# Magnesium Oxide Nanoparticles as Enhancers of Growth and Biochemical Traits in Cowpea (*Vigna unguiculata*)

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## ABSTRACT

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This study investigates the role of magnesium oxide nanoparticles (MgO-NPs) in improving the growth, yield, and biochemical characteristics of cowpea variety, revealing significant treatment effects on key physiological and biochemical parameters. MgO-NPs enhanced seed germination and increased plant biomass and moisture content at mainly 25 ppm, underscoring their potential to promote vegetative growth. Chlorophyll and protein content in leaves demonstrated a dose-dependent response, with NPK fertilizer achieving the highest values, while moderate MgO-NPs concentrations (40-80 ppm) provided slight improvements over the control. Biochemical yield parameters also showed notable variation, with sugar content peaking at 62.96% under 100 ppm MgO-NPs and lipid content reaching its highest value (49.23%) at 60 ppm, suggesting optimal dosages for sugar and lipid synthesis. Fiber content remained consistent across treatments, indicating no effect of MgO-NPs on structural carbohydrates. These findings highlight MgO-NPs as a promising tool for enhancing crop productivity, while further research is warranted to assess their long-term effects and environmental sustainability in agricultural practices.

*Keywords*: Biochemical properties, chlorophyll, cowpea, magnesium oxide, nanoparticles, sugar content, *Vigna unguiculata*

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Cowpea (*Vigna unguiculata* L. Walp) is one of the most versatile and significant leguminous crops, particularly in tropical and subtropical regions. It serves as a vital source of protein, income, and soil fertility enhancement, primarily for resource-limited farmers in sub-Saharan Africa, Asia, and Central America. Its adaptability to harsh environmental conditions, including drought and nutrient-poor soils, underpins its importance in sustainable agriculture.

Cowpea is integral to food security, providing essential dietary protein and energy, especially in regions where animal protein is scarce. For example, it constitutes the cheapest source of dietary protein in many African nations, being consumed as green pods, dry grains, or leaves. Additionally, the crop's haulm is highly valued as livestock fodder,

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particularly in mixed farming systems where integration of crop and livestock production is practiced (Kamara et al., 2018).

Nigeria is the world's largest cowpea producer, accounting for significant global production, with over 2.5 million tons of annual output. Despite its prominence in the sub-saharan region, the yields on smallholder farms remain low due to biotic and abiotic stresses, such as pests, diseases, and drought (Horn et al., 2022). Nevertheless, the potential for yield improvement through targeted agronomic interventions, improved varieties, and integrated pest management is substantial (Togola et al., 2023).

In addition to its nutritional benefits, cowpea plays a crucial ecological role by enhancing soil fertility through nitrogen fixation. This makes it a cornerstone of sustainable agricultural practices, particularly in regions with declining soil fertility and limited access to synthetic fertilizers (Timko and Singh, 2008).

The crop also demonstrates remarkable adaptability to varying climatic and agronomic conditions, thriving in regions prone to drought and heat stress. For instance, studies highlight its tolerance to water deficits during critical growth stages, making it a resilient choice for areas affected by climate change (Ezin et al., 2021).

Despite its advantages, the development of improved cowpea varieties and agronomic practices has not kept pace with its potential. Investments in molecular breeding, agronomic research, and pest management strategies are critical to unlocking the full potential of this crop to enhance food security and improve livelihoods (Maria Figueira Gomes et al., 2019).

The multifaceted impacts of magnesium oxide nanoparticles (MgO-NPs) are increasingly substantiated by research, highlighting their role as nano-fertilizers and growth modulators. MgO-NPs have been shown to significantly enhance seed germination and seedling vigor across various plant species (Abbas et al., 2024). For instance, low concentrations of MgO-NPs improved germination rates and early growth parameters in maize (*Zea mays*), including root and shoot lengths, by facilitating water and nutrient uptake (Jayarambabu et al., 2016). Similarly, in green gram (*Vigna radiata*), MgO-NP nanopriming significantly boosted seed germination and seedling vigor when compared to conventional hydropriming techniques (Anand et al., 2020). MgO-NPs enhance plant growth and stress tolerance by improving photosynthetic pigments and metabolic processes. By increasing chlorophyll and carotenoid contents, MgO-NPs promote efficient photosynthesis and nutrient absorption under challenging conditions. For example, in *Nigella sativa*, MgO-NPs boosted chlorophyll a, b, and carotenoid levels, leading to improved physiological performance and resilience (Abdel-Aal Amin et al., 2024). They improve photosynthetic efficiency by increasing chlorophyll content, a critical factor for plant growth. MgO-NPs also promoted photosynthetic pigment accumulation, increasing chlorophyll content by up to 60%, and carotenoids by 40%, resulting in higher biomass and carbohydrate accumulation. Studies on soybean (*Glycine max*) indicated that MgO-NPs mitigated arsenic toxicity, improving chlorophyll content and photosynthetic parameters like stomata conductance and net photosynthesis rates (Faizan et al., 2022). Additionally, their role in enhancing nutrient uptake has been observed, where MgO-NPs promoted higher magnesium accumulation in plant tissues, directly supporting enzymatic and metabolic functions crucial for growth.

MgO-NPs influence key biochemical processes, leading to higher protein and carbohydrate accumulation. For example, in horse gram (*Macrotyloma uniflorum*), MgO-NPs increased the protein content by up to 127%, along with improvements in carbohydrate and polyphenol levels, thus elevating the plant's nutritional quality (Koçak et al., 2023). Moreover, enhanced antioxidant enzyme activities such as superoxide dismutase (SOD) and catalase (CAT) have been documented, boosting the plant's defense against oxidative stress.

The application of MgO-NPs demonstrated significant improvements in vegetative growth and yield of mustard (*Brassica juncea*). Nano-priming with MgO-NPs enhanced shoot and root length, leaf area, number of leaves, and secondary roots, with shoot length increasing up to 138% and root length up to 83% (Liao et al., 2024). Additionally, mustard grain yield was significantly improved, with seed count increasing up to six-fold, though protein content and bioavailability were reduced under MgO-NPs exposure. These findings establish MgO-NPs as promising agents for enhancing mustard growth and yield while impacting protein metrics (Gautam et al., 2023). Similarly, in cowpea, MgO-NPs improved both morphological and biochemical traits, particularly in mitigating nematode-induced stress (Tauseef et al., 2021). The ability of MgO-NPs to enhance plant growth while being cost-effective and eco-friendly underscores their value in sustainable agriculture. Green synthesis methods for MgO-NPs, utilizing plant extracts, further reduce environmental impact while maintaining their efficacy (Jeevanandam et al., 2017). This study aims to evaluate the effects of MgO-NPs on cowpea by examining their impact on germination rates, seedling vigor, and growth parameters such as biomass and leaf area. It seeks to analyze yield-related traits, including pod formation and grain production, while investigating biochemical changes such as chlorophyll content, protein levels, and antioxidant enzyme activity. The research also explores the role of MgO-NPs in enhancing stress resilience and assesses their potential as a sustainable agricultural input by evaluating environmental compatibility and scalability.

## MATERIALS AND METHODS

### Study area.

This study was conducted in Makurdi, Benue State, Nigeria, located at coordinates 8°30’E to 8°35’E longitude and 7°30’N to 7°43’N latitude, covering approximately 804 km². The area lies within the Lower Benue Valley, characterized by low relief (73-167 m above sea level) and ferruginous tropical soils. Makurdi experiences a tropical sub-humid climate with distinct wet (April-October) and dry (November-March) seasons. Annual rainfall averages 1190 mm, ranging from 775 to 1792 mm. Relative humidity varies from 43% in January to 81% in July-August. The region falls within the Guinea Savannah belt, a transitional zone with mixed vegetation of tall grasses and medium-height deciduous trees that shed leaves in the dry season (Tyowua et al., 2013).

### Materials.

The materials used in the work included cowpea seeds of a variety, FUAMPEA-3; synthesized and characterized Magnesium oxide nanoparticles (MgO-NPs) as reported by Fayomi et al. (2024a). The MgO-NPs, as white powder with an average crystallite size of 22.33 nm, were characterized using UV/VIS, FTIR, SEM, and XRD methods. All glassware was thoroughly washed with deionized water and oven-dried before use. Deionized water was employed for all homogenization processes.

**Experimental design.**

**Seed germination test.**

Seed germination test were conducted using sterilized agar supplemented with varying MgO-NPs concentrations from 0, 10, 25, 50, to 100 ppm on the variety FUAMPEA-3, at ambience temperature in the laboratory. Percentage germination was calculated as the number of germinated seeds divided by the total number of seeds treated. Different growth and yield related parameters such as number of emergence, percentage survival, average length of plantlet in cm, and average root length were recorded at day 7.

**Pot experiment.**

The MgO-NPs used in this work was synthesized, characterized as reported previously by Fayomi et al. (2024a).

For the determination of the growth and yield of the cowpea seeds on the field, a completely randomized design with five replicates was used. Followed by the treatment of the cowpea seed using the synthesized MgO-NPs, Mg salt and the NPK fertilizer.

As adapted from Olasan et al. (2025), the cowpea seeds were sown into pots, with four seeds placed in each pot at 3 cm depth on September 1, 2023. After establishment, seedlings were thinned to two plants per pot. Watering was carried out twice daily, morning and evening, till pods maturity stage. During the germination stage, the pots were covered to avoid rainwater ingress and with mosquito nets to guard against pests and animals. On the field, the thirty-day-old seedlings were treated at the root with different concentrations of the synthesized MgO-NPs, ranging from 20, 40, 60, 80, and 100 ppm, along with a 0.03% adjuvant. Meanwhile, 5 g each of Mg salt and NPK 10-10-10 fertilizer were added.

**Growth parameters determination of cowpea.**

After ninety days, the growth of the cowpea plantlets was carefully measured by determining their length from the base to the apex using a meter rule, with the average height recorded from five selected plants per pot. Similarly, length was measured by encircling the stem with a small rope, which was then laid against a ruler to determine the root length. The number of emerging cowpea plants in each experimental pot was counted to calculate the percentage survival rate. Biomass assessment involved uprooting the entire plant, weighing it, and recording its mass. One of the fresh mature plants from each pot, having removed the soil from the root, was collected and weighed on the weighing balance. The same sets of plants were oven dried at 200ºC for 12 h to remove the moisture content for dry biomass assessment. Plant vigor was evaluated based on key factors such as color, size, overall health, and growth rate, with a numerical score assigned on a scale from 0 (poor) to 5 (very good) (Fayomi et al., 2024b).

**Evaluated parameters.**

**Protein content determination.**

Protein content was analyzed using the micro-Kjeldahl method. Cowpea powder (2 g) harvested from germinated pods was digested with concentrated

$H_2SO_4$ and a selenium catalyst under heat. The digest was diluted and reacted with NaOH before distillation into boric acid containing an indicator. The distillate was titrated with 0.02N $H_2SO_4$, and the nitrogen content was calculated. Protein percentage was determined using the formula:

$$\text{Protein } (\%) = \text{N6.25 } (\%)$$

$$N_2(\%) = \frac{(100 \times)\ N \times 14 \times V_f x T}{w \times 100 \times V_A}$$

with w = weight of sample, N = Normality of filtrate (($H_2S0_4$) = 0.02N), $V_F$ = Total volume of the digest = 100 ml, $V_A$ = Volume of the digest distilled.

This method provides a reliable estimate of protein content by calculating nitrogen concentration (Moore et al., 2010).

**Fat content determination.**

The Soxhlet extraction method was employed for fat analysis. Ground cowpea samples (1 g) were subjected to lipid extraction using hexane as the solvent in a Soxhlet apparatus for 4 h. During post-extraction, the solvent was evaporated, and the residual lipids were dried to constant weight. The fat content was calculated using the formula:

$$\text{Fat } (\%) = \frac{w_2 - w_1}{w_s} \times \frac{100}{1}$$

with $w_1$ = weight of empty extraction flask; $w_2$ = weight of extracted fat; $w_s$ = weight of sample. This process ensures efficient lipid extraction and precise quantification (Khan et al., 2021).

**Fiber content determination.**

The Weende method was utilized to measure fiber content. Defatted cowpea samples (2 g) were digested sequentially with $H_2SO_4$ and NaOH under reflux. Residues were washed, dried at 150°C, and weighed. The dried sample was heated to ashes at 550°C, and the weight loss was used to calculate fiber content:

$$Fibre\ (\%) = \frac{W_1 - W_2}{W_s} \times \frac{100}{1}$$

This method effectively distinguishes indigestible fibers in plant-based materials (Möller, 2014).

**Sugar content determination.**

Soluble sugars were extracted from ground cowpea (1 g) using a water-ethanol mixture. Extracts were treated with phenol-sulfuric acid and incubated to develop a color reaction. Absorbance was measured spectrophotometrically, with sugar concentration determined by comparison to a standard curve:

$$Concentration\ of\ sugar = \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \text{ x concent. of standard}$$

The phenol-sulfuric acid method is widely regarded for its sensitivity in quantifying soluble sugars (Masuko et al., 2005).

**Moisture content determination.**

The air oven method was employed to measure moisture content. Clean, dry crucibles were weighed, and 5 g of cowpea samples were added to each. Samples were dried at 103-105°C for 2 h, cooled in a desiccator, and weighed. The heating, cooling, and weighing process was repeated until a constant weight was achieved. Moisture content was calculated using the formula:

$$\text{Moisture } (\%) = \frac{w_2 - w_3}{w_2 - w_1} \times \frac{100}{1}$$

with $w_1$ = weight of the empty crucible; $w_2$ = weight of crucible and sample before drying; $w_3$ = weight of crucible and sample after drying.

This standardized method ensures accurate determination of moisture content in agricultural samples (Hay et al., 2023).

**Chlorophyll content determination.**

Chlorophyll content was assessed spectrophotometrically. Fresh cowpea leaves (0.1 g) were macerated in 10 ml acetone and incubated at 4°C in the dark for 24 hours to extract chlorophyll. Absorbance readings of the extract were taken at 663 nm (chlorophyll a) and 645 nm (chlorophyll b) wavelengths using a spectrophotometer. Total chlorophyll content was calculated using the formula:

$Total_{Chl}$ (mg/g) = $(8.2 \times A_{663}) + (20.2 \times A_{645})$

This method is widely adopted due to its precision in quantifying chlorophyll levels in plant tissues (Aher et al., 2014).

**Statistical analysis.**

Data were analyzed using Minitab 16.0 software. Descriptive statistics, including mean and standard error, were calculated. One-way ANOVA and Pearson's correlation were applied to assess variations and relationships between variables. Tukey's method was used for mean separation at a 95% confidence level ($p$ = 0.05), ensuring robust statistical interpretation of the results (Ostertagová & Ostertag, 2013).

## RESULTS

**Effects of MgO-NPs treatments on germination of cowpea.**

Magnesium oxide (MgO) nanoparticles significantly influenced germination and growth parameters in cowpea varieties. For the cowpea, the highest seed germination rate and survival (100%) were observed at concentrations of 0 ppm (control) and 25 ppm. Optimal growth, reflected in plantlet length (13.25 cm) and root length (4.45 cm), occurred at 25 ppm. However, higher concentrations (50-100 ppm) resulted in reduced growth, suggesting potential toxicity effects. Declines in performance were evident at 100 ppm, underscoring the adverse effects of excessive nanoparticle exposure.

**Effects of MgO-NPs treatments on plant biomass and moisture.**

The application of MgO-NPs significantly improved the physiological performance and yield of the plant. As presented in Table 2, the treatment concentrations notably influenced key parameters (fresh and dry biomass, as well as moisture content). Plants showed no significant difference in their response to MgO-NPs ($p$ > 0.05), highlighting the treatment's uniform effectiveness across genetic backgrounds.

Fig. 1, which represents plant vigor of cowpea before and after the application of MgO-NPs, demonstrates visible improvements in plant health, especially at the optimal concentration of 40 ppm. Enhanced chlorophyll intensity and canopy expansion suggest that MgO-NPs positively influence physiological traits such as photosynthetic efficiency and nutrient assimilation. These findings align with studies indicating that MgO-NPs facilitate better growth by improving nutrient delivery and enzymatic activities within plants (Singh et al., 2024).

**Table 1.** Effects of MgO-NPs treatments on germination of cowpea seeds

| MgO-NPs concentration (ppm) | No of seed inoculated | Day of emergence after inoculation | Number of emergence | Survival (%) | Average length of plantlet (cm) | Plant vigor | Average root length (cm) |
|---|---|---|---|---|---|---|---|
| | | | Day 7 | | | | |
| **0** | 5 | 3 | 5 | 100 | 7.65 | 3 | 2.1 |
| **10** | 5 | 3 | 4.5 | 90 | 11.4 | 5 | 3.85 |
| **25** | 5 | 3 | 5 | 100 | 13.25 | 5 | 4.45 |
| **50** | 5 | 3 | 4.5 | 90 | 13.1 | 5 | 4.65 |
| **100** | 5 | 3 | 4.5 | 90 | 10.25 | 5 | 2.9 |

Physiological yield parameters, including biomass and moisture retention, were profoundly influenced by MgO-NP treatments. Table 2 illustrates that the 40 ppm concentration yielded the highest fresh biomass (289.0 ± 41.7 g) and dry mass (89.50 ± 4.09 g), outperforming other treatments. The trend underscores a dose-dependent response, where concentrations higher or lower than 40 ppm were less effective. Excessive doses (e.g., 80 ppm) may have induced mild toxicity, while lower doses (20 ppm) were likely insufficient to trigger optimal physiological responses.

The moisture content of the treated plants, a critical indicator of water-use efficiency, exhibited significant improvements in the presence of MgO-NPs. As shown in Table 3, 40 ppm again resulted in the highest moisture percentage (69.78 ± 2.47%). This suggests enhanced water uptake and retention capacity, likely due to the nanoparticles' role in modifying root permeability and hydraulic conductivity. Comparatively, conventional treatments such as magnesium salts (45.60 ± 3.77%) and NPK fertilizer (40.87 ± 5.33%) lagged behind, emphasizing the superior performance of MgO-NPs. These observations resonate with prior studies that demonstrated nanoparticles' potential to enhance water retention in plants through altered soil-plant water relations (Abdel-Aal Amin et al., 2024).

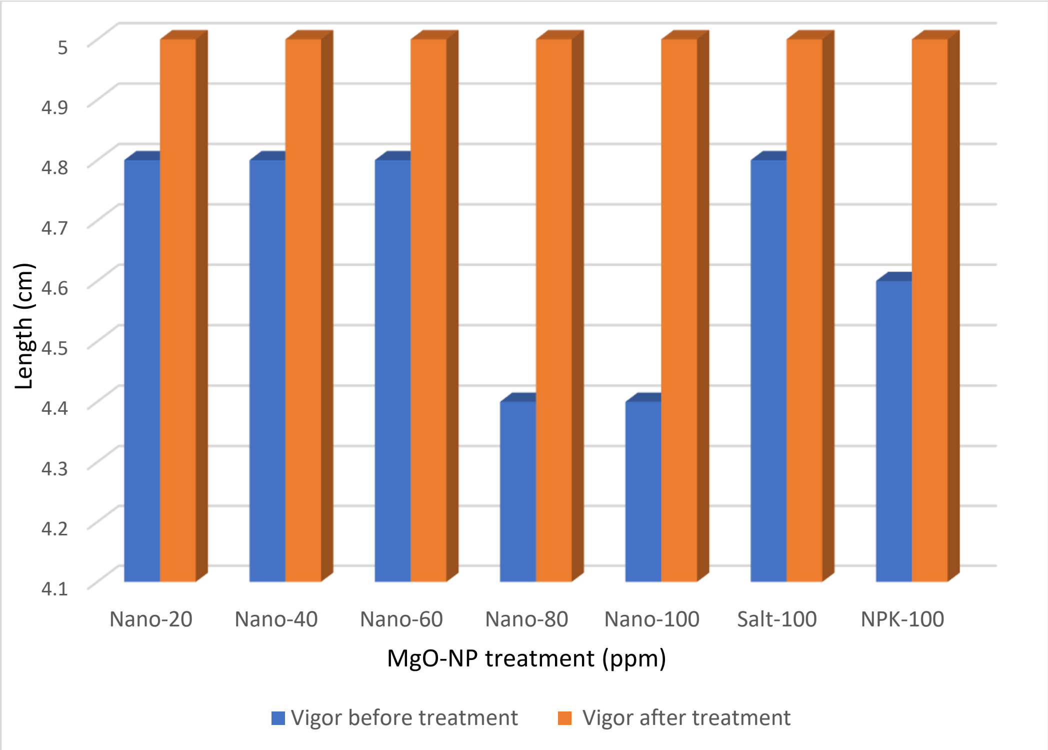


**Fig. 1.** Plant vigor before and after MgO-NPs application on cowpea.

**Table 2.** Effects of MgO NPs treatments on cowpea plant biomass and moisture

| Treatments | Fresh biomass (g) | Dry mass (g) | % Moisture (%) |
|---|---|---|---|
| **Control** | 73.28±4.10$^{c}$ | 40.27±2.29$^{d}$ | 45.89±4.50$^{d}$ |
| **20 ppm MgO-NPs** | 160.2±64.5$^{b}$ | 63.99±17.29$^{c}$ | 59.36±10.52$^{bc}$ |
| **40 ppm MgO-NPs** | 289.0±41.7$^{a}$ | 89.50±4.09$^{a}$ | 69.780±2.471$^{a}$ |
| **60 ppm MgO-NPs** | 279.2±140.5$^{a}$ | 81.60±24.01$^{ab}$ | 65.52±11.89$^{ab}$ |
| **80 ppm MgO-NPs** | 160.4±64.1$^{b}$ | 63.96±16.21$^{c}$ | 57.35±8.00$^{c}$ |
| **100 ppm MgO-NPs** | 208.4±43.9$^{b}$ | 73.74±9.96$^{bc}$ | 63.80±4.12$^{ab}$ |
| **Mg Salt** | 86.07±20.24$^{c}$ | 48.80±7.04$^{d}$ | 45.60±3.77$^{d}$ |
| **NPK fertilizer** | 40.82±4.72$^{c}$ | 26.06±4.50$^{e}$ | 40.87±5.33$^{d}$ |
| **F (Treatment)** | F=21.47, P=0.00 | F=27.66, P=0.00 | F=22.10, P=0.00 |

Data presented are the means ± standard error of mean (n = 5). Means followed by the same letter (s) within the column are not significantly different at ($p \leq 0.05$).

**Effect on chlorophyll and protein contents in plant leaf.**

The statistical analysis revealed, the control group exhibited moderate levels of leaf chlorophyll (5.13%) and protein content (3.85%), whereas the application of NPK fertilizer significantly increased these parameters, yielding chlorophyll and protein levels of 12.64% and 9.48%, respectively.

Chlorophyll content varied significantly among MgO-NPs treatments. The control group maintained intermediate chlorophyll levels (5.13%), while the application of NPK fertilizer resulted in the highest chlorophyll content (12.64%). Lower concentrations of MgO-NPs, such as 20 ppm and 60 ppm, significantly reduced chlorophyll levels (1.65% and 1.53%, respectively), which could suggest inhibitory effects at these dosages. In contrast, moderate concentrations of MgO-NPs (40 ppm and 80 ppm) showed slight improvements in chlorophyll content, achieving levels of 3.70% and 4.13%, respectively, indicative of a non-linear relationship between MgO-NPs dosage and photosynthetic pigment synthesis (Abbas et al., 2024).

**Table 3.** Effects of MgO-NPs treatments on the quantity of chlorophyll and protein in cowpea plant leaf

| Treatments | Leaf chlorophyll (%) | Leaf protein content (%) |
|---|---|---|
| **Control** | 5.13±1.54[b] | 3.85±1.16[b] |
| **20 ppm MgO-NPs** | 1.65±0.35[c] | 1.24±0.27[c] |
| **40 ppm MgO-NPs** | 3.70±0.08[b] | 2.77±0.06[b] |
| **60 ppm MgO-NPs** | 1.53±0.10[c] | 1.15±0.08[c] |
| **80 ppm MgO-NPs** | 4.13±3.10[b] | 3.23±2.32[b] |
| **100 ppm MgO-NPs** | 1.34±0.07[c] | 1.60±0.05[c] |
| **Magnesium Salt** | 1.61±0.16[c] | 1.20±0.12[c] |
| **NPK fertilizer** | 12.639±0.479[a] | 9.479±0.359[a] |
| **F (Treatment)** | F=37.18, P=0.00 | F=37.18, P=0.00 |

Data presented are the means ± standard error of mean (n = 5). Means followed by the same letter (s) within the column are not significantly different at ($p \leq 0.05$).

**Effect of MgO-NPs on sugar, fiber and lipid contents.**

The application of MgO-NPs has demonstrated significant effects on the biochemical parameters of cowpea. Statistical analyses revealed that MgO-NPs notably influenced sugar accumulation (F = 16.30) and lipid content (F = 19.63), indicating enhanced metabolic pathways associated with sugar and lipid synthesis. In contrast, fiber content remained unaffected, with no significant differences across treatments suggesting a uniform response across cowpea samples.

Further studies have detailed the concentration-dependent effects of MgO-NPs on biochemical yield parameters, such as sugar, lipid, and fiber content in crops. Sugar content exhibited a marked increase, peaking at 100 ppm MgO-NPs (62.96%), significantly surpassing levels observed in the control (23.88%), NPK fertilizer treatment (19.86%), and 20 ppm MgO-NPs (18.62%). This pronounced response suggests a strong enhancement of sugar synthesis pathways at optimal MgO-NP concentrations. Lipid content followed a similar trend, reaching a maximum of 49.23% at 60 ppm MgO-NPs, while lower levels were observed in control (30.25%) and NPK fertilizer treatments (25.02%).

**Table 4.** Effects of MgO NPs treatments on the sugar, fiber and lipid contents of cowpea seeds

| Treatments | Sugar content (%) | Fiber (%) | Lipid (%) |
|---|---|---|---|
| **Control** | 23.88±1.07[cd] | 187.88±8.25[a] | 30.25±0.29 [cd] |
| **20 ppm MgO-NPs** | 18.62±2.35[d] | 189.43±7.96[a] | 35.42±6.00[bc] |
| **40 ppm MgO-NPs** | 37.30±19.19[b] | 189.75±8.11[a] | 40.80±0.98[b] |
| **60 ppm MgO-NPs** | 33.36±2.67[bc] | 191.25±7.53[a] | 49.23±2.34[a] |
| **80 ppm MgO-NPs** | 28.78±2.15[bcd] | 190.28±6.05[a] | 25.45±6.09[d] |
| **100 ppm MgO-NPs** | 62.96±2.26[d] | 190.25±0.29[a] | 30.25±0.87[cd] |
| **Mg Salt** | 30.27±0.98[bc] | 190.05±8.68[a] | 30.60±0.41[d] |
| **NPK fertilizer** | 19.86±1.29[d] | 190.25±5.77[a] | 25.02±5.74[d] |
| **F (Treatment)** | F=16.30, P=0.00 | F=0.08, P=0.10 | F=19.63, P=0.00 |

Data presented are the means ± standard error of mean (n = 5). Means followed by the same letter (s) within the column are not significantly different at ($p \leq 0.05$).

## DISCUSSION

The impact of MgO-NPs on seed germination and growth can be attributed to their role in enhancing nutrient availability and uptake. Magnesium is a critical element for photosynthesis and enzyme activation, and its nanoscale delivery likely facilitates efficient absorption by plant cells. Previous studies have shown that nanoparticles improve physiological processes, such as water uptake and nutrient assimilation, leading to enhanced seedling vigor (Zhao et al., 2024). However, high concentrations of nanoparticles can disrupt these processes, possibly due to oxidative stress or interference with cellular homeostasis (Wang et al., 2022). The decline in growth observed at 100 ppm may result from nanoparticle-induced ionic imbalance or accumulation of toxic substances within plant tissues.

Moderate concentrations of MgO-NPs demonstrated the most pronounced benefits for germination rates and seedling establishment. Cowpea exhibited peak performance at 25 ppm, with robust plantlet and root development. This variation underscores the importance of tailoring nanoparticle concentrations to specific crop varieties. Excessive nanoparticle exposure, as observed at 100 ppm, led to diminished plant vigor and growth, aligning with reports of nanoparticle-induced stress responses in plants (Sharma et al., 2021). Such effects may result from the overproduction of reactive oxygen species, leading to cellular damage and impaired metabolic functions.

The impact of MgO-NPs on physiological yield parameters is evident in their influence on biomass and moisture retention. The dose-dependent response observed suggests that an optimal concentration exists for maximizing yield, as demonstrated by the highest biomass production at a specific treatment level. When applied at higher concentrations, MgO-NPs may induce mild toxicity, whereas lower doses may be insufficient to elicit the desired physiological enhancements. These findings corroborate existing literature that highlights the role of MgO-NPs in enhancing plant metabolic functions, ultimately improving yield parameters (Mirrani et al., 2024).

The concentration of treatment had a significant influence on both biomass growth and moisture retention. Among the tested levels, 40 ppm proved to be the most effective, striking a balance between promoting plant growth and conserving water. Interestingly, higher concentrations, such as 60 ppm and 80 ppm, produced similar but slightly reduced effects, suggesting that beyond a certain point, the benefits may plateau or even lead to mild toxicity. These results highlight the potential of MgO-NPs in regulating plant growth and hydration, aligning with recent studies that demonstrate how nanoparticles can enhance drought tolerance and metabolic efficiency in legumes (Chandrashekar et al., 2023).

The MgO-NP treatment has demonstrated a significant enhancement in plant moisture content, a crucial factor in water-use efficiency. This improvement is due to the MgO-NP influence on root permeability and hydraulic conductivity, facilitating greater water uptake and retention. Compared to traditional sources of magnesium, such as magnesium salts and NPK fertilizers, MgO-NPs exhibit superior performance in maintaining plant hydration. This suggests that MgO-NPs may offer an advanced approach to optimizing water availability, potentially mitigating drought stress and improving overall plant health. The distinct advantage of MgO-NPs underscores the evolving role of metal oxide nanoparticles as the findings corroborate previous research highlighting the capacity of nanoparticles to improve soil moisture retention and plant hydration by altering physicochemical interactions (Abdel-Aal Amin et al., 2024).

The effects of MgO-NPs on chlorophyll and protein content were significant across treatments. NPK fertilizer demonstrated superior performance, producing significantly higher levels of chlorophyll and protein compared to MgO-NPs. Conversely, higher concentrations of MgO-NPs (100 ppm) and magnesium salt treatments resulted in reduced chlorophyll and protein content, suggesting potential bioavailability limitations or adverse effects on nutrient synthesis processes at elevated MgO-NP concentrations (Kanjana, 2020; Koçak et al., 2023).

Furthermore, the treatment by MgO-NPs and other substances significantly influenced sugar accumulation and lipid content in the cowpea, enhancing key metabolic pathways. However, fiber content remained unchanged, indicating that some biochemical traits are unaffected by metal oxide nanoparticle exposure. The similar responses of the plant suggest that sugar and fiber accumulation are regulated by stable physiological mechanisms.

While MgO-NPs clearly modulate specific biochemical traits, environmental factors and nutrient availability may also play a role. Further research is needed to understand these interactions and optimize MgO-NP applications in agriculture. Nevertheless, external factors such as environmental conditions and nutrient availability may influence these outcomes, warranting further investigation (Balachandrakumar et al., 2024).

Concentration-dependent responses to MgO-NPs were further validated in cowpea seeds, where sugar levels peaked at 100 ppm MgO-NPs, significantly exceeding levels in control and other treatments. Lipid content showed maximum enhancement at 60 ppm, affirming the role of MgO-NPs in lipid metabolism. However, fiber content remained stable at approximately 190% across all treatments, indicating a robust cell wall structure unaffected by MgO-NP applications. While protein content was not explicitly addressed in these studies, the findings are consistent with broader research highlighting the positive effects of MgO-NPs and conventional fertilizers on legume biochemistry (Fayomi et al., 2024a). These results underscore the capacity of MgO-NPs to enhance lipid metabolism. In contrast, fiber content remained stable across all treatments, maintaining a consistent structural carbohydrate composition, aligning with previous findings on the resilience of fiber content under varying fertilization conditions (Khayoon and Reshag, 2024).

While the benefits of MgO-NPs in enhancing specific biochemical traits are evident, potential ecological risks associated with excessive nanoparticle use require careful consideration. Over-reliance on MgO-NPs could lead to unforeseen environmental impacts, underscoring the need for a balanced approach to nanoparticle-based fertilization in sustainable agriculture (Kiri et al., 2024; Kumah-Amenudzi et al., 2024).

In conclusion, this study demonstrated that magnesium oxide nanoparticles (MgO-NPs) enhance the growth, yield, and biochemical traits of the cowpea seeds by improving germination, biomass, chlorophyll, protein, sugar, and lipid content while maintaining stable fiber levels. These findings highlight MgO-NPs as a promising tool for boosting crop productivity and nutritional quality. However, further research is needed to assess their long-term environmental impacts, ensuring sustainable and safe agricultural practices.

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## RESUME

**Michael F.O., Olalekan O.J., Uzoma A.C. et Aondoehemen, A. 2025. Nanoparticules d'oxyde de magnésium comme activateurs de croissance et de caractéristiques biochimiques du niébé (*Vigna unguiculata*). Tunisian Journal of Plant Protection 20 (1): 1-16.**

Cette étude examine le rôle des nanoparticules d’oxyde de magnésium (MgO-NPs) dans l’amélioration de la croissance, du rendement et des caractéristiques biochimiques du niébé (*Vigna unguiculata*), révélant des effets significatifs des traitements sur des paramètres physiologiques et biochimiques clés. Les MgO-NPs ont amélioré la germination des graines, augmenté la biomasse des plantes et la teneur en humidité à des concentrations spécifiques, soulignant leur potentiel à favoriser la croissance végétative. La teneur en chlorophylle et en protéines des feuilles a montré une réponse dose-dépendante, l'engrais NPK enregistrant les valeurs les plus élevées, tandis que des concentrations modérées de MgO-NPs (40–80 ppm) ont montré des améliorations légères par rapport au témoin. Les paramètres biochimiques liés au rendement ont également montré des variations notables, la teneur en sucre atteignant un pic de 62,96 % à 100 ppm de MgO-NPs et la teneur en lipides atteignant 49,23 % à 60 ppm, suggérant des doses optimales pour la synthèse du sucre et des lipides. La teneur en fibres est restée constante, indiquant l'absence d'effet des MgO-NPs sur les glucides structurels. Ces résultats mettent en évidence les MgO-NPs comme un outil prometteur pour améliorer la productivité agricole, bien que des recherches supplémentaires soient nécessaires pour évaluer leurs effets à long terme et leur durabilité environnementale dans les pratiques agricoles.

*Mots-clés*: Chlorophylle, nanoparticules, niébé, oxyde de magnésium, propriétés biochimiques, teneur en sucre, *Vignaun guiculata*

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**ملخص**

**مايكل، فايومي أوموتولا وأولاسان جوزيف أولاليكان وأقيورو سيليستين يوزوما و أبي أوندوهيمن. 2025. جسيمات أكسيد المغنيسيوم النانوية كمعززات للنمو والصفات الكيميائية الحيوية في نبات اللوبيا (*Vigna unguiculata*).**
**Tunisian Journal of Plant Protection 20 (1): 1-16.**

تتناول هذه الدراسة دور جزيئات أكسيد المغنيسيوم النانوية (MgO-NPs) في تحسين النمو والإنتاجية والخصائص البيوكيميائية للوبيا (*Vigna unguiculata*)، حيث كشفت عن تأثيرات علاجية ملحوظة على المعايير الفسيولوجية والبيوكيميائية الرئيسية. عززت MgO-NPs إنبات البذور وزادت من الكتلة الحيوية للنبات ومحتوى الرطوبة عند تركيزات محددة، مما يبرز إمكاناتها في تعزيز النمو الخضري .أظهرت محتويات الكلوروفيل والبروتين في الأوراق استجابة تعتمد على الجرعة، حيث حقق سماد NPK أعلى النتائج، بينما أظهرت التركيزات المعتدلة من MgO-NPs (40-80جزء من المليون) تحسينات طفيفة مقارنةً بالشاهد .كما أظهرت معايير العائد البيوكيميائي تنوعا ملحوظًا، حيث بلغت نسبة السكر ذروتها عند 62.96% مع 100 جزء من المليون من MgO-NPs، وبلغت نسبة الدهون أعلى قيمة لها (49.23%) عند 60 جزء من المليون، مما يشير إلى الجرعات المثلى لتكوين السكر والدهون. بقي محتوى الألياف ثابتًا عبر المعاملات، مما يدل على عدم تأثير MgO-NPs على الكربوهيدرات الهيكلية .تسلط هذه النتائج الضوء على MgO-NPs كأداة واعدة لتحسين إنتاجية المحاصيل، مع الحاجة إلى مزيد من الدراسات لتقييم آثارها طويلة الأمد واستدامتها البيئية في الممارسات الزراعية.

*كلمات مفتاحية*: أكسيد المغنيسيوم، جزيئات نانوية، خصائص بيوكيميائية، كلوروفيل، لوبيا، محتوى السكر، *Vigna unguiculata*

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