International Journal of Advances in Life Science and Technology
2026 Vol. 10, No. 1, pp. 20-28.
ISSN(e): 2313-8335
ISSN(p): 2412-3803
DOI: 10.18488/72.v10i1.4968

Physiological and nutraceutical properties of mung bean (*Vigna radiata L.*) pre-soaked in bioregulators

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Article History
Received: 1 April 2026
Revised: 4 May 2026
Accepted: 14 May 2026
Published: 22 May 2026

Keywords
Antioxidants
Growth parameters
Indole acetic acid
Mung bean
Phytochemicals.

ABSTRACT

Mung bean (*Vigna radiata*) is a highly nutritious legume with significant potential for enhancing food security. However, its productivity is often constrained by suboptimal growth. This study investigated the effects of Indole Acetic Acid (IAA) and Gibberellic Acid (GA) on the physiological and nutraceutical properties of mung beans. *V. radiata* (n=10) were soaked in 0.75 and 1.5 µM of Indole Acetic Acid and Gibberellic Acid, respectively. They were later sown (n=5) in a pot of soil in a completely randomized block design. The plants were harvested at maturity. Growth parameters (weight of the leaves, number of leaves, stem girth, percentage germination, number of seeds per pod, and plant height), nutraceutical properties (phytochemicals ; flavonoids, steroids, terpenes, coumarins, glycosides, polyphenols, alkaloids, tannins, saponins), and antioxidant activities (DPPH, FRAP, nitric oxide, and hydrogen peroxide scavenging activity), proximate compositions (crude protein, fat, fibre, moisture, ash and carbohydrate), and mineral elements (Na, K, Ca, P, Fe, Zn and Mn) were evaluated. The results showed that IAA and GA significantly ($P \leq 0.05$) increased all measured parameters in a concentration-dependent manner as compared with the control. The 1.5 µM GA treatment consistently yielded the highest values, demonstrating superior efficacy in promoting growth and increasing nutraceutical properties. This study indicated that GA at 1.5 µM could be an appropriate and effective concentration for improving the agronomic performance, phytochemicals, nutritional, and antioxidant properties of mung beans. Therefore, it could be adopted by farmers and relevant stakeholders to enhance the yield and nutritional quality of mung beans for sustainable agricultural production.

Contribution/Originality: This study contributes to the field of plant biofortification and crop improvement by exploring biochemical and biotechnological approaches. It involves the application of plant growth hormones in seed treatment to enhance plant growth. The primary contribution is the development of an appropriate concentration of 1.5 µM GA to improve the nutraceutical quality and growth of the mung bean.

1. INTRODUCTION

The mung bean (*Vigna radiata*) is a leguminous plant species belonging to the family Fabaceae. Its common names includes: mung pea, four-angled bean, and goa bean, among others, depending on the region (Aletor & Aladetohun, 2010; James, Townsend, & Williams, 2021). Mung bean is an appropriate crop in temperate, subtropical, and tropical regions of the world, possessing high adaptability to various soil types and climatic conditions, requiring an optimal soil pH of 6.2 to 7.2. It is ready for harvest when 90% of the pods' color has turned black. The plant is a fast-growing, herbaceous, twining vine with edible roots, stems, leaves, flowers, and pods

(Bautista, 2016; Karthikeyan, Karuppaiah, & Ganesan, 2020; Taufik, Damayanti, & Hidayat, 2022). Mung bean is a tropical legume that belongs to the group of pulses or legumes and is classified within the subfamily Faboideae of the Fabaceae family (Bulgari, Franzoni, & Ferrante, 2019; Kumar, Upadhyaya, & Sharma, 2015; Lewis, Schrire, Mackinder, & Lock, 2005). It is primarily cultivated for its highly nutritious seeds and pods, both of which offered an important protein source for local populations. The crop can be categorized as an annual or perennial legume depending on local growing practices (Duke, 1981; Mithen, Phipps, & McGann, 2001; Nair, 2021). It is considered as a multi-purpose crop because every part of the plant can be utilized, from the root to the seeds (Herridge & Rose, 2000; Lawn & Cottrell, 2018). Given the rising global demand for nutrient-rich and climate-resilient crops, the mung bean stands out as an excellent candidate for promoting food security and sustainable farming systems (Lebot, 2020; Lewis et al., 2005; Mohan & Aghora, 2022). It can also be regarded as a highly nutritious crop with the potential to contribute to food security and sustainable agriculture. This is due to the fact that it contains a high amount of nutrients. A mung bean contains about 50–70% carbohydrate, 20-50% protein, and is rich in vitamins and minerals. It is regarded as a substantive source of dietary proteins. Sprouting increases the proteolytic cleavage of these proteins. Mung bean carbohydrates are simply digestible, which decreases the flatulence factors most common to other underutilized legumes. Lower calories are found in both the seeds and sprouts of the mung bean compared to cereal, making it a choice in obesity and diabetes (Tomooka, Vaughan, Moss, & Maxted, 2003). The lipid content of mung beans is minimal, at only about 1-2%. This is because the lipid fraction is nutritionally significant, being predominantly composed of unsaturated fatty acids, with linoleic acid (omega-6). This fraction also contains phospholipids and tocopherols (Vitamin E), which contribute to the seed's overall antioxidant capacity and stability against oxidation.

Mung beans are a good source of B vitamins, including; folate (B9), thiamine (B1), riboflavin (B2), niacin (B3), and pyridoxine (B6). The mineral profile is rich, containing potassium, magnesium, iron, zinc, phosphorus, and manganese. The mung bean is native to Southeast Asia, particularly Indonesia and New Guinea, where it was domesticated and first cultivated (Pal, Singh, & Prasad, 2020). Historically, the plant spread to the Pacific Islands, the Philippines, and other parts of Asia due to its high nutritional value and adaptability to different growing conditions (Soenandar, Wibowo, & Murti, 2019; Syed, Mond, & Mohammed, 2016). Today, it is cultivated in several parts of tropical Africa, Southeast Asia, and Central and South America. Despite its wide geographical distribution, it remains underutilized in many regions, although it has shown potential for improved food security and agricultural sustainability (Arumughan & Thiyagarajan, 2014; Taufik et al., 2022). Mung bean thrives in well-drained soils with a tropical climate, where it can grow from sea level up to altitudes of about 1,200 meters. It is tolerant of various soil types, including those that are less fertile, and can even grow in low-input farming systems, making it a valuable crop for resource-poor farmers (Du Jardin, 2015; Nair, 2021; Virdi, Sharma, & Jain, 2014). The immature pods, mature seeds, leaves, flowers, and tuberous roots are all consumed, providing a versatile source of protein, vitamins, and minerals to human diets (Mohan & Aghora, 2022; Soenandar et al., 2019). This nutritional profile makes it a crucial tool for combating malnutrition and enhancing food security in vulnerable communities. Beyond subsistence farming, the mung bean presents opportunities for commercial exploitation and income generation. The growing global demand for novel plant-based proteins and functional foods has sparked interest in mung bean seeds and tubers as ingredients for high-value food products, nutraceuticals, and protein isolates (Taufik et al., 2022). The plant's close resemblance, with its vibrant flowers and unique mung pods, also finds application in ornamental and educational uses, while its rapid growth and soil-enhancing properties make it valuable in agroforestry and land rehabilitation projects. Despite its high nutritional value and versatility, the global acceptability of mung bean has been limited compared to other legumes like soybeans, lentils, or chickpeas (Battacharyya, Babgohari, Rathor, & Prithiviraj, 2015; Khatun, Siddique, & Uddin, 2020). One of the primary reasons for this limited acceptability is the lack of awareness regarding its potential, especially in Western countries (Talekar, 2018). Additionally, several other factors limit its yield, including biotic and abiotic stress. Meanwhile, the stress is not only decreasing the productivity but also affects the biochemical and physical quality of seeds, making them unhealthy for consumers (Fuller & Harvey, 2006; Lambrides & Godwin, 2007; Van Damme, 2007). In fact, both stresses can result in substantial loss in yield. Common insect pests like stem fly, whitefly, and spotted pod borer attack mung beans at all stages of growth, even till storage. Some pests cause direct damage to the mung bean, while others transmit diseases (Fuller & Harvey, 2006; McLelland, 2010). The main fungal disease includes: *Cercospora* leaf spot, dry root rot, powdery mildew, and anthracnose, while halo blight and bacterial leaf spot are most common in Pakistan. Abiotic stresses like salinity, high temperature, drought, and excess soil and atmospheric moisture significantly affect plant growth and productivity, causing extensive agricultural losses worldwide (Lin et al., 2023; Sequeros et al., 2021).

Environmental variations have steadily increase crop yield reduction over the decades. Salinity impacts mung bean growth and yield through osmotic stress, excessive ions, and poor nodulation, leading to reduced nitrogen fixation and photosynthesis. High temperatures inhibit reproduction by affecting flowering, pollen viability, fertilization, and seed quality (Ohwi, 2005; Ong et al., 2023; Smartt, 1990).

Moreover, mung bean are more susceptible to water deficiency compared to many other food legumes because it requires a light moisture regime in the soil during their growing period, but must remain dry during harvest. Water deficit during growth can affect vegetative growth, the initiation of flowers, and cause abnormalities in pollen behavior. Excessive soil and atmospheric moisture can also result to sprouting in mature pods at the pre-harvest stage, leading to spoilage and poor seed quality (Ganesan & Xu, 2018; Pratap et al., 2019). However, conventional practices for improving crop productivity often rely on chemical fertilizers and synthetic growth enhancers, which can degrade soil health and pose risks to the environment and human health (Yakhin, Lubyanov, Yakhin, & Brown, 2017).

Bioregulators such as IAA and GA are plant growth hormones that regulate plant growth, affecting various biological and chemical processes. Improving the physiological and biochemical properties of this crop using bioregulators could significantly enhance its growth performance, yield, and nutritional quality (Bautista, 2016; Du Jardin, 2015). The application of bioregulators offers a sustainable solution to these challenges by enhancing plant growth, increasing nutrient use efficiency, and improving stress tolerance. Although bioregulators have been successfully used in other legumes, there is a paucity of information on their effects on some physiological, phytochemical, and nutritional properties of mung bean (James et al., 2021). Nandan, Yadav, Singh, Singh, Singh (2021) reported that growth characters such as plant height, total dry biomass, chlorophyll content, nitrogen content in green leaves, and protein content in mature seeds were significantly superior with seed priming of GA3-100 ppm followed by NAA-100 ppm over the control. Bekheta and Talaat (2009) also reported that foliar application of salicylic acid (5, 10, and 15 mg/L), 50, 100, and 150 mg/L glutathione, or paclobutrazole (PBZ) significantly increased plant height, number of branches per plant, fresh and dry weights of leaves, fresh and dry weights of branches, and yield (g/plant).

These treatments also increased total carbohydrates, total proteins, and mineral ion content, and caused positive changes in protein electrophoresis gels and photosynthetic pigments of the mung bean. Mitra and Kumar (2024) reported that foliar treatments of 10 mM ascorbic acid, 0.5 mM salicylic acid, 75 mM calcium nitrate, 10 mM thiourea, 30 mM trehalose, and water spray as control, applied at flowering, enhanced mung bean yield by improving greenness, photosynthetic pigment levels, Fv/Fm ratio, ETR, NPQ, photosynthesis, canopy temperature depression, biomass, pod number, pod weight, test weight, and dry matter partitioning toward economic yield. Yadav and Singh (2014) found that mung bean treated with BA (10^{-1} mM) significantly increased germination percentage, germination energy, seed vigor, and plant height. Therefore, the aim of the present study is to investigate some physiological, phytochemical, proximate, and mineral element composition of mung bean seed pre-soaked in bioregulators (indole acetic acid and gibberellic acid).

2. MATERIALS AND METHODS

2.1. Plant Materials

Mung bean seeds (MSWCC-20) were obtained from the Institute of Agricultural Research Training, Ibadan, Nigeria.

2.2. Preparation of Indole Acetic and Gibberellic Acid

This was carried out using the procedure of Al-Amri (2018) with slight modifications.

2.3. Planting

Mung bean seeds (MSWCC-20) were soaked in a bottle with two concentrations each of Indole Acetic Acid (IAA) and Gibberellic Acid (GA) at 0.75 µM and 1.50 µM, respectively. Distilled water was used instead of IAA and GA for the control seeds. All were kept for 18 hours in the dark at room temperature. Subsequently, the solutions were decanted, and the seeds were air-dried for 1 hour. The seeds were sown in pots with soil, with n=5, and allowed to germinate until maturity. The plants were harvested at maturity and divided into leaves and seeds for various analyses: growth parameters (weights of leaves, number of leaves, stem girth, percentage germination, number of seeds per pod, plant height), phytochemicals (flavonoids, steroids, terpenes, coumarins, glycosides, polyphenols, alkaloids, tannins, saponins), antioxidant activity (DPPH, FRAP, nitric oxide, hydrogen peroxide scavenging activity), proximate composition (crude protein, fat, fibre, moisture and carbohydrate), and mineral elements (Na, K, Ca, P, Fe, Zn and Mn).

2.4. Procedure for Determination of Growth Parameters

Weight of the leaves, number of leaves, number of seeds per pod, stem girth, and percentage germination were determined according to the method of Pasarla, Madanu, and Dawson (2021).

2.5. Procedure for Quantitative Phytochemical Determination and Antioxidant Activity

Phytochemicals (flavonoids, steroids, terpenes, coumarins, glycosides, polyphenols, alkaloids, tannins, saponins) and antioxidant activities (DPPH, FRAP, nitric oxide, hydrogen peroxide scavenging) were determined according to the methods of Al-Amri (2018).

2.6. Procedure for Determination of Proximate Composition

Proximate compositions (crude protein, fat, fibre, moisture, ash, and carbohydrate) was determined according to the methods of AOAC (2003).

2.7. Procedure for Determination of Mineral Nutrients

Mineral elements (Na, K, Ca, P, Fe, Zn and Mn) were determined according to the methods of AOAC (2003).

2.8. Statistical Analysis

The data obtained were analyzed using statistical analysis software (SAS) version 9. Analysis of variance was used to separate the means, and Duncan Multiple Range Test (DMRT) was used to test the level of significance ($P \leq 0.05$)

3. RESULTS

The results in Tables 1-5 showed the effects of bioregulators (IAA and GA) on the growth parameters, phytochemical, antioxidant, proximate, and mineral element composition of mung bean. Table 1 presents the effects of bioregulators (IAA and GA) on the growth parameters of the mung bean.

Table 1. Effects of Bioregulators (IAA and GA) on the Growth parameters of Mung bean.

Treatments	Weight of the leaf (g)	Plant height (cm)	Stem girth (cm)	Number of leaves	Percentage Germination	Number of seed/pod
Control	0.26±0.002^{e}	40.00±0.37^{e}	3.91± 0.01^{e}	10.01± 0.18^{e}	71.10±0.67^{e}	15.30±0.22^{e}
IAA 0.75 µM	0.35±0.002^{d}	47.00±0.25^{d}	4.22±0.01^{d}	12.11± 0.11^{d}	78.29±0.71^{d}	17.51± 0.25^{d}
IAA 1.50 µM	0.41±0.001^{c}	51.00±0.31^{c}	5.62± 0.02^{c}	13.91± 0.12^{c}	80.16±0.76^{c}	21.20± 0.27^{c}
GA 0.75 µM	0.52±0.001^{b}	56.00±0.42^{b}	6.91±0.02^{b}	15.25± 0.12^{b}	85.11±0.79^{b}	25.15± 0.31^{b}
GA 1.5 µM	0.61±0.001^{a}	62.10±0.51^{a}	7.17±0.02^{a}	16.90±0.15^{a}	92.19±0.81^{a}	28.11±0.33^{a}

Note: Means with different letters are significantly different from each other at P≤0.05. Values are presented as Mean ± Standard Error, n=3. Letters (a,b,c,d,e) indicate different level of significance difference at (P≤0.05) according to Duncan Multiple Range Test.

Table 2. Effects of Bioregulators (IAA and GA) on the Phytochemical composition of Mung bean.

Phytochemicals (%)	Control	IAA (0.75 µM)	IAA (1.5 µM)	GA (0.75 µM)	GA (1.5 µM)
Flavonoids	0.03±0.000^{e}	0.06±0.001^{d}	0.09±0.002^{c}	0.12±0.010 ^{b}	0.16±0.05 ^{a}
Steroids	0.01±0.001^{e}	0.05±0.002 ^{d}	0.07±0.001^{c}	0.08±0.001 ^{b}	0.11±0.02 ^{a}
Terpenes	0.04±0.001^{e}	0.07±0.001 ^{d}	0.09±0.001^{c}	0.13±0.014 ^{b}	0.15±0.04 ^{a}
Coumarins	0.03±0.001^{e}	0.05±0.001 ^{d}	0.07±0.001^{c}	0.09±0.011 ^{b}	0.11±0.02 ^{a}
Glycoside	0.04±0.001^{e}	0.06±0.001 ^{d}	0.09±0.002^{c}	0.08±0.005 ^{b}	0.12±0.03 ^{a}
Polyphenol	0.11±0.020^{e}	0.12±0.002 ^{d}	0.14±0.010^{c}	0.16±0.012 ^{b}	0.19±0.05 ^{a}
Alkaloids	0.08±0.015^{e}	0.12±0.011 ^{d}	0.14±0.012^{c}	0.15±0.013 ^{b}	0.17±0.06 ^{a}
Phytate	0.07±0.002^{e}	0.09±0.001 ^{d}	0.11±0.013 ^{c}	0.14±0.012 ^{b}	0.18±0.04 ^{a}
Oxalate	0.05±0.001^{e}	0.06±0.002 ^{d}	0.08±0.001 ^{c}	0.10±0.011 ^{b}	0.14±0.03 ^{a}
Tannin	0.04±0.001^{e}	0.06±0.001 ^{d}	0.08±0.000 ^{c}	0.12±0.013 ^{b}	0.15±0.03 ^{a}
Saponin	0.07±0.002^{e}	0.09±0.002 ^{d}	0.11±0.010 ^{c}	0.13±0.012 ^{b}	0.16±0.01^{a}

Note: Means with different letters are significantly different from each other at P≤0.05. Values are Mean ± Standard error, n=3.
Letters (a,b,c,d,e) indicate different level of significance difference at (P≤0.05) according to Duncan Multiple Range Test.

Table 3. Effects of Bioregulators (IAA and GA) on Antioxidants in Mung bean.

Phytochemicals	Control	IAA (0.75 µM)	IAA (1.5 µM)	GA (0.75 µM)	GA (1.5 µM)
% Total antioxidants	63.57±0.80^{e}	68.85±1.10^{d}	68.76±1.10^{c}	68.49±1.11^{b}	72.77±1.23^{a}
%DPPH	71.25±0.80^{e}	74.21±0.82 ^{d}	73.55±0.79^{c}	75.18±0.78^{b}	75.86±0.70^{a}
FRAP(mmol/100g)	117.34±0.70^{e}	123.45±0.71^{d}	118.79±0.72^{c}	125.69±0.69^{b}	126.17±0.61^{a}
% NO	48.79± 0.23^{e}	49.67±0.32^{d}	51.08±0.41^{c}	53.29±0.43^{b}	55.08±0.47^{a}
%H_2O_2	52.05±0.45^{e}	55.89±0.40^{d}	53.78±0.33^{c}	57.18±0.37^{b}	58.09±0.40^{a}

Note: DPPH: Diphenyl picryl hydrazyl, FRAP: Ferric Reduced Antioxidant Power, NO: Nitric Oxide, H_2O_2: Hydrogen Peroxide.
Values are presented as Mean ± Standard Error, n=3; means with different letters are significantly different from each other at P≤0.05. Letters (a,b,c,d,e) indicate different level of significance at (P≤0.05) according to Duncan Multiple Range Test.

Table 4. Effects of Bioregulators (IAA and GA) on Proximate composition of Mung bean.

Sample parameters (%)	Control	IAA (0.75 µM)	IAA (1.5 µM)	GA (0.75 µM)	GA (1.5 µM)
Crude Protein	17.69±0.10^{e}	18.09±0.23^{d}	18.19±0.19^{c}	18.28±0.14^{b}	18.37±0.22^{a}
Crude Fat	1.38±0.01^{e}	1.41±0.02^{d}	1.45±0.03^{c}	1.53±0.05^{b}	1.55±0.03^{a}
Crude Fibre	2.10±0.01^{e}	2.15±0.00^{d}	2.21±0.01^{c}	2.27±0.00^{b}	2.31±0.02^{a}
Ash	3.69±0.01^{e}	3.78±0.01^{d}	3.81±0.02^{c}	3.89±0.01^{b}	3.97±0.02^{a}
Moisture	11.58±0.09^{e}	11.76±0.05^{d}	11.83±0.02^{c}	11.92±0.01^{b}	11.97±0.01^{a}
Carbohydrate	63.56±0.48^{e}	62.81±0.58^{d}	62.51±0.61^{c}	62.11±0.60^{b}	61.83±0.65^{a}

Note: Means with different letters are significantly different from each other at P≤0.05.
Values are presented as Mean ± Standard Error, n=3.
Letters (a,b,c,d,e) indicate different level of significance difference at (P≤0.05) according to Duncan Multiple Range Test.

Table 5 presents the effects of bioregulators (IAA and GA) on mineral element of mung bean.

Table 5. Effects of Bioregulators (IAA and GA) on Mineral elements of Mung bean.

Sample Parameters	Control	IAA (0.75μM)	IAA (1.5 μM)	GA (0.75 μM)	GA (1.5 μM)
%Na	0.07 ± 0.01^{e}	0.09 ± 0.01^{d}	0.11 ± 0.01^{c}	0.17 ± 0.03^{b}	0.18 ± 0.01^{a}
%K	0.11 ± 0.01^{e}	0.13 ± 0.01^{d}	0.15 ± 0.02^{c}	0.16 ± 0.01^{b}	0.19 ± 0.02^{a}
%Ca	0.03 ± 0.01^{e}	0.04 ± 0.00^{d}	0.06 ± 0.01^{c}	0.07 ± 0.01^{b}	0.09 ± 0.01^{a}
%P	0.16 ± 0.02^{e}	0.17 ± 0.02^{d}	0.19 ± 0.03^{c}	0.20 ± 0.04^{b}	0.22 ± 0.11^{a}
Fe(mg/kg)	50.60 ± 0.34^{e}	51.90 ± 0.36^{d}	53.60 ± 0.49^{c}	55.20 ± 0.44^{b}	57.10 ± 0.46^{a}
Zn(mg/kg)	24.40 ± 0.11^{e}	25.50 ± 0.12^{d}	27.40 ± 0.15^{c}	28.80 ± 0.18^{b}	29.90 ± 0.20^{a}
Mn(mg/kg)	16.20 ± 0.10^{e}	16.70 ± 0.13^{d}	18.70 ± 0.15^{c}	18.90 ± 0.16^{b}	19.40 ± 0.17^{a}

Note: Na: Sodium, K: Potassium, Ca: Calcium, P: Phosphorus, Fe: Iron, Zn: Zinc, Mn: Manganese.
Means with different letters are significantly different from each other at $P \leq 0.05$.
Values are presented as Mean ± Standard Error, n=3.
Letters (a,b,c,d,e) indicate different level of significance difference at ($P \leq 0.05$) according to Duncan Multiple Range Test.

4. DISCUSSION

The results in Table 1 showed that the bioregulators (IAA and GA) significantly increased the growth parameters of the mung bean as compared with the control. However, 1.5 μM GA-treated mung bean showed the highest mean values. The increased in value is attributed to the stimulatory effect of the bioregulators, which enhanced minerals uptake and thus promoted faster vegetative growth. This finding aligned with the work of (Syed et al., 2016), who reported a significant increased in growth parameters of cowpea treated with hydrogen peroxide, a known plant growth stimulant. Moreover, the results in Table 2 showed the effects of IAA and GA on the phytochemicals of mung bean. Both IAA and GA showed increased in mean values, but the highest mean value was observed in 1.5 μM GA-treated mung bean. This was due to enhanced antioxidant potential, resulting in more efficient plant functions. This also aligns with the work of Al-Amri (2018), who reported the functional activity of IAA (Indole acetic acid), gibberellic acid, and kinetin on cowpea. Additionally, Tables 3-4 showed the effects of bioregulators (IAA and GA) on the mineral elements and antioxidant activity of mung bean. IAA and GA significantly increased the mineral elements and antioxidant activity, with the highest value observed in 1.5 μM GA-treated mung bean. This was due to the stimulation of the bioregulators to activate regulatory genes that facilitate nutrient uptake from the soil, boost antioxidant activity, and neutralize oxidants formed from reactive oxygen species encountered by the plant, thereby ensuring overall plant health. This aligns with the work of Pasarla et al. (2021), who reported the effects of plant growth regulators on the growth and yield of mung beans. A similar result was reported by Parveen et al. (2023), who found that a 60 mg L^{-1} concentration of IAA and GA_3 led to significant changes in growth, yield traits, total carbohydrate, protein, nitrogen contents in mung bean seeds, nutrient profile, photosynthesis, and soil N availability compared to non-treated plants. GA_3 positively influenced biological yield compared to the control. Moreover, the endogenous concentration of IAA, GA_3, and zeatin was enhanced after the combined application of IAA and GA_3 ($IAA_2 + GA_2$) compared to the CK treatment. Senthil, Pathmanaban, and Srinivasan (2003) also reported that foliar spray of brassinosteroids (BR), salicylic acid (SA), NAA, IAA, and kinetin significantly increased physiological parameters such as chlorophyll content, soluble protein, NRase, and peroxidase activity in soybean (Var CO-5). Kumar et al. (2023) reported that various combination of plant growth regulators (salicylic acid at 100 ppm and paclobutrazol at 150 ppm) and plant growth-promoting bacteria (*Bacillus subtilis*, *Bacillus thuringiensis*, and *Bacillus megaterium*) significantly increased physio-biochemical parameters, including chlorophyll meter readings, membrane stability index, protein content, proline content, and antioxidant enzymes in mung beans.

5. CONCLUSION

Mung bean is regarded as a cheap and good source of protein in most developing and developed countries of the world, but it was underexplored due to some physiological limitations and low awareness, which could ensure food security in most developing nations if adequately explored. The present study showed that the application of bioregulators (IAA and GA) significantly enhanced growth parameters, phytochemicals, mineral elements, and antioxidant activity of mung bean, with the highest value observed in 1.5 µM GA-treated mung bean. This demonstrates the potent role of bioregulators in stimulating metabolic processes, enhancing nutrient assimilation, and boosting the plant's intrinsic quality. The use of IAA and GA therefore represents a viable, sustainable strategy to overcome production constraints and improve the yield and nutritional value of mung bean, thereby potentially increasing their utilization and adoption by both subsistence and commercial farmers.

Funding: This work received no specific funding from any organization.
Ethical Approval: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.
Acknowledgement: The authors acknowledge the Institute of Agricultural Research &Training Ibadan Nigeria for providing mungbean seeds and facilities for the research.

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