid organic fertilizer (L ha^{-1})			Means
	O_0	O_1	O_2	
F_0	5.16	6.12	7.66	6.31
F_1	5.56	6.40	8.03	6.66
F_2	5.75	6.83	8.38	6.98
F_3	5.91	7.32	8.72	7.32
Means	5.59	6.67	8.19	

$LSD_{0.05}$ Liquid organic fertilizer (O) = 0.02
$LSD_{0.05}$ Nano copper (F) = 0.04
$LSD_{0.05}$ O × F Interactions = 0.07

The study's findings demonstrated the plant responded to the application of liquid organic fertilizer and nano copper spraying, as well as their combined effect on increasing the number of plant branches. The increase in branches was likely a result of the liquid organic fertilizer, particularly due to the role of humic acid in improving nutrient availability and absorption from the soil. This, in turn, had a positive influence on the accumulation of essential plant materials such as starch, sugars, and protein, all of which are crucial for plant growth and development. Furthermore, the availability of soil nutrients such as nitrogen, phosphorus, and potassium plays a crucial role in promoting plant branches and root development. These factors may contribute to the production of the hormone zeatin, which could help reduce apical dominance and stimulate the formation of lateral buds, thus increasing the number of plant branches [15]. The plant's response to nano copper spraying was also notable, as increasing the concentration had a significant effect on increasing the number of plant branches. This may be attributed to the positive role of copper in promoting the formation, division, and elongation of plant cells, resulting in increased vegetative branches in the plant [16].

Number of leaves (leaf plant^{-1})

The results from Table 3. showed that adding liquid organic fertilizer had a significant effect on the number of leaves in the plant. The (O_2) addition level was significantly superior, resulting in the highest mean of 30.56 leaf plant^{-1}, while the (O_0) comparison level had the lowest mean of 23.02 leaf plant^{-1}, representing a 32.75% increase. The results also demonstrated a significant effect of spraying with nano copper on the number of leaves in the plant. The (F_3) concentration showed the highest mean of 28.34 leaves per plant, while the (F_0) concentration had the lowest mean of 24.62 leaves plant^{-1}, reflecting a 15.11% increase. Furthermore, the table indicated a significant effect of the interaction between liquid organic fertilizer and nano copper spraying on the number of leaves. The (O_2F_3) treatment recorded the highest mean of 32.70 leaves

per plant, while the O0F0 treatment had the lowest mean of 20.08 leaves per plant, showing a 62.85% increase.

The study results demonstrated that the plant responded positively to the application of liquid organic fertilizer and nano copper spray, as well as their combined effect, leading to an increase in the number of leaves. This can be attributed to the liquid organic fertilizer's rich nutrient content, including essential elements like nitrogen, phosphorus, and potassium. These nutrients play a crucial role in enhancing the plant's metabolic functions, cell division, and growth, consequently causing an increase in internode length and the number of nodes on the stem that support the leaves.

Table(3): The Effect of adding liquid organic fertilizer, nano copper, and their interaction on Number of leaves (leaf plant^{-1}).

Nano copper (mg L^{-1})	Liquid organic fertilizer (L ha^{-1})			Means
	O_0	O_1	O_2	
F_0	20.08	25.47	28.32	24.62
F_1	22.96	26.15	29.95	26.35
F_2	24.22	26.82	31.30	27.44
F_3	24.82	27.50	32.70	28.34
Means	23.02	26.48	30.56	

$LSD_{0.05}$ Liquid organic fertilizer (O) = 0.33
$LSD_{0.05}$ Nano copper (F) = 0.23
$LSD_{0.05}$ O × F Interactions = 0.43

The presence of tryptophan, an amino acid essential for auxin production, influences cell division and elongation, resulting in increased growth of the plant's vegetative parts. Moreover, nitrogen aids in the synthesis of plant hormones that activate leaf forming cells, thereby promoting leaf production. Similarly, phosphorus supports various physiological processes within plants, contributing to the formation of energy compounds and enhancing cell size, division, and elongation. This positive effect on plant growth is supported by previous studies [17,18] Additionally, the application of nano copper spray also demonstrated a significant effect on increasing the number of leaves. Sufficient copper application enhances the plant's ability to develop a robust root system, facilitating nutrient absorption from the soil and increasing nutrient concentration within the plant. Nano copper is known for its rapid absorption due to its small size and large surface area. This can enhance metabolic reactions in plants, increase the rate of photosynthesis, and stimulate nutrient uptake, leading to improved plant growth characteristics [19].

Leaf Chlorophyll Index (SPAD)

The results presented in Table 4. demonstrate the significant effect of adding liquid organic fertilizer on the chlorophyll index in the leaves. The addition level (O_2) resulted in the highest mean of 54.24%, with an increase of 21.20% compared to the comparison level (O_0), which produced the lowest mean of 44.75%. The table also shows significant differences in the chlorophyll index in the leaves when spraying with nano copper. In this case, concentration (F_3) was superior, with the highest mean of 51.58% and an increased rate of 12.66% compared to concentration (F_0), which resulted in 45.78%. Furthermore, the interaction between the two study factors presents significant differences. Treatment (O_2F_3) achieved the highest chlorophyll index in the leaves at 60.70%, while the comparison treatment (O_0F_0) recorded 43.53%, reflecting an increase rate of 39.44%.

Table (4): The Effect of adding liquid organic fertilizer, nano copper, and their interaction on Leaf Chlorophyll Index (SPAD)

Nano copper (mg L^{-1})	Liquid organic fertilizer (L ha^{-1})			Means
	O_0	O_1	O_2	
F_0	43.53	44.77	49.03	45.78
F_1	44.47	46.53	50.10	47.03
F_2	45.10	47.27	57.13	49.83
F_3	45.90	48.13	60.70	51.58
Means	44.75	46.68	54.24	

$LSD_{0.05}$ Liquid organic fertilizer (O) = 1.64
$LSD_{0.05}$ Nano copper (F) = 1.54
$LSD_{0.05}$ O × F Interactions = 2.59

The study's results indicated that using liquid organic fertilizer and applying nano copper, as well as their combined effect, resulted in increased chlorophyll levels in the plants. This response may be attributed to the role of liquid organic fertilizer in promoting plant growth by increasing leaf area, which consequently leads to higher chlorophyll levels in the leaves. Moreover, the fertilizer contributed to the formation of proteins, sugars, and energy compounds, thereby enhancing plant growth and chlorophyll production. This finding is consistent with the conclusions reached by [5] Additionally, liquid organic fertilizer contains various organic compounds such as humic and fulvic acid, along with essential plant nutrients like nitrogen, phosphorus, potassium, and micronutrients. Its addition to the soil increased the availability of these nutrients due to its acidic nature, ensuring a balanced nutrient supply for the plants. Furthermore, it influenced respiration and carbon metabolism, increased antioxidants, and expanded the plant's leaf area, thereby enhancing plant performance. This is crucial as leaves are the primary source of food for plants, and their area directly impacts

the efficiency of photosynthesis. Consequently, a larger leaf area intercepts more light and produces more chlorophyll, leading to increased photosynthesis efficiency [20]

The application of nano copper had a significant effect on increasing chlorophyll in the leaves. This is because copper plays a crucial role in chlorophyll production. Copper serves two main functions in plants: firstly, it affects the oxidizing enzyme of ascorbic acid, thereby enhancing the acid's oxidative activity. Secondly, copper is an essential element in the formation of the basic substance Ironporphyrin for chlorophyll pigment. Approximately 70% of the copper present in the plant is concentrated in chlorophyll. Consequently, an increase in plant height and leaf area has a positive effect on chlorophyll formation in the leaves. A larger leaf area results in a higher interception of light, thereby increasing the efficiency of the photosynthesis process in the plant [21]. The plant's response to nano copper spraying in growth characteristics can be attributed to the significance of nano fertilizers in plant nutrition. These fertilizers work to boost photosynthesis processes by increasing the chlorophyll content in leaves. They also enhance the ability of crops to withstand various stress conditions and resist diseases, ultimately achieving the best nutritional balance for these nutrients within the plant. This pushes the plant towards better growth as a result of the clear role of these nutrients in improving the plant's chances of utilizing growth factors in a more effective way [19].

Biological yield (ton ha^{-1})

The results in Table 5. demonstrate a significant effect of adding liquid organic fertilizer on biological yield. The addition level (O_2) resulted in the highest mean yield of 3.753 tons ha^{-1}, representing a 67.32% increase compared to the comparison level (O_0), which yielded a mean of 2.243 tons ha^{-1}. Additionally, significant differences were observed when spraying with nano copper. The (F_3) concentration showed a significantly superior effect, with the highest biological yield of 3.215 tons per hectare, a 21.41% increase compared to the (F_0) concentration, which yielded 2.648 tons ha^{-1}. Moreover, there was a significant difference in the interaction between the treatments. The (O_2 F_3) treatment yielded the highest biological yield, with a mean of 4.057 tons ha^{-1}, compared to the (O_0 F_0) treatment, which recorded 2.099 tons ha^{-1}, representing a 93.28% increase.

Table (5): Effect of liquid organic fertilizer, nano copper, and their interaction on Biological yield (ton ha^{-1})

Nano copper (mg L^{-1})	Liquid organic fertilizer (L ha^{-1})			Means
	O_0	O_1	O_2	
F_0	2.099	2.470	3.374	2.648
F_1	2.215	2.772	3.642	2.876
F_2	2.293	3.034	3.939	3.089
F_3	2.366	3.222	4.057	3.215
Means	2.243	2.874	3.753	

$LSD_{0.05}$ Liquid organic fertilizer (O) = 0.051

$LSD_{0.05}$ Nano copper (F) = 0.031

$LSD_{0.05}$ O × F Interactions = 0.062

The biological yield is the amount of carbon dioxide accumulated by a plant during the growing season, which depends on the balance between photosynthesis and respiration. It encompasses the total dry matter produced by the plant during its life cycle, including stems, leaves, branches, and pods. Biological yield is influenced by environmental and genetic factors, as well as the addition of nutrients that support plant growth. Achieving maximum growth rates requires an adequate number of leaves and a robust leaf area for vegetation cover, which is linked to plant growth speed and duration [15], Research results indicate that the biological yield of plants increases in response to the application of liquid organic fertilizer and nano copper spray. This increase may be attributed to the positive effect of the liquid organic fertilizer, which creates a favorable environment for the growth and reproduction of microscopic soil organisms, supporting overall plant health. Liquid organic fertilizer, containing organic acids like humic acid, acts as a natural chelator for nutrients, enabling the plant roots to effectively absorb them, and thereby promoting vital processes within the plant. This, in turn, supports healthy plant growth, enhancing crop productivity [18]. The application of nano copper spray has been found to positively effect the biological yield of plants. This is attributed to the significant role of copper in increasing plant height, number of branches, number of leaves, dry weight of the plant, and seed yield, ultimately contributing to the overall biological yield. These findings are consistent with the work of [11, 22]. Copper plays an important role in enhancing vegetative growth by influencing the photosynthesis process through its involvement in chloroplast specific proteins and electron transfer within the photosynthesis system. The combination of liquid organic fertilizer and nano copper spray contributes to achieving a balanced nutritional profile for the plant, thereby promoting better growth and production [16, 23].

Harvest Index

The results presented in Table 6. demonstrate the significant effect of adding liquid organic fertilizer on the harvest index. The addition level (O_2) resulted in the highest harvest index at a mean of 39.01%, representing an 18.78% increase compared to the comparison level (O_0) which yielded the lowest harvest index at a mean of 32.84%. Additionally, the results indicate a significant difference in the effect of spraying with nano copper. The highest harvest index was achieved with concentration (F_3) at a mean of 38.91%, reflecting a 9.38% increase compared to concentration (F_0) which resulted in a mean of 35.57%. Furthermore, when considering the interaction of both factors, the treatment (O_2 F_3) achieved the highest harvest index with a mean of 43.99%, while the comparison treatment (O_0 F_0) yielded the lowest mean at 31.76%, representing a significant increase of 38.51%. The harvest index is an important characteristic of a crop, representing the plant's efficiency in converting carbon metabolism products into seeds. The study results demonstrate the plant's response to the application of liquid organic fertilizer and spraying with nano copper. The interaction of these treatments led to an increase in the harvest index, likely due to the effect of the liquid

organic fertilizer. This resulted in an increased total seed yield and biological yield, subsequently positively affecting the harvest index. The liquid organic fertilizer also played a significant role in plant growth by increasing dry matter and transferring it from the vegetative part to the fruitful part, ultimately accumulating in the seeds [18]. Additionally, spraying with nano copper also had a significant effect on increasing the harvest index, attributed to the positive role of copper in enhancing the efficiency of the photosynthesis process and nutrient transfer to the seeds, resulting in increased seed and biological yield [24].

Table (6): Effect of liquid organic fertilizer, nano copper, and their interaction on Harvest Index.

Nano copper (mg L^{-1})	Liquid organic fertilizer (L ha^{-1})			Means
	O_0	O_1	O_2	
F_0	31.76	36.74	38.23	35.57
F_1	32.07	37.96	37.20	35.74
F_2	32.78	38.22	36.60	35.87
F_3	34.75	37.99	43.99	38.91
Means	32.84	37.73	39.01	

$LSD_{0.05}$ Liquid organic fertilizer (O) = 0.34
$LSD_{0.05}$ Nano copper (F) = 0.87
$LSD_{0.05}$ O × F Interactions = 1.33

Protein yield (kg h^{-1})

In Table 7, the results demonstrate the significant effect of adding liquid organic fertilizer on protein yield. The addition level (O_2) produced the highest mean protein yield of 483.20 kg ha^{-1}, showing a substantial 223.43% increase compared to the lowest protein yield of 149.40 kg ha^{-1} at the comparison level (O_0). Additionally, significant differences in protein yield were observed when using nano copper spray, with concentration (F_3) showing the highest mean yield of 389.30 kg ha^{-1}, a 56.03% increase compared to concentration (F_0), which yielded 249.50 kg ha^{-1}. The interaction between the two factors also demonstrated significant differences, with treatment (O_2 F_3) resulting in the highest protein yield at a mean of 608.60 kg ha^{-1}, while the comparison treatment (O_0 F_0) yielded the lowest mean of 109.70 kg ha^{-1}, showing an increase of 454.78%.

Table (7): Effect of liquid organic fertilizer, nano copper, and their interaction on Protein yield (kg h^{-1})

Nano copper (mg L^{-1})	Liquid organic fertilizer (L ha^{-1})			Means
	O_0	O_1	O_2	
F_0	109.70	233.10	405.50	249.50
F_1	132.40	284.80	438.10	285.10
F_2	158.70	325.70	480.50	321.70
F_3	196.60	362.60	608.60	389.30
Means	149.40	301.50	483.20	

$LSD_{0.05}$ Liquid organic fertilizer (O) = 9.86
$LSD_{0.05}$ Nano copper (F) = 7.79
$LSD_{0.05}$ O × F Interactions = 13.75

The results indicate how the crop responded to the application of liquid organic fertilizer and spraying with nano copper, as well as their combined effect on increasing protein yield. The increase in protein yield can be attributed to the significant effect of liquid organic fertilizer on total seed yield and its higher protein concentration in the seeds, which led to an overall increase in protein yield. These findings align with the results of [18 ,25], the results also demonstrated the significant effect of spraying with nano copper in increase protein yield, as a result of its superior effect on both total seed yield and protein concentration in the seeds. This subsequently led to an increase in protein yield in the [21, 26]. The response of the mung bean crop to organic fertilization and spraying with nano copper in terms of growth characteristics can be explained by achieving a better nutritional balance for these nutrients within the plant. This balanced nutrition encouraged better growth and production by enhancing the plant's ability to effectively utilize growth factors

The mung bean crop's growth, yield, and quality were significantly improved by increasing the amount of liquid organic fertilizer in the soil and spraying the crop with Nano copper, the best results in the plant traits studied were achieved with the treatment involving the addition of (10 L ha^{-1}) of liquid organic fertilizer to the soil and foliar feeding with (45 mg L^{-1}) of nano copper.

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