

Productivity and profitability of peanut (*Arachis hypogaea* L. var. NSIC Pn18) as affected by indigenous microorganisms 6 (IMO6) bio-fertilizer application

Ulysses A. Cagasan^{1*}, Rogelio N. Coral¹ and Joseph B. Merano¹

¹Department of Agronomy, Visayas State University, Visca, Baybay City, Leyte 6521-A, Philippines

*Corresponding author's email: ulycagasan@vsu.edu.ph

Abstract

Bio-fertilizers provide essential nutrients that contribute to healthy plant growth and facilitate normal physiological development and are considered environmentally safer alternatives to conventional fertilizers. This study aimed to determine the effects of IMO6 bio-fertilizer on the productivity and profitability of peanut production. The treatments consisted of T₁, zero fertilizer; T₂, 2 t ha⁻¹ IMO6; T₃, 4 t ha⁻¹ IMO6; T₄, 6 t ha⁻¹ IMO6; and T₅, 30–30–30 kg ha⁻¹ N–P₂O₅–K₂O as the positive control. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The results revealed that the application of IMO6 bio-fertilizer significantly increased the number of days from planting to flowering, maturity duration, and plant height. Similarly, the highest leaf area index (LAI) was recorded in peanut plants treated with 30–30–30 kg ha⁻¹ N–P₂O₅–K₂O (2.65),

followed by 6 t ha⁻¹ IMO6 (1.93). In contrast, the highest fresh herbage yield was recorded with 6 t ha⁻¹ IMO6 (8.87 t ha⁻¹), followed by 30–30–30 kg ha⁻¹ N–P₂O₅–K₂O (8.32 t ha⁻¹). The highest gross margin of PhP 92,110.00 ha⁻¹ was obtained from plants treated with inorganic fertilizer, followed by those treated with 6 t ha⁻¹ IMO6, which recorded a gross margin of PhP 72,070.00 ha⁻¹. The lowest gross margins were obtained with 2 and 4 t ha⁻¹ IMO6, primarily due to lower grain yield and the relatively high cost of IMO6 application. Based on the results, the application of 4–6 t ha⁻¹ IMO6 may be considered as a potential bio-fertilizer option for peanut production to improve crop performance while supporting the maintenance of soil fertility. © 2026 The Author(s)

Keywords: Bio-fertilizer, Economic return, Indigenous microorganisms, Organic soil amendment, Peanut, Productivity

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Introduction

Peanut (*Arachis hypogaea* L.), commonly known as groundnut, is an annual herbaceous legume characterized by self-pollination and an indeterminate growth habit (Akram et al., 2018). It is an important oilseed and food legume cultivated widely in tropical and subtropical regions. Globally, peanut ranks among the major food crops, serving 13th among the world's major food crops, 4th largest source of edible oil and 3rd largest source of vegetable protein (Taru et al., 2018). Peanut seeds contain substantial amounts of protein, oil, carbohydrates, vitamins, minerals, and other nutritionally valuable compounds, making the crop important for food and nutritional security. It is consumed in various forms and is also widely used for oil extraction and the preparation of different food products. The crop is important to both smallholder and commercial producers because of its nutritional and economic value. Peanut also contributes to agricultural sustainability through its ability to establish symbiotic associations with nitrogen-fixing

microorganisms (Yakubu et al., 2020). The crop can be cultivated throughout the year when adequate production inputs are available. However, the quantity of peanuts produced locally may fall short of the demand generated by the processing and manufacturing sector, resulting in dependence on imports from other countries. In the Philippines, interest in organic agriculture is increasing, particularly in response to land-resource degradation associated with the excessive use of synthetic fertilizers and agricultural chemicals. This has increased the need for sustainable production practices and alternative nutrient sources. According to Veeramani and Subrahmani (2011), peanut showed a significant response to the application of organic fertilizers.

Despite its considerable nutritional and economic importance, peanut productivity varies among production systems due to differences in soil fertility, cultivar, climatic conditions, crop management, and the availability of essential nutrients (Gelaye & Luo, 2024). Therefore, improving peanut productivity through sustainable and cost-effective production practices is important for

increasing production efficiency, maintaining soil fertility, and enhancing the economic value of the crop (Xiao et al., 2026). The productivity of peanut is strongly influenced by soil fertility and adequate nutrient availability. Conventional crop production commonly relies on synthetic fertilizers to supply nutrients required for plant growth and yield formation (Gelaye & Luo, 2024). Although mineral fertilizers can rapidly supply nutrients, their excessive or inefficient use may increase production costs and may adversely affect soil properties and the surrounding environment. Continuous dependence on chemical fertilizers can also contribute to nutrient imbalance and deterioration of soil quality when fertilizers are not properly managed (Abay et al., 2025). These concerns have increased interest in alternative nutrient-management strategies that can maintain crop productivity while reducing dependence on synthetic inputs (Yimer & Tarnawa, 2025). Organic amendments and beneficial microorganisms have received increasing attention as components of sustainable agricultural production (Bonanomi et al., 2020). The application of organic inputs contributes to improvements in soil physical condition, chemical properties, and biological activity while contributing organic matter and nutrients to the soil (Oyebiye et al., 2026). Some microorganisms are capable of fixing atmospheric nitrogen, solubilizing otherwise unavailable forms of phosphorus and other nutrients, producing growth-promoting substances, and improving root development (Rakhmatova et al., 2026). The integration of organic materials and beneficial microorganisms may therefore provide an environmentally friendly approach for improving soil fertility, plant growth, and crop productivity (Oyebiye et al., 2026).

Bio-fertilizers consist of beneficial living microorganisms that establish themselves in the rhizosphere or within plant tissues and enhance the availability and uptake of essential nutrients, thereby supporting plant growth and development (Krska et al., 2022). Beyond their contribution to crop productivity, biofertilizers may also help limit the development of aflatoxin-producing fungi, offering potential benefits for both yield and food safety (Asoegwu et al., 2020). Consequently, the use of biofertilizers in groundnut production represents a promising approach to promoting sustainable farming practices while producing safer and higher-quality agricultural products (Pathania et al., 2020). Rhizobacteria including *Pseudomonas*, *Azotobacter*, and *Bacillus*, establish populations around plant roots and stimulate growth through several biological processes, such as atmospheric nitrogen fixation, phosphate solubilization, and the synthesis of plant growth-promoting compounds (Palai et al., 2021). Furthermore, *Pseudomonas* and *Bacillus* species are capable of producing phytohormones and other growth-regulating substances that encourage the development of fine roots, thereby increasing the root surface area available for the absorption of water and nutrients (El-Maraghy et al., 2021). Similarly, nitrogen-fixing bacteria, particularly *Rhizobium* and *Bradyrhizobium*, produce a range of physiologically active substances. These compounds can promote plant growth and contribute to biological nitrogen fixation in groundnut (Priya et al., 2022). These microbial activities can promote the formation of numerous healthy and functionally

effective root nodules, improving biological nitrogen fixation and soil fertility and, consequently, helping to overcome productivity constraints in groundnut cultivation.

Moreover, the application of organic fertilizers can contribute to improvements in soil physical structure, chemical characteristics, and biological activity, while also promoting greater productivity of field crops (Ansari et al., 2016). Indigenous microorganism 6 (IMO6) bio-fertilizers may serve as a potential source of nutrients for peanut production. It is part of a self-sufficient farming system in which indigenous microorganisms (bacteria, fungi, nematodes, and protozoa) are cultured and used as an alternative to inorganic fertilizers to improve soil fertility (Siam et al., 2015). According to the developer and producer of the fertilizer, IMO6 is named for its composition of six products prepared from different indigenous materials and microorganisms. These include vermicast, fish amino acid (FAA), and fruit and plant juice (FPJ) (Mukim et al., 2025). The use of IMO6 may enhance soil biological activity, decomposition of organic materials, nutrient transformation, and nutrient availability, thereby supporting peanut growth and development. Improved nutrient availability may contribute to vegetative growth, root development, biomass accumulation, pod formation, and seed development. However, the optimum IMO6 application rate for supplying the nutrients needed to support adequate growth and development of peanut plants has not yet been established, and information on its effectiveness in peanut production remains limited. Accordingly, the present study aimed to identify the most suitable IMO6 bio-fertilizer application rate and assess its effects on the productivity and profitability of peanut var. NSIC Pn18.

Materials and Methods

Experimental site and land preparation

A 362 m² flat experimental area with Omingan clay loam soil at Brgy. Pangasugan, Baybay City, Philippines, was selected for this study. The experimental field was prepared by conducting two rounds of plowing and harrowing with a tractor-mounted implement, with a one-week interval between operations. The soil was thoroughly pulverized and levelled to prepare it for planting. These operations were carried out to loosen the soil and incorporate weeds into the soil. Upon completion of the final harrowing, furrows were laid out 0.5 m apart to establish the required planting configuration. The experiment was established using a Randomized Complete Block Design (RCBD) with three replications. Each experimental plot covered an area of 12 m², with dimensions of 6 m × 2 m. To facilitate field operations and data collection, 1.0-m-wide alleyways were maintained between replications, while 0.5 m spacing was provided between individual treatment plots. Five fertilizer treatments were evaluated: T₁, no fertilizer (control); T₂, 2 t ha⁻¹ IMO6; T₃, 4 t ha⁻¹ IMO6; T₄, 6 t ha⁻¹ IMO6; and T₅, 30–30–30 kg ha⁻¹ N–P₂O₅–K₂O.

Planting and fertilizer application

Planting was done by hill method at 3 seeds hill⁻¹ spaced at 0.5 m between rows and 0.20 m between hills. After sowing, the seeds were lightly covered with soil to protect them from bird damage. Seedlings were thinned one week after emergence, retaining two plants per hill to achieve the target plant population of 200,000 hills ha⁻¹. The recommended fertilizer rate of 30–30–30 kg ha⁻¹ N–P₂O₅–K₂O for peanut production was used as the positive control (check) and supplied through complete fertilizer (14–14–14). The fertilizer was applied uniformly to all designated plots one week after seedling emergence. On the other hand, IMO6 bio-fertilizer was applied as a soil-based mixture directly into the furrows at planting. A soil layer of approximately 2 cm was placed over the bio-fertilizer before seed placement to prevent direct contact between the bio-fertilizer and seeds.

Pest and weed management

Pest infestations, including aphids, worms, and leafhoppers, were observed during the study but remained below the critical threshold level (less than 30% damage). Therefore, no pesticide spraying was conducted throughout the study. However, rodenticide was applied three months after planting due to damage to peanut pods. The rodenticide was applied at the early occurrence of rats to minimize damage to the peanut pods. The bait was prepared by mixing Racumin with rice grain and placed around the experimental area. Weeds were controlled by hand weeding, which was carried out twice using a bolo. The first weeding operation was performed two weeks after plant emergence, while the second was conducted two weeks after the first weeding, before flowering, to prevent unnecessary damage to the developing pegs.

Harvesting and post-harvest handling

Harvesting was carried out when 85% of the pods in each treatment plot had reached maturity, as indicated by the yellowing and dropping of the lower leaves and the firmness of the pods. Only plants from the four inner rows were harvested, covering a harvestable area of 5.2 m². The plants were harvested by pulling them with the aid of a bolo to minimize the number of pods remaining in the soil. The harvested pods from each treatment plot were washed and sun-dried for two days until moisture content of 14% was attained, as measured using a seed moisture meter, before collecting data on the yield components.

Agronomic characteristics

The agronomic characteristics evaluated were: days from planting to flowering, days from planting to maturity, plant height (cm), leaf area index (LAI), and fresh herbage yield (t ha⁻¹). Yield and yield components were assessed based

on the number of pods plant⁻¹, number of seeds pod⁻¹, 1,000-seed weight (g), fresh pod yield, and seed yield (kg ha⁻¹).

Cost and return analysis

Composite soil samples were collected for initial and final soil analysis. Cost and return analysis were also conducted to evaluate the economic performance of the different treatments.

Climatic information

Table 1 presents the monthly rainfall (mm), mean daily minimum and maximum temperatures (°C), and relative humidity (%) recorded throughout the experimental period. The climatic data were obtained from the Philippine Geophysical, Astronomical, Services and Administration (PAGASA) Station at Visayas State University, Visca, Baybay City, Leyte, Philippines. The records covered the period from May to August 2019. During the experiment, weekly rainfall ranged from 80 to 116 mm, with a total accumulated rainfall of 410.22 mm. Orbeta and Cagasan (2020) indicated that peanut requires approximately 500–600 mm of water per cropping season for satisfactory growth and development. The rainfall received during the experiment was therefore below the reported water requirement of the crop. To compensate for the insufficient rainfall, supplemental irrigation was provided during the late afternoon, particularly during the early stages of crop growth, to maintain adequate soil moisture. During the study period, the average daily minimum and maximum temperatures ranged from 25.49 to 32.83 °C, while the mean relative humidity was 77%. Bozóki et al. (2025) reported that suitable conditions for peanut growth include temperatures of approximately 25–33 °C and relative humidity between 75 and 85%. Accordingly, the temperature and relative humidity recorded during the experiment fell within the favorable ranges for peanut growth and development. These suitable climatic conditions likely supported important reproductive processes, particularly flowering and pod filling, and contributed to the higher grain yield (t ha⁻¹) observed in the fertilized treatments compared with the unfertilized control.

Statistical analysis

The data obtained from the experiment were statistically analyzed using analysis of variance (ANOVA) through the Statistical Tool for Agricultural Research (STAR). Differences among treatment means were evaluated using Tukey's Honestly Significant Difference (HSD) test at the 5% probability level ($P \leq 0.05$).

Table 1 Climatic data obtained from the PAGASA Station of VSU, Visca, Baybay City, Leyte

Period (Monthly)	Total rainfall (mm)	Temperature (°C)		Relative humidity (%)
		Minimum	Maximum	
May	80.95	25.52	34.23	78.00
June	116.21	26.43	32.76	80.00
July	115.46	25.43	31.57	75.00
August	97.60	24.60	32.76	76.00
Total	410.22			
Mean		25.49	32.83	77.00

Results

Soil chemical properties

Table 2 shows the result of the initial and final soil analysis of the experimental area. Initial analysis indicated that the soil had a pH of 5.5, 1.47% organic matter, 0.08% total nitrogen, 23.15 mg kg⁻¹ available phosphorus, and 0.54 cmol kg⁻¹ exchangeable potassium. These results indicated

that the experimental area was strongly acidic with deficient organic matter and nitrogen but sufficient available phosphorus and exchangeable potassium. Final soil analysis showed a slight increase in all soil chemical properties such as pH, organic matter, total N, available P, and exchangeable K. The increase of the final soil properties can be attributed to the applied IMO6 bio-fertilizer and from the crop residues of the previous cropping.

Table 2 Soil test results before planting and after harvest of peanut applied with IMO6 bio-fertilizer

Treatment	Soil pH	Organic matter (%)	Total N (%)	Available P (mg kg ⁻¹)	Exchangeable K (cmol kg ⁻¹)
Initial soil analysis	5.5	1.47	0.08	23.15	0.54
Final soil analysis	6.3	1.98	0.14	26.98	0.75

Agronomic characteristics

Table 3 shows the agronomic characteristics of peanuts applied with different levels of IMO6. Results revealed that all the agronomic characteristics were significantly affected by the different levels of IMO6. Peanut plants applied with IMO6 regardless of the levels significantly developed flowers and matured late than the plants not applied with any fertilizer. The late flowering and maturity were comparable to plants applied with recommended inorganic fertilizers. On the other hand, plant height (cm) of peanut plants significantly increased when plants were applied with IMO6 regardless of the levels than the plants not applied with fertilizers. Leaf area index differed significantly among treatments. The highest LAI was

recorded with the recommended inorganic fertilizer treatment (2.65), while 6 t ha⁻¹ IMO6 produced an intermediate LAI (1.93) and was statistically comparable to the inorganic fertilizer treatment. The control, 2 t ha⁻¹ IMO6, and 4 t ha⁻¹ IMO6 treatments recorded lower LAI values of 1.32, 1.54, and 1.34, respectively. Fresh herbage yield also varied significantly among treatments. The highest fresh herbage yield was obtained with 6 t ha⁻¹ IMO6 (8.87 t ha⁻¹), followed by the recommended inorganic fertilizer treatment (8.32 t ha⁻¹); both treatments were statistically comparable. The control, 2 t ha⁻¹ IMO6, and 4 t ha⁻¹ IMO6 treatments produced significantly lower fresh herbage yields of 6.92, 7.03, and 6.77 t ha⁻¹, respectively.

Table 3 Agronomic characteristics of peanut as affected by different levels of IMO6 bio- fertilizer

Treatment	Number of days from planting to		PH (cm)	LAI	FH (t ha ⁻¹)
	50% Flowering	Maturity			
T ₁ : Zero fertilizer	28.00a	104.67a	57.43b	1.32b	6.92b
T ₂ : 2 t ha ⁻¹ IMO ₆	30.00b	109.33b	81.33a	1.54b	7.03b
T ₃ : 4 t ha ⁻¹ IMO ₆	30.00b	111.33bc	87.00a	1.34b	6.77b
T ₄ : 6 t ha ⁻¹ IMO ₆	29.33b	112.00bc	90.23a	1.93ab	8.87a
T ₅ : 30-30-30 kg ha ⁻¹ N, P ₂ O ₅ , K ₂ O	29.67b	110.67bc	85.00a	2.65a	8.32a
Mean	29.86	110.48	82.48	1.01	3.39
C.V. (%)	10.54	4.43	5.47	11.60	9.66

PH = Plant height; LAI = Leaf area index; FH = Fresh herbage yield; Means followed by different letters differ significantly at the 5% level according to Tukey's HSD test.

Yield and yield components

Table 4 shows the yield and yield components of peanuts applied with different levels of IMO6 as bio-fertilizer. Results revealed that all the yield and yield components of peanut were significantly influenced by the application of IMO6 bio-fertilizer except on the number of seeds per plant. Plants applied with 6 t ha⁻¹ IMO6 produced similar

number of pods per plant and seed yield kg ha⁻¹ to plants applied with inorganic fertilizer. On the other hand, few pods per plant were noted in the treatments without fertilizer comparable to the plants applied with IMO6 at 2 and 4 t ha⁻¹. However, the weight of 1,000 seeds and % shelling recovery was high on the plants applied with IMO6 regardless of the levels comparable to plants applied with inorganic fertilizer. Moreover, the weight of pods ha⁻¹

was significantly higher on the plants applied with IMO6 at 4 and 6 t ha⁻¹ but significantly similar to the plants applied with inorganic fertilizer. Likewise, a higher seed weight ha⁻¹ was obtained by plants treated with 6 t ha⁻¹ (T₄) which was significantly comparable with plants applied with pure inorganic fertilizer (T₅). These results implied that the application of IMO6 bio-fertilizer at 4 and 6 t ha⁻¹ was the optimum rate because it obtained the heaviest of 1,000 seeds, weight of pods, and seeds per hectare of peanut plants. This result could be attributed to the level of nutrients provided by the IMO6 for peanuts for yield development.

Profitability analysis

Table 4 Yield and yield components of peanut as affected by different levels of IMO6 bio-fertilizer

Treatments	NPP	NSP	1000-SW (g)	SR	PY (kg ha ⁻¹)	SY (kg ha ⁻¹)
T ₁ : Zero fertilizer	20.33c	2.00	49 b	67.67b	1,224.00b	0884c
T ₂ : 2 t ha ⁻¹ IMO ₆	24.33bc	2.13	53ab	75.33ab	1,275.33b	0956c
T ₃ : 4 t ha ⁻¹ IMO ₆	24.33bc	2.03	53ab	76.00a	1,561.33ab	1186b
T ₄ : 6 t ha ⁻¹ IMO ₆	32.47ab	2.20	53ab	78.00a	1,951.37a	1521a
T ₅ : 30-30-30 kg ha ⁻¹ N, P ₂ O ₅ , K ₂ O	36.67a	2.00	57a	80.33a	1,973.71a	1637a
Mean	28.87	2.12	53.00	76.24	1687	1,359
C. V. (%)	6.85	6.29	4.45	3.82	15.23	12.36

NPP = Number of pods plant⁻¹; NSP = Number of seeds plant⁻¹; 1000-SW = 1000-seed weight; SR = Shelling recovery (%); PY = Pod yield (kg ha⁻¹); SY = Seed yield (kg ha⁻¹); Means followed by different letters differ significantly at the 5% level according to Tukey's HSD test.

Table 5 Cost and return analysis of peanut production per hectare as influenced by different levels of IMO6 bio-fertilizer

Treatments	Grain yield (kg ha ⁻¹)	Gross income (PhP ha ⁻¹)	Total variable cost (PhP ha ⁻¹)	Gross margin (PhP ha ⁻¹)
T ₁ : Zero fertilizer	1,224.00	85,680	34,500	50,773.00
T ₂ : 2 t ha ⁻¹ IMO ₆	1,275.33	89,273	48,500	40,773.00
T ₃ : 4 t ha ⁻¹ IMO ₆	1,561.33	109,270	62,500	46,770.00
T ₄ : 6 t ha ⁻¹ IMO ₆	1,951.37	136,570	64,500	72,070.00
T ₅ : 30-30-30 kg ha ⁻¹ N, P ₂ O ₅ , K ₂ O	1,973.71	138,110	46,000	92,110.00

Based on the current price of PhP 70.00 kg⁻¹ dry pods of peanut

Discussion

In this research study, the initial soil analysis indicated that the experimental soil was strongly acidic and relatively low in organic matter and total nitrogen, with a pH of 5.5, organic matter of 1.47%, and total nitrogen of 0.08%. After harvest, these values increased to 6.3, 1.98%, and 0.14%, respectively. Available phosphorus and exchangeable potassium also increased from 23.15 to 26.98 mg kg⁻¹ and from 0.54 to 0.75 cmol kg⁻¹, respectively. The improvement in soil chemical properties following IMO6 application suggests that the bio-fertilizer contributed to improved nutrient availability and soil fertility. The improvement in soil organic matter was particularly important because organic matter contributes to soil aggregation, nutrient cycling, water retention, cation exchange capacity, and pH buffering. Organic amendments can therefore improve the physical, chemical, and biological environment of the rhizosphere and subsequently support crop productivity (Celestina et al., 2019). Our findings are also consistent with research on groundnut showing that organic nutrient sources can increase soil organic carbon and available N, P, and K compared with unfertilized soil. Patra et al. (2011) reported

Cost and return analysis of peanut as affected by different levels of IMO6 was presented in Table 5. Peanut plants applied with 6 t ha⁻¹ (T₄) obtained the highest gross margin of PhP72,070.00 ha⁻¹, followed by peanut plants applied with zero application (T₀) with PhP50,773.00. The lowest gross margin was obtained on the plant applied with 2 and 4 t ha⁻¹ IMO6 (T₂-T₃). This result was due to the higher variable cost incurred in the procurement of IMO6 bio-fertilizer. In terms of profitability, peanut plants applied with pure inorganic fertilizer obtained the highest profit at PhP92,110.00. This was due to the high yield with the lower cost of inorganic fertilizer compared to the IMO6 bio-fertilizer.

that organic nutrient sources improved soil fertility as well as nutrient uptake and yield of groundnut. The increase in soil pH from 5.5 to 6.3 was also agronomically important because the initial soil was strongly acidic. Improvement in soil chemical conditions may have enhanced nutrient availability and root development, thereby contributing to the improved growth and yield observed under IMO6. Nevertheless, because the present study did not directly measure microbial population, nutrient mineralization, or microbial activity, the improvement in soil properties should be attributed to the overall effect of IMO6 and crop-residue inputs rather than to a specific microbial mechanism alone. This distinction is important because the effectiveness of microbial amendments depends on interactions between introduced or cultivated microorganisms, resident soil microbiota, soil conditions, and available organic substrates (Wang et al., 2024).

Application of IMO6 significantly affected the agronomic characteristics of peanut. Plants receiving IMO6 flowered and matured later than the unfertilized plants, while plant height, leaf area index (LAI), and fresh herbage production generally increased with IMO6 application. The 6 t ha⁻¹ IMO6 treatment produced 112.00 cm plant height, 1.93 LAI, and 8.87 t ha⁻¹ fresh herbage, compared with 104.67 cm, 1.32, and 6.92 t ha⁻¹,

respectively, under the unfertilized control. These results indicate that IMO6 promoted vegetative development and canopy formation. The greater LAI under 6 t ha⁻¹ IMO6 may have increased the photosynthetically active leaf surface and consequently improved assimilate production during reproductive development. The delayed flowering and maturity observed under IMO6 may therefore reflect a longer vegetative growth period rather than a negative response. Greater vegetative development can provide a larger source of assimilates for pod and seed formation when adequate nutrients are available. Similar improvements in groundnut growth and yield have been reported under integrated organic and biological nutrient-management systems, where improved nutrient availability and soil biological conditions contributed to greater growth and productivity (Arsalan et al., 2024). The response observed in the present study may also be related to the role of beneficial microorganisms in nutrient cycling and plant-microbe interactions. Recent research indicates that microbial inoculants can influence the soil-plant system through interactions with the resident microbiome, potentially improving nutrient availability and plant performance (Wang et al., 2024). The increase in pod and seed production may be associated with the improved soil fertility observed after IMO6 application. Greater availability of nutrients, together with improved soil organic matter, may have supported vegetative growth, reproductive development, pod formation, and seed filling (Liu et al., 2024). MowBot (2018) mentioned that when IMO6 is applied in the soil, it increases soil organic matter. Furthermore, it can enhance the soil's capacity to retain and supply essential nutrients while also helping to reduce the effects of soil acidification (Ievinsh, 2011). Good crop productivity is also dependent on good soil structure. When soil structure is favorable, the crop developed its roots and vegetative parts vigorously, resulting in delayed flowering and maturity but producing a high LAI as observed in the peanut plants applied with 6 t ha⁻¹ and recommended inorganic fertilizer (Zaki et al., 2017). This result showed that applying 6 t ha⁻¹ IMO6 is enough to increase the LAI and fresh herbage yield of peanut plants. Unfertilized peanut plants exhibited lower leaf area index (LAI) and fresh herbage weight, with values comparable to those recorded in plants receiving 2 and 4 t ha⁻¹ IMO6.

The present results are also consistent with recent research demonstrating that biological and organic nutrient-management practices can improve groundnut productivity when they enhance soil biological and chemical fertility. An integrated organic amendment and biofertilizer treatment in a groundnut field experiment in Pakistan increased plant growth, pods plant⁻¹, pod yield, and soil fertility indicators, while also improving economic returns (Arsalan et al., 2024). Similarly, long-term integrated nutrient management involving compost and reduced inorganic fertilizer improved groundnut-system productivity, soil fertility, microbial biomass, and profitability in a semi-arid environment (Bana et al., 2024). Although the 6 t ha⁻¹ IMO6 treatment produced high pod and seed yields, the recommended inorganic fertilizer treatment recorded slightly greater values, with 1,973.71 kg ha⁻¹ pod yield and 1,637 kg ha⁻¹ seed yield. Thus, IMO6 at 6 t ha⁻¹ approached the productivity obtained with the

recommended inorganic fertilizer but did not completely equal it. This result suggests that IMO6 has potential as a biological nutrient source, but its ability to completely replace mineral fertilizer may depend on soil fertility, nutrient composition of the bio-fertilizer, microbial activity, and crop nutrient requirements. Studies on groundnut nutrient management similarly indicate that integrated approaches can provide a more reliable balance between productivity, soil health, and fertilizer use than relying exclusively on either organic or inorganic nutrient sources (Babu et al., 2024).

Our results indicate that 6 t ha⁻¹ IMO6 was the most effective IMO6 treatment for peanut productivity. It produced the highest number of pods plant⁻¹, shelling recovery, pod yield, and seed yield among the IMO6 treatments. Pod yield increased progressively from 1,224.00 kg ha⁻¹ in the control to 1,275.33, 1,561.33, and 1,951.37 kg ha⁻¹ under 2, 4, and 6 t ha⁻¹ IMO6, respectively. This trend suggests that the higher IMO6 rate supplied or facilitated greater nutrient availability and supported improved crop development. However, the response to organic or microbial amendments should not automatically be interpreted as a universal recommendation for all soils and production systems. Yield responses to organic amendments vary with amendment characteristics, soil organic matter, nutrient availability, crop species, environmental conditions, and amendment rate. Meta-analysis has shown that the response to organic amendments is highly dependent on soil and amendment characteristics and that nutrient supply can be an important driver of yield improvement (Wortman et al., 2017). Therefore, the 6 t ha⁻¹ rate should be regarded as the optimum rate under the soil and environmental conditions of the present experiment, rather than as a universally optimal rate for peanut.

The economic results demonstrate that the increase in yield obtained with IMO6 translated into improved gross margin compared with the unfertilized control at the 6 t ha⁻¹ rate. Gross margin increased from PhP 50,773 ha⁻¹ in the control to PhP 72,070 ha⁻¹ under 6 t ha⁻¹ IMO6. Thus, the 6 t ha⁻¹ treatment generated approximately 42% greater gross margin than the unfertilized treatment. The lower profitability of the higher IMO6 treatment relative to inorganic fertilizer appears to be mainly associated with the cost of producing or procuring the large quantity of IMO6 required. The total variable cost increased from PhP 46,000 ha⁻¹ under inorganic fertilizer to PhP 64,500 ha⁻¹ under 6 t ha⁻¹ IMO6. Therefore, despite its high yield, the additional cost of IMO6 reduced the economic advantage of the treatment (Datta et al., 2014). These findings indicate that IMO6 may be particularly valuable where farmers prioritize improvement of soil fertility and reduction of dependence on synthetic fertilizers, even when the immediate financial return is lower than that of conventional fertilizer. Long-term studies have shown that organic and bio-based nutrient-management systems can improve soil biological and chemical properties while maintaining or improving system productivity and profitability when appropriately integrated with mineral fertilizers (Bana et al., 2024).

Conclusion and Recommendation

This study showed that peanut plants treated with IMO6, regardless of the application level, produced flowers, exhibited later maturity, and attained greater plant height. Application of 6 t ha⁻¹ and plants applied with pure inorganic fertilizer at 30-30-30 kg ha⁻¹ N, P₂O₅, K₂O obtained a high LAI and fresh herbage weight. Likewise, yield and yield components of peanut were significantly influenced by the application of IMO6 bio-fertilizer except on the number of seeds per plant. However, applications of 4 and 6 t ha⁻¹ IMO6 obtained a high weight (g) of 1000 grains, % shelling recovery, and gave the highest pod yield (t ha⁻¹). However, the highest gross margin ha⁻¹ at PhP92,110.00 was obtained in peanut plants applied with pure inorganic fertilizer followed by plants applied with 6 t ha⁻¹ PhP72,070.00. This result indicates that the use of inorganic fertilizer can be a practical and cost-effective option for peanut production, particularly because it requires relatively lower labor and handling costs compared with organic fertilizers. The application of 4 and 6 t ha⁻¹ in peanut production can be recommended to the farmers to enhance the yield and to improve the fertility status of the soil. It is recommended that a similar study be conducted during the dry season to further validate and confirm the results obtained in the present study.

Declarations

i. Ethics approval and consent to participate

Ethical approval and informed consent were not required for this study as it did not involve human participants, human data, or animals.

ii. Consent for publication

Consent for publication is not applicable.

iii. Data availability

All data generated or analyzed during this study are included in this article.

iv. Competing interests

The authors would like to declare that there is no conflict of interest in this study.

v. Authors' contributions

U.A.C. designed the study and performed the experiments; R.N.C. performed the statistical analysis and interpreted the results; J.B.M. contributed to data collection and manuscript preparation. U.A.C. wrote the first draft, and all authors reviewed and approved the final manuscript.

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viii. SDGs addressed

Zero Hunger (SDG 2), Decent Work and Economic Growth (SDG 8), Responsible Consumption and Production (SDG 12), Life on Land (SDG 15)

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