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Comparative Growth and Yield Performance of Peanut (*Arachis hypogaea L.*) Varieties under Different Pest Control Strategies

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Abstract

This study evaluated the growth and yield performance of peanut varieties subjected to different pest control strategies during wet-season cropping. Specifically, it aimed to (1) determine varietal performance in terms of yield and growth; (2) identify the highest-yielding variety under wet-season conditions; (3) determine the most effective biological pest control strategy and frequency of application; (4) assess the efficacy of control strategies against major defoliating insect pests; and (5) conduct production economic analysis of peanut production under the different treatments. A two-factor factorial experiment arranged in a randomised complete block design (RCBD) with three replications was employed. Factor A included three peanut varieties: farmers' variety (Ilocos Red), NSIC Pn9, and NSIC Pn12. Factor B comprised eight pest control strategies: control (no application), chemical insecticide, three application schedules of *Trichogramma*, and three schedules of *Metarhizium anisopliae*. Results revealed significant varietal differences in emergence, flowering, peg formation, vine length, and biomass. NSIC Pn9 consistently exhibited earlier phenological development, while NSIC Pn12 showed superior biomass and seed size. Pest incidence across all treatments remained very low, with damage indices indicating high resistance. Economic analysis indicated that NSIC Pn9 applied with *Trichogramma* once at the vegetative stage yielded the highest net income and benefit–cost ratio. The findings indicate that NSIC Pn9, applied with a single *Trichogramma* release, is the most profitable combination for wet-season peanut production. The study recommends further validation under dry-season conditions to strengthen conclusions.

Keywords: *peanut varieties, biological control agents, Trichogramma, Metarhizium, wet-season cropping, pest management.*

INTRODUCTION

Peanut (*Arachis hypogaea L.*) is ranked among the top 10 leguminous crops in the world, which means it is highly valued for its two main uses (oil and protein) and also as a source of essential nutrients for human diets and animal feeds. The major part of the edible peanut is the kernel, which contains around 25–28% protein and up to 48%–50% oil on a dry basis, along with carbohydrates, minerals, and bioactive compounds. Janila et al. (2013) have cited these nutritional components while discussing groundnut enhancement through genetic and genomic resources.

In fact, the peanut is the most nutrient-dense of the major oilseed crops, which makes it highly versatile in several value chains. Besides that, it can be eaten as a raw product (roasted peanuts, peanut butter), turned into an edible oil source, and made into feed with the help of the defatted peanut meal that is left after oil extraction. The multifunctionality of this product gives it great socioeconomic importance, especially in low- and middle-income countries, where smallholder farmers, who produce peanuts for their own consumption and for cash income, are the most vulnerable (Gelaye & Luo, 2024).

However, biotic stresses have caused significant production losses in peanuts over the years.

Insect herbivores, especially defoliators such as caterpillars (e.g., *Spodoptera spp*.) and cutworms, remain among the most destructive pests of peanuts. These defoliators can significantly damage foliage, impair photosynthesis, and thereby reduce yield, particularly under favourable environmental conditions for pest proliferation (IPM in Groundnut, 2024).

In addition to defoliators, subterranean pests like white grubs (Holotrichia spp.) Infestations of these types of pests can seriously injure the seed vessels that are on their way to maturing. The damage caused by pests of this kind is not limited to the reduction of seed numbers and weights, but they can also lower the quality of the product. For example, in Georgia, USA, the study before the harvest has shown that the presence of certain insect pests such as cutworm species, burrower bugs (*Pangaeus bilineatus*), and lesser cornstalk borers (*Elasmopalpus lignosellus*) is a major contributor to the elevated levels of insect-damaged pods, kernel deterioration, and aflatoxin contamination at the time of harvest.

Biological control may be a valuable resource to a few chemical insecticides or even a complete replacement in the control of such pests, particularly when implemented as a part of an Integrated Pest Management (IPM) system. One of the most striking instances is the case of the entomopathogenic fungus *Metarhizium anisopliae*. The research of Liu et al. (2017) demonstrated that the infection of M. anisopliae at sowing not only alleviated the disease but also accelerated the early development of peanut roots; hence, the fungus may be used as a biocontrol agent as well as a plant growth promoter.

Moreover, the timing of *M. anisopliae* application is critical. Li et al. (2020) found that applying the fungus at the early flowering stage of peanut maximised its persistence in the rhizosphere, which in turn increased mortality of white grub larvae and reduced damage to pods, ultimately improving yield.

Besides fungi, parasitoid wasps of the genus *Trichogramma* are also a promising source of biologic control of lepidopteran pests in peanuts. Lima Pinto & Fernandes (2020) carried out an experiment with *Telenomus remus* and *Trichogramma* pretiosum on the eggs of the most serious moth pests (e.g., Spodoptera cosmioides and Stegasta bosqueella) under controlled conditions, and the results showed that these parasitoids can effectively parasitise these eggs.

Although much of the classical *Trichogramma* work in peanuts has focused on stored-product pests, there is strong evidence from related systems. Brower (1990) reported that releases of *Trichogramma* pretiosum in simulated peanut storage reduced larval feeding of *Plodia interpunctella* and *Cadra cautella,* pointing to its value in integrated pest control programmes. However, despite these promising biocontrol options, empirical field data remain limited — especially in tropical wet-season contexts. The interaction between peanut cultivar (i.e., variety) and biological control agents is often overlooked: different peanut genotypes may influence how well M. anisopliae persists in the rhizosphere, or how attractive or suitable they are for *Trichogramma* parasitoids.

The scientific and agronomic importance of evaluating biologically compatible peanut varieties along with their yield potential is very high. These studies highlight genotype management interactions, revealing those combinations of variety and pest management that give the highest benefits under real production conditions. Basically, a research programme that tests several peanut genotypes under different BCA (biological control agent) treatments, while recording pest incidence, yield parameters, and financial returns, is a prompt and necessary one. This way, we can proceed to sustainable, integrated pest management strategies, which, on the one hand, optimise productivity and, on the other hand, respect the environment in peanut cropping systems.

METHODOLOGY

Study Site

The experiment was conducted at the CAFSD satellite experimental farm, Mariano Marcos State University, Puruganan, Dingras, Ilocos Norte, Philippines. Soil analysis revealed a light-textured soil with a pH of 6.20, organic matter content of 1.77%, available nitrogen of 0.0885%, phosphorus at 0.00 ppm, and potassium at 230.81 ppm. The site is primarily rainfed, supplemented with groundwater irrigation from a shallow tubewell. Adjacent fields were planted with soybean, cowpea, and peanut, and the western boundary was lined with trees, reflecting typical agronomic conditions in the region.

Experimental Design and Treatments

The study employed a two-factor factorial experiment arranged in a randomised complete block design (RCBD) with three replications. Each replication consisted of 24 plots measuring 8 m² each.

Factor A (Varieties):

- V1: Ilocos Red (local farmer variety)
- V2: NSIC Pn9
- V3: NSIC Pn12

Factor B (Pest Management Strategies):

1. No application (control)
2. Chemical insecticide (farmer's practice)
3. Trichogramma once (vegetative stage)
4. Trichogramma twice (vegetative and pod formation stages)
5. Trichogramma thrice (vegetative, pod formation, and pod filling stages)

6. Metarhizium anisopliae once (vegetative stage)
7. Metarhizium anisopliae twice (vegetative and pod formation stages)
8. Metarhizium anisopliae thrice (vegetative, pod formation, and pod filling stages)

Plot spacing and layout were implemented according to standard recommendations for field legumes.

Application of Pest Control Agents

Trichogramma cards were procured from Northern Foods Corporation (NFC), while *Metarhizium anisopliae* was obtained from the Ilocos Norte Research and Experiment Center.

• ***Trichogramma: 200 cards per hectare per*** application, suspended directly on the peanut plants according to the scheduled treatment.

• *Metarhizium anisopliae:* Two packs per 16-L spray load, equivalent to 40 packs per hectare per application. Applications followed the timing specified for each treatment.

Data Collection

Data were collected throughout the cropping season and included:

• Agro-climatic parameters (rainfall, temperature, relative humidity)
• Phonological observations (emergence, flowering, peg formation)
• Vine length at 60 and 90 days after sowing (DAS)
• Biomass accumulation (kg ha^{-1})
• Pest incidence and damage severity
• Yield components (pods per plant, seed count, filled pods, seed size)
• Marketable pod yield, shelling percentage, and dry pod yield
• Economic performance (cost and return analysis, including gross income, net income, cost per kg, and benefit–cost ratio [BCR])

Pest Incidence and Damage Assessment

Insect pests were visually surveyed, and specimens were collected for identification. Damage severity was scored according to the NCT Manual for Legumes (2017):

• 0 = Immune
• 1 = Highly resistant (1–20% leaf damage)
• 2–5 = Increasing susceptibility

Statistical Analysis

All quantitative data were subjected to analysis of variance (ANOVA) for a two-factor factorial RCBD using standard statistical procedures. Significant differences among treatment means weremseparated using the Least Significant Difference (LSD) test at a 5% probability level. Economic indicators, including gross income, net income, cost per kilogram, and BCR, were computed following standard enterprise budgeting methods.

RESULTS AND DISCUSSION

Plant Growth Parameters

Emergence, Flowering and Peg Formation

The growth performance of peanut varieties in terms of emergence, flowering, and peg formation showed clear varietal differences, while the application of biological control agents (BCAs) and insecticide did not significantly influence the timing of these parameters (Table 1). This indicates that genetic makeup played a more dominant role in regulating early phenological development than the pest control strategies applied during the wet season

Table 1: Phenological Development of Peanut Varieties under Different Pest Control Strategies during Wet Season Cropping

Factor / Treatment	Emergence (days)	Flowering (days)	Peg Formation (days)
Variety (A)			
Ilocos Red	7.02[a]	22.98[a]	29.98[b]
NSIC Pn9	6.77[b]	22.77[b]	29.73[a]
NSIC Pn12	6.96[a]	22.96[a]	29.98[b]
Significance (A)	*	*	**
Pest Control Strategies (B)			
Control (T1)	6.72	22.72	29.78
Insecticide (T2)	7.17	23.06	30.06
Trichogramma once (T3)	6.83	22.83	29.83
Trichogramma twice (T4)	6.95	23.11	29.94
Trichogramma thrice (T5)	7.11	23.11	30.11
Metarhizium once (T6)	7.17	23.17	30.17
Metarhizium twice (T7)	6.78	22.78	29.78
Metarhizium thrice (T8)	6.61	22.61	29.50
Significance (B)	ns	ns	ns
Interaction (A × B)	ns	ns	ns
CV (%)	4.43	1.06	0.48

*Values in a column followed by the same superscript letter are not significantly different (LSD test). ns = not significant; * = significant at 5%; ** = significant at 1%.*

Significant differences were observed in the number of days from sowing to 50% emergence. NSIC Pn9 emerged the earliest (6.77 days), followed by NSIC Pn 12 (6.96 days), while Ilocos Red was the latest to emerge (7.02 days). These results suggest that NSIC Pn9 possesses more vigorous early seedling growth, which may be attributed to its genetic traits, seed vigor, or adaptability under wet-season conditions. These findings agree with (Gonzales, De Jesus & Pangilinan, 2008), who noted that varietal characteristics significantly influence early growth behavior and adaptation in peanut, especially in stress-prone environments. Similarly, (Prasad et al., 2011) emphasized that emergence and early growth are largely governed by inherent varietal attributes such as seed size, seed coat permeability, and internal hormonal regulation. The slight delays noted in Ilocos Red may reflect its adaptation to drier environments, as reported by regional crop improvement programs (PCARRD, 2000).

Significant varietal differences were also found in days to 50% flowering. NSIC Pn9 flowered the earliest (22.77 days), followed closely by NSIC Pn12 (22.96 days), while Ilocos Red flowered last (22.98 days). Though numerically small, these differences were statistically significant. This supports (Gatan & Gonzales, 2014), who reported that flowering time in peanut is variety-specific and influenced by growth habit and inherent hormonal regulation. Bunch-type varieties like NSIC Pn9 typically exhibit earlier flowering, which aligns with the present findings.

Although pest control strategies did not significantly affect flowering, it is notable that plants treated with *Metarhizium* thrice (T8) exhibited the earliest flowering (22.61 days). *Metarhizium anisopliae* is known to produce secondary metabolites that may influence plant physiological processes, including growth stimulation, root development, and stress tolerance (Tiago et al., 2002). Entomopathogenic fungi can indirectly promote plant growth by reducing pest pressure early in the vegetative stage, allowing plants to allocate more energy toward reproductive development as further noted by (Jalali et al, 2016). However, the lack of significance in the present study may indicate that the wet-season environment—with ample moisture and rapid vegetative growth—minimized the observable effects of BCAs.

Highly significant differences among varieties were observed on days to peg formation. NSIC Pn9 again showed the earliest peg formation (29.73 days), while NSIC Pn12 and Ilocos Red both formed pegs later (29.98 days). This is consistent with earlier flowering trends and suggests that earlier reproductive initiation leads directly to earlier peg development.

Peg formation is a critical stage in peanut production. According to (Kumar et al., 2019), the peg plays a vital role in transporting nutrients and moisture to the developing pods through its root hair-like structures.

Varieties that initiate peg development earlier typically achieve longer pod development periods, often contributing to higher yield potential under favorable growing conditions.

As with flowering, pest control strategies did not significantly influence peg formation, although numerical differences were noted. Plants treated with *Metarhizium* thrice (T8) had the earliest peg formation (29.50 days), while *Metarhizium* once (T6) had the latest (30.17 days). This trend, although not statistically significant, aligns with studies such as those by (Tiago et al., 2002) and (Regional Crop Protection Center, 2014), which observed that repeated applications of *Metarhizium* can provide more consistent pest suppression and may contribute indirectly to more stable plant development.

However, the insignificant interaction effects (A × B) suggest that varietal genetic factors overshadowed the influence of pest management strategies during the wet season. High soil moisture and favorable growing conditions possibly masked the subtle benefits of BCAs in influencing developmental timelines.

Vine Length and Biomass

Significant varietal differences were observed in vine length at 60 DAS. Ilocos Red exhibited the longest vine length (48.71 cm), closely followed by NSIC Pn12 (48.61 cm), while NSIC Pn9 produced the shortest vines (44.98 cm). This indicates that growth habit is strongly varietal-dependent, which aligns with the observations of (Gatan and Gonzales, 2014), who highlighted that peanut varieties differ markedly in vegetative vigor depending on their genetic composition and growth type (bunch vs. runner).

NSIC Pn9, classified as a more compact variety, tends to allocate resources more efficiently to early reproductive development rather than vine elongation, explaining its shorter vine length—consistent with reports by (Gonzales et al., 2008) that newer NSIC varieties often exhibit reduced vine growth but improved reproductive efficiency.

At 90 DAS, however, no significant differences were attributed to variety alone, suggesting that environmental and treatment effects became more influential during later growth, particularly during the pod formation and pod filling stages. The increase in vine length across all varieties at 90 DAS reflects the wet-season growing environment, where high moisture availability promotes vigorous vegetative growth, as noted by (Prasad, Kakani, & Upadhyaya, 2011).

Table 2: Growth Parameters of Peanut Varieties under Different Pest Control Strategies

Factor / Treatment	Vine Length(cm)	Vine Length (cm)	Biomass (kg ha^{-1})
	60 DAS	**90 DAS**	
Variety (A)			
Ilocos Red	48.71^{ab}	75.68	1211.86^{b}
NSIC Pn 9	44.98^{b}	79.13	1371.54^{b}
NSIC Pn 12	48.60^{a}	81.73	1548.00^{a}
Significance (A)	*	ns	**
Pest Control Strategies (B)			
Control (T1)	47.22	75.15	1405.80^{b}
Insecticide (T2)	46.21	73.56	1180.26^{a}
Trichogramma once (T3)	48.98	79.56	1341.66^{b}
Trichogramma twice (T4)	48.41	81.56	1625.56^{b}
Trichogramma thrice (T5)	47.37	77.62	1194.95^{a}
Metarhizium once (T6)	47.15	80.95	1294.97^{a}
Metarhizium twice (T7)	47.81	81.42	1487.44^{b}
Metarhizium thrice (T8)	46.31	81.22	1464.19^{b}
Significance (B)	ns	ns	**
Interaction (A × B)	*	ns	**
CV (%)	10.68	12.15	16.56

*Values in a column followed by the same superscript letter are not significantly different (LSD test). ns = not significant; * = significant at 5%; ** = significant at 1%.*

Although pest control strategies did not significantly affect vine length at 60 and 90 DAS, numerical trends showed that treatments involving *Trichogramma* twice (T4) and *Metarhizium* twice (T7) consistently produced longer vines (81.56 cm and 81.42 cm, respectively).

These findings are supported by the work of (Jalali et al., 2016), who noted that repeated application of biological control agents can indirectly enhance plant vigor by suppressing insect pests early, reducing stress on the plant, and allowing for more resource allocation to vegetative growth.

Similarly, (Tiago et al., 2002) documented that *Metarhizium anisopliae* colonizes the rhizosphere and may stimulate plant growth through enhanced nutrient uptake and changes in root physiology.

In contrast, the shortest vine length was observed in the insecticide-treated plants (T2), suggesting possible phytotoxic effects or reduced beneficial microbial interactions in soil due to chemical disturbance—an effect previously indicated in biological-control literature.

The significant interaction between variety and treatment at 90 DAS indicates that some varieties respond better to specific BCAs, reflecting genotype × management interactions common in peanut cultivation (Janila & Mula, 2015).

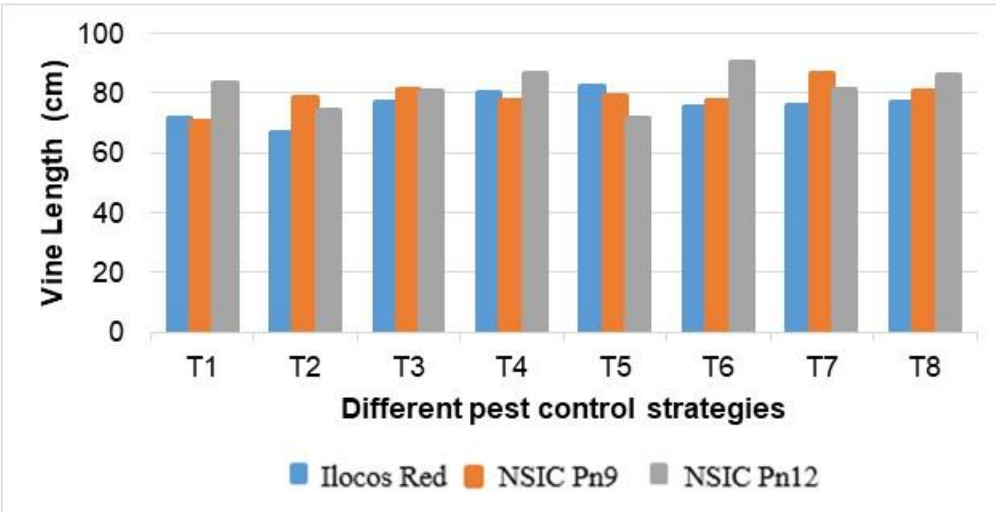

Figure 2: Interaction effects of peanut varieties and pest control strategies on vine length (cm) at 90 days after sowing (DAS). Values represent treatment means; error bars indicate standard error. *Trichogramma* applied twice produced the longest vines across varieties.

Highly significant differences were noted among varieties in terms of biomass. NSIC Pn12 produced the highest biomass (1,548 kg ha^{-1}), followed by NSIC Pn9 (1,371.54 kg ha^{-1}), while Ilocos Red recorded the lowest (1,211.86 kg ha^{-1}). These results align with the growth patterns observed in Table 2. NSIC Pn12, which also showed comparatively longer vine length at 90 DAS, appears to have greater vegetative vigor and biomass accumulation capacity.

This finding supports the literature wherein (Prasad et al., 2011) emphasized that peanut varieties with more robust vegetative structures tend to accumulate greater total dry matter, which contributes to improved reproductive performance under favorable environmental conditions.

Pest control strategies resulted in highly significant differences in biomass production. The highest biomass was recorded in Trichogramma twice (T4) with 1,625.56 kg ha^{-1}, closely followed by Metarhizium twice (T7) with 1,487.44 kg ha^{-1}. Meanwhile, the chemical insecticide treatment (T2) resulted in the lowest biomass (1,180.26 kg ha^{-1}).

Biological control agents promote plant growth indirectly, according to (Jalali et al., 2016), eco-friendly BCAs reduce pest pressure while maintaining beneficial soil microbes. This reduces stress and allows more assimilates to be channeled into biomass production. Repeated application enhances effectiveness, both Trichogramma twice (T4) and Metarhizium twice (T7) involve two applications at vegetative and pod formation stages, key periods when minimizing insect damage is crucial. (Regional Crop Protection Center, 2014) likewise reported that staged Metarhizium applications improved legume health and biomass.

Lower biomass in chemical insecticide treatment (T2) reflects findings by (Tiago et al., 2002) that persistent chemical inputs can suppress entomopathogenic fungi and other rhizosphere organisms that contribute to plant health.

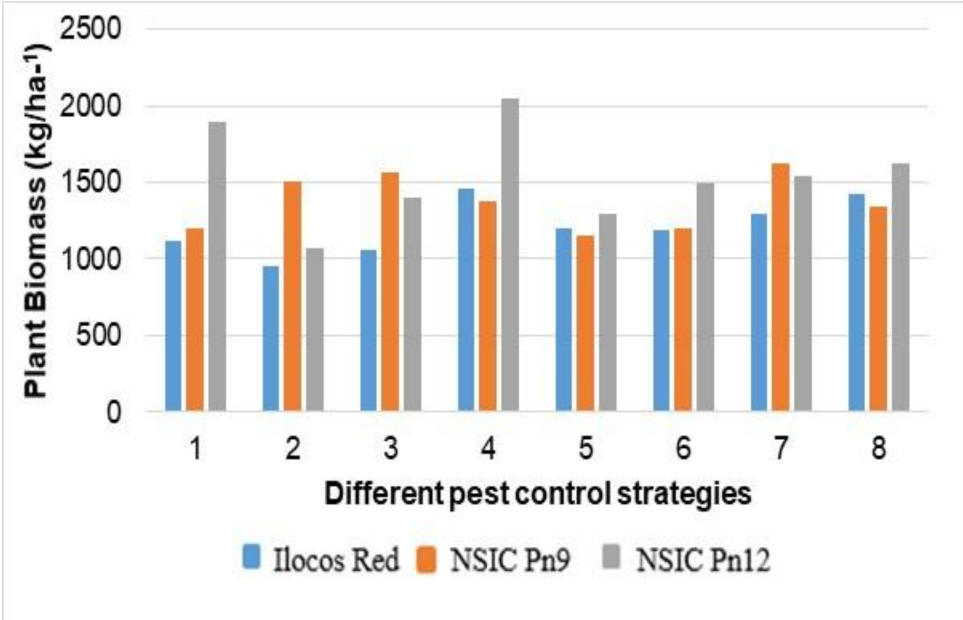

Figure 3: *Interaction between variety and pest control strategies on biomass (kg ha^{-1}). NSIC Pn12 treated with Trichogramma twice produced the highest biomass, while Ilocos Red treated with insecticide had the lowest.*

The highly significant interaction between variety and pest management strategy further indicates that biomass production is influenced not only by genetics but by how each variety physiologically responds to specific BCAs. The highest biomass (2,053.29 kg ha^{-1}) was achieved by NSIC Pn12 × Trichogramma twice (T4), suggesting strong compatibility between this variety's growth pattern and the biological control strategy. Conversely, Ilocos Red × insecticide (T2) produced the lowest biomass (956.68 kg ha^{-1}), revealing potential sensitivity of this traditional variety to chemical inputs.

These results align with (Janila & Mula, 2015), who emphasized that genotype × management interactions are critical in groundnut production, and certain modern varieties respond more positively to biological or integrated pest management strategies.

Pest Incidence

Pest pressure during the trial was very low, with all treatments and varieties scoring "1"—highly resistant. The minimal presence of leaf piercers, chewers, and other pests may have limited observable differences in BCA efficacy. This low pest occurrence is consistent with certain wet-season peanut environments where rainfall disrupts pest life cycles.

This observation is supported by (Prasad et al., 2011), who reported that wet-season conditions often reduce the severity of major peanut insect pests due to weather-mediated mortality, weakened reproduction, and lower feeding activity. Similarly, (Jalali et al., 2016) emphasized that many pod borers and leaf-feeding insects thrive under warm and dry conditions, and their populations decline significantly during periods of heavy rainfall.

Table 3: Pest Incidence in Peanut Under Different Pest Control Strategies

Treatment / Variety	Powdery Mildew	Leaf Piercing Insects	Chewing Insects	Bean Fly	Pod Borer
T1–T8 (All treatments)	1.0	1.0	1.0	1.0	1.0
Varieties (A1–A3)	1.0	1.0	1.0	1.0	1.0
Significance	ns	ns	ns	ns	ns

Damage index: 0 = immune; 1 = highly resistant (1–20% damage).

All varieties (Pn9, Ilocos Red, and Pn12) scored “1,” indicating inherent tolerance or resistance traits, even though environmental suppression was the stronger contributing factor. According to PCARRD (2000), most Philippine peanut varieties possess moderate to high tolerance to common foliar pests, particularly under favorable moisture conditions that enhance plant vigor. In addition, (Kumar et al., 2019) emphasized that healthier peanut plants with well-developed canopy structures—typical in moist environments—can physiologically compensate for minor pest feeding, further reducing apparent damage.

Yield and Yield Components

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The results for yield components (Table 4) show that varietal characteristics had stronger influence on the number of pods per plant, seed count per pod, and seed weight than the applied pest control strategies, given that pest pressure was extremely low during the wet season. Most parameters showed non-significant differences across pest control treatments, indicating that the biological control agents (BCAs) and insecticides did not substantially influence the reproductive development of peanut under low pest conditions. These trends are consistent with the pest incidence data, where all treatments recorded “1” (highly resistant), suggesting minimal pest interference with yield formation

Table 4: Yield Components of Peanut Varieties Under Different Pest Control Strategies

Factor / Treatment	Pods/Plant	Seed Count/Pod	Filled Pods (%)	100-Seed Weight (g)
Variety (A)				
Ilocos Red	12.45	3.00[a]	84.36	38.24[b]
NSIC Pn9	11.64	3.02[a]	86.46	35.69[c]
NSIC Pn12	13.28	2.00[b]	84.33	46.22[a]
Significance (A)	ns	**	ns	**
Pest Control Strategies (B)				
T1	11.54	2.67	83.67	38.80
T2	12.89	2.67	83.72	39.09
T3	12.53	2.67	84.00	41.77
T4	12.06	2.67	87.51	39.81
T5	11.80	2.67	86.72	40.46
T6	13.56	2.67	83.78	39.34
T7	12.39	2.67	85.67	40.12
T8	12.87	2.72	85.33	40.99
Significance (B)	ns	ns	ns	ns
Interaction (A × B)	**	ns	ns	ns

*Values in a column followed by the same superscript letter are not significantly different (LSD test). ns = not significant; * = significant at 5%; ** = significant at 1%.*

Although the main effect of variety was not significant, inspection of the means reveals biologically important differences, NSIC Pn12 had the highest pod number (13.28 pods/plant), followed by Ilocos Red (12.45 pods/plant), while NSIC Pn9 recorded the fewest (11.64 pods/plant). These differences reflect inherent genotypic variability in reproductive potential. NSIC Pn12, known for vigorous reproductive growth, tends to form more pods even under minimal stress.

The significance of the A × B interaction confirms that pod number was strongly influenced by the combination of variety and pest management strategy. NSIC Pn9 under insecticide treatment (T2) achieved the highest pod count (14.87 pods/plant), while NSIC Pn9 under *Metarhizium* once (T6) produced only 7.94 pods, showing that environmental and physiological interactions can amplify or suppress varietal traits.

These results align with (Ajeigbe et al., 2015), who emphasized that pod number in peanuts is primarily genotype-dependent but can be modified by management practices when stress occurs. In this study, however, the consistently low pest pressure minimized treatment effects.

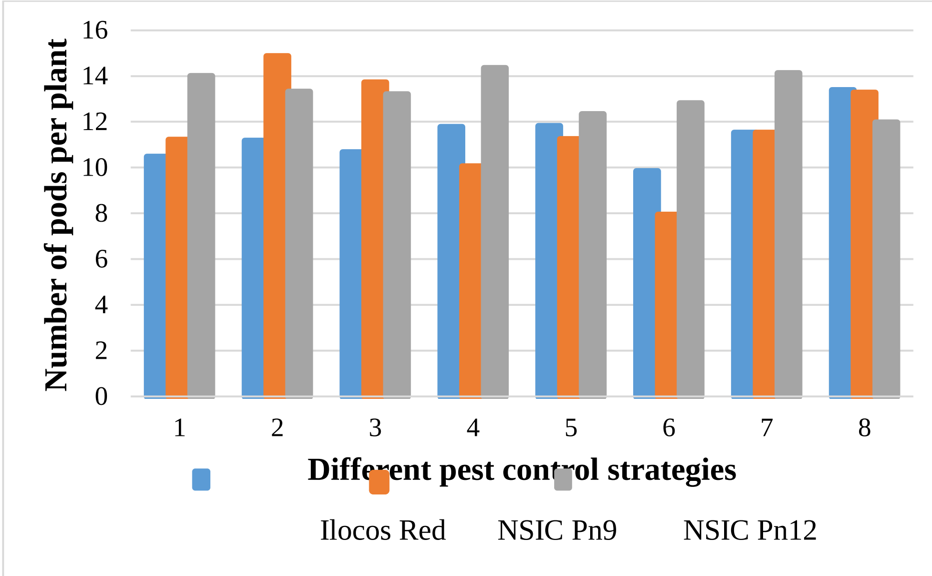

Figure 4: *Interaction effects of varieties and pest control treatments on number of pods per plant. NSIC Pn9 treated with insecticide yielded the highest pod count, while NSIC Pn9 with Metarhizium once yielded the lowest.*

Varietal differences in seed count per pod were highly significant and the numerical values demonstrate clear genetic distinctions, NSIC Pn9 3.02 seeds per pod, Ilocos Red, 3.00 seeds per pod and NSIC Pn12 with 2.00 seeds per pod. NSIC Pn9 and Ilocos Red showed a three-seeded pod tendency, while NSIC Pn12 typically produced two-seeded pods. These differences are consistent with published varietal descriptors indicating that some peanut varieties express larger but fewer seeds per pod, while others express more seeds but with smaller individual sizes (Upadhyaya et al., 2011).

Seed count showed no sensitivity to pest control strategies, with nearly identical treatment means (2.67 seeds per pod). This supports the literature stating that seed number is highly heritable and less responsive to short-term management (Janila & Nigam, 2015).

Despite numerically varied means, filled pod percentage was statistically non-significant for both factors. Still, the values show useful patterns, NSIC Pn9 (86.46%) recorded the highest filled pod percentage followed by Ilocos Red and NSIC Pn12.

Among treatments, T4 (*Trichogramma* twice) achieved the highest filling percentage (87.51%), but the differences were biologically small and statistically non-significant.

These results reflect favorable wet-season conditions, which enhance pod filling because adequate moisture reduces embryo abortion and supports nutrient mobilization to developing pods. (Prasad et al., 2011) reported similar findings, who observed that pod filling is more affected by environmental conditions (water, temperature) than by pest management when pest damage is minimal.

Seed size showed strong, highly significant varietal differences, NSIC Pn12 with 46.22 g (large-seeded), Ilocos Red recorded 38.24 g and NSIC Pn9 with 35.69 g (smallest seeds). This is consistent with known variety traits. NSIC Pn12 is classified as a large-seeded peanut, which enhances market value. Seed size is an important yield determinant, and the ~10 g difference between NSIC Pn12 and Ilocos Red illustrates substantial genetic influence.

Treatment effects were non-significant, with means ranging from 38.80–41.77 g. This stability supports literature stating that seed weight is one of the most heritable peanut traits and is less responsive to external inputs—especially when pest pressure is low (Upadhyaya et al., 2011; Prasad et al., 2011).

The slightly higher seed weights under *Trichogramma* treatments (e.g., T3 = 41.77 g) may be linked to reduced physiological stress and improved plant vigor, a trend consistent with reports by (Jalali et al., 2016) and (Uelese et al., 2014) on the value of biological control in enhancing crop health even in low-pest environments.

Dry Pod Yield and Profitability

The results in Table 5 show clear varietal differences in marketable pod percentage and shelling efficiency, while dry pod yield did not differ significantly among the peanut varieties evaluated. Pest control strategies, including biocontrol agents (BCAs) and insecticide, produced no significant effects on any of the yield-quality parameters due to the low pest pressure during the cropping period.

Varietal effects were highly significant, NSIC Pn12 (97.82%) and NSIC Pn9 (97.43%) exhibited significantly higher marketable pod percentages than Ilocos Red (94.11%). The narrow range of treatment means (95.41–97.20%) indicates that pest control interventions did not influence pod marketability. The higher marketable pod percentage in Pn12 and Pn9 likely results from their genetic predisposition to produce well-filled, disease-free pods, even under minimal pest pressure. Ilocos Red's slightly lower value may be attributed to varietal susceptibility to pod deformation or partial filling, traits that are often genotype-specific. These findings are consistent with (Janila et al., 2013) and (Nigam et al., 2012), who noted that marketable pod proportion is primarily genotype-driven, with environmental and pest-management factors exerting smaller influences when pest incidence is low. Similarly, (Ajeigbe et al., 2015) documented that improved peanut cultivars show greater pod development stability under varying environments, explaining why Pn12 and Pn9 performed better.

Highly significant varietal differences were also observed, NSIC Pn12 exhibited the highest shelling percentage (71.18%), followed by NSIC Pn9 (67.89%), and Ilocos Red (63.36%), which had the lowest. Shelling percentage is influenced by kernel-to-shell ratio, kernel density, and pod structure. NSIC Pn12's superior shelling percentage indicates that it allocates more biomass to seed development relative to shell growth. Ilocos Red's lower shelling percentage suggests a thicker shell or less dense seed fill. This aligns with the findings of (Upadhyaya et al., 2005), who reported that shelling percentage is a stable genetic trait, strongly associated with kernel recovery efficiency and seed density. It was also noted that modern cultivars (similar to Pn12) generally outperform traditional lines (like Ilocos Red) in shelling efficiency due to improved breeding for kernel weight and pod structure.

Despite differences in pod quality traits, no significant difference in dry pod yield was found among varieties. The lack of significant yield differences suggests that, all varieties performed similarly under wet-season conditions, with adequate moisture supporting pod filling across genotypes and the low pest pressure minimized the need for differential pest resistance traits to influence yield outcomes. The small variations in pods/plant and seed size may have offset each other, resulting in comparable final yields. These results are in agreement with (Prasad et al., 2011) and (Gulluoglu et al., 2017), who reported that peanut yield during wet seasons is more strongly influenced by environmental conditions (moisture availability, temperature) than by pest control inputs, especially when pest damage is minimal.

Prasad et al., emphasized that adequate moisture during reproductive stages stabilizes yield across genotypes, reducing the expression of genetic yield differences.

Similarly, (Ajeigbe et al., 2015) found that under low-stress conditions, yield differences among varieties often shrink due to uniformly favorable growth environments.

Table 5: Marketable Pods, Shelling Percentage, and Dry Pod Yield

Factor / Treatment	Marketable Pods (%)	Shelling (%)	Dry Pod Yield (t ha^{-1})
Variety (A)			
Ilocos Red	94.11^{b}	63.36^{c}	1.47
NSIC Pn9	97.43^{a}	67.89^{b}	1.42
NSIC Pn12	97.82^{a}	71.18^{a}	1.45
Significance (A)	**	**	ns
Pest Control Strategies (B)			
All treatments (T1–T8)	95.41–97.20	66.06–68.23	1.22–1.60
Significance (B)	ns	ns	ns
Interaction (A × B)	ns	ns	ns

Values in a column followed by the same superscript letter are not significantly different (LSD test).
*ns = not significant; * = significant at 5%; ** = significant at 1%.*

Table 6: Cost and Return Analysis of Peanut Production Under Different Pest Control Strategies

Variety	Treatment	Cost of Production (PHP ha⁻¹)	Yield (t/ha⁻¹)	Cost per kg (PHP)	Gross Income (PHP ha⁻¹)	Net Income (PHP ha⁻¹)	BCR
Ilocos Red	T1 – Control	55,315.68	1.26	44.27	100,800.00	45,484.32	0.83
	T2 – Insecticide	59,134.80	1.61	36.74	128,800.00	69,665.20	1.18
	T3 – Trichogramma once	57,194.90	1.44	40.30	115,200.00	58,005.10	1.01
	T4 – Trichogramma twice	60,194.90	1.58	38.22	126,000.00	65,805.10	1.10
	T5 – Trichogramma thrice	63,694.90	1.62	39.45	129,200.00	65,505.10	1.03
	T6 – Metarhizium once	55,643.50	1.25	44.69	99,600.00	43,956.50	0.80
	T7 – Metarhizium twice	57,554.68	1.36	42.48	108,400.00	50,845.32	0.88
	T8 – Metarhizium thrice	59,914.68	1.61	37.24	128,800.00	68,885.32	1.15
NSIC Pn 9	T1 – Control	55,315.68	1.42	39.27	113,600.00	58,284.32	1.06
	T2 – Insecticide	59,134.80	1.61	37.10	128,400.00	69,265.20	1.18
	T3 – Trichogramma once	57,194.90	**1.85**	32.59	**148,000.00**	**90,805.10**	**1.58**
	T4 – Trichogramma twice	60,194.90	1.13	53.46	90,400.00	30,205.10	0.50
	T5 – Trichogramma thrice	63,694.90	1.22	52.80	97,200.00	33,505.10	0.53
	T6 – Metarhizium once	54,318.50	1.10	51.22	88,000.00	32,356.50	0.59
	T7 – Metarhizium twice	57,554.68	1.42	41.58	113,200.00	55,645.32	0.96
	T8 – Metarhizium thrice	59,914.68	1.64	43.27	130,800.00	70,885.32	1.17
NSIC Pn 12	T1 – Control	55,315.68	1.71	32.48	136,800.00	81,484.32	1.48
	T2 – Insecticide	59,134.80	1.32	47.63	105,200.00	46,065.20	0.77
	T3 – Trichogramma once	57,194.90	1.51	38.05	120,800.00	63,605.10	1.11
	T4 – Trichogramma twice	60,194.90	1.62	38.10	129,200.00	69,005.10	1.14
	T5 – Trichogramma thrice	63,694.90	1.55	41.29	123,600.00	59,905.10	0.94
	T6 – Metarhizium once	55,643.50	1.31	45.25	104,800.00	49,156.50	0.90
	T7 – Metarhizium twice	57,554.68	1.34	43.35	106,800.00	49,245.32	0.86
	T8 – Metarhizium thrice	59,914.68	1.26	49.55	100,800.00	40,885.32	0.69

Price of dry pods = PHP 80.00/kg.

The cost and return analysis of the study (Table 6) shows that treatment 5 (application of *trichogramma* thrice) recorded the highest total cost of production of Php 63,694.90 per hectare. Variety 2 (NSIC Pn9) applied with treatment 3 (application of *trichogramma* once at vegetative stage) recorded the highest Net Income of Php 90,805.10 as manifested by the high production of 1.85 (t/ha-1) and with highest return than the other treatments having the highest Benefit Cost Ratio (BCR) of 1.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study concludes that while biological pest control strategies did not significantly influence yield under low pest pressure, varietal differences were notable in growth and yield components. NSIC Pn9 demonstrated favorable agronomic performance and, when combined with *Trichogramma* applied once during the vegetative stage, resulted in the highest profitability during wet-season production.

Recommendations

Farmers are encouraged to adopt NSIC Pn9 with a single *Trichogramma* application for optimal yield and economic return in wet-season peanut production. Future research should validate these findings under dry-season conditions, where pest pressure is typically higher. Studies should also explore environmental interactions affecting BCA performance, particularly under varying rainfall patterns.

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