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RESEARCH PAPER

Interactive effects of planting density and integrated nutrient applications on the growth and yield of Peanut (*Arachis hypogaea* L.)

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Key Message: The study demonstrated that planting density (one or two plants per hill) did not significantly influence peanut growth, yield, or yield components. However, nutrient management significantly affected nodule number and non-marketable pod yield. These findings suggest that increasing planting density or applying additional fertilizers does not necessarily improve peanut productivity or profitability under the tested conditions.

Abstract

Peanut farmers commonly sow two seeds per hill to improve stand establishment. This experiment evaluated how plant population and integrated nutrient management affect peanut growth, yield, yield components, and production profitability. It also examined whether the two factors interact and identified the treatment combination associated with favorable yield and economic performance. The study used a split-plot arrangement in a Randomized Complete Block Design (RCBD) with three replications. Planting density was assigned to the main plots: D_1, one plant per hill, and D_2, two plants per hill. The subplots consisted of six nutrient treatments: N0, no fertilizer; N_1, 45-45-45 kg ha^{-1} N-P_2O_5-K_2O; N_2, 5 t ha^{-1} poultry litter plus Hyfer Plus foliar fertilizer; N_3, 2.5 t ha^{-1} poultry litter plus 22.50-22.50-22.50 kg ha^{-1} N-P_2O_5-K_2O and foliar fertilizer; N4, 5 t ha^{-1} vermicompost plus Hyfer Plus foliar fertilizer; and N5, 2.5 t ha^{-1} vermicompost plus 22.50-22.50-22.50 kg ha^{-1} N-P_2O_5-K_2O and Hyfer Plus foliar fertilizer. Planting density did not significantly alter the measured agronomic or yield traits. Nutrient treatments significantly affected nodule number and non-marketable pod yield. Economically, D2 produced a net return of PHP62,480.00 with a 115% return on investment, while the unfertilized treatment (N_0) recorded PHP104,160.00 and 187% return on investment (ROI). These results suggest that peanut farmers should prioritize cost-effective production practices rather than increasing plant populations or fertilizer inputs without clear yield advantages. Future studies should investigate these treatment combinations across different soil types, growing seasons, and environmental conditions to validate their agronomic and economic benefits and identify sustainable nutrient management strategies for peanut production. © 2026 The Author(s)

Keywords: Inorganic fertilizer, Integrated nutrient applications, Organic fertilizer, Peanut, Planting density, Return on investment

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Introduction

Peanut (*Arachis hypogaea L.*), locally called "mani," is an herbaceous annual legume belonging to the family Leguminosae and originating in South America, where it has been cultivated for several millennia (Zheng et al., 2024; de Blas et al., 2025; Du et al., 2026). The crop has an indeterminate growth habit and produces small yellow flowers that are mainly self-pollinated. After fertilization, the ovary forms a peg that elongates downward into the soil, where the pod develops at its tip (Variath & Janilla, 2017); the protective outer structure is commonly referred to as the shell or hull (Kaiser & Ernst, 2012). Peanut is sometimes characterized as a "zero-waste" crop because many plant parts, including roots and hulls, can be put to useful purposes (Hashem et al., 2024). Its comparatively modest water requirement and relatively low carbon footprint also contribute to its agricultural value (Gerber & Roberts, 2024). Although botanically classified as a legume, peanut is commonly treated as a nut in culinary, nutritional, and commercial contexts (McElwain, 2019), and raw kernels have a characteristic beany flavor (Sun et al., 2024). Peanut is an economically important food legume in Philippines, where it is widely cultivated, particularly as a dry-season rotational crop following rice cultivation (Bernabe & Sugui, 2019). Worldwide, the crop is consumed directly in raw, roasted, or baked forms and is processed into products such as oil, butter, flour, confectionery ingredients, soups, and meat extenders (Machado et al., 2025). Peanut proteins also have functional properties such as solubility, foaming, water- and oil-binding, and emulsification, which increase their usefulness in food processing (Singh et al., 2021). In addition, peanut provides minerals, vitamins, and antioxidant compounds (Variath & Janilla, 2017).

Peanut is an important crop for both food supply and farm income, comparable in significance to other major crops such as corn and rice in local production systems (Sarcol & Cagasan 2016). Philippine peanut output declined slightly from 12.30 thousand metric tons in 2018

to 12.25 thousand metric tons in 2019, representing a 0.5% reduction (Philippine Statistics Authority, 2019). Improving productivity therefore remains an important production objective. One management factor that can influence crop performance is plant population. Plant density refers to the number of plants established within a specified land area (Wang et al., 2026), and selecting an appropriate density is a key agronomic decision (Assefa et al., 2016). Increasing plant population can raise total yield until a suitable optimum is reached; beyond that point, excessive density may reduce productivity because of stronger competition among plants (Ngouajio, 2011; Cordeiro et al., 2025).

Nutrient management is another major component of crop production (Amanullah et al., 2023). Organic materials alone may not always supply nutrients in amounts or proportions sufficient for optimum crop growth, which provides a rationale for integrating organic and inorganic nutrient sources (Imran, 2024; Haufiku et al., 2025; Hayat et al., 2026). Organic fertilizers can originate from plant residues, animal manures, bedding materials, and agricultural by-products, and their nutrient availability varies with the material used (Green, 2015; Araújo et al., 2026; Hambo et al., 2026). Applying organic inputs at effective rates can require considerable quantities of material and labor for collection and handling (Muscănescu, 2013). In contrast, inorganic fertilizers are manufactured with defined nutrient concentrations and can provide nutrients in readily available forms, although excessive application can increase the risk of nutrient losses and adverse effects on crop growth (Mowbot Team, 2018; Zhang et al., 2025; Siudak et al., 2026; Chojnacka & Mikulewicz, 2026). Although fertilizer combinations have been examined in many crops, comparatively limited information is available on their interaction with planting density in peanut production.

Beyond its influence on crop establishment, population arrangement regulates canopy architecture, radiation interception, biomass accumulation, and reproductive development (Wang et al., 2026). Closely spaced plants can establish faster ground coverage and intercept a greater proportion of incoming solar radiation during early vegetative development. Overcrowding may restrict lower-canopy illumination, accelerate interplant competition, and alter the balance between vegetative biomass production and reproductive allocation (Desmae et al., 2022; Cordeiro et al., 2025). Increasing the number of established plants within a given field area raises collective nutrient demand and may intensify competition within the root zone. Under nutrient-deficient conditions, densely established stands may experience stronger limitations in mineral acquisition, whereas adequate nutrient availability can support greater canopy development and dry matter accumulation (Darwish et al., 2020; Hu et al., 2023). However, additional nutrient inputs cannot necessarily compensate for unfavorable spatial arrangements, because restricted light penetration, moisture limitations, and competition may continue to constrain reproductive performance (Yılmaz & Jordan, 2022). This relationship suggests that population management and nutrient supply should be evaluated jointly rather than treated as completely independent production decisions (Paramasivan et al., 2024; Kalaria & Gediya, 2026). Despite these advances, the combined influence of population establishment and complementary nutrient regimes requires further investigation under locally relevant production environments. In particular, determining whether improved nutrient availability can enhance the productivity of different population arrangements, or whether excessive crowding reduces the effectiveness of nutrient inputs, remains an important agronomic question. Evaluating these factors simultaneously can provide information about treatment interactions, nutrient-use efficiency, reproductive development, and the economic feasibility of alternative management combinations. Accordingly, this study evaluated peanut growth and yield under different planting densities and integrated nutrient applications and determined the treatments associated with favorable peanut productivity.

Materials and Methods

The experiment occupied a 569.8 m² and was established as a split-plot experiment within a Randomized Complete Block Design (RCBD), with three replications. Planting density was assigned to the main plots at two levels: one plant per hill (D_1) and two plants per hill (D_2). Integrated nutrient treatments were allocated to the subplots: N_0, unfertilized control; N_1, inorganic fertilizer at 45-45-45 kg ha^{-1} N-P_2O_5-K_2O; N_2, 5 t ha^{-1} poultry litter plus Hyper Plus foliar fertilizer; N_3, 2.5 t ha^{-1} poultry litter plus 22.50-22.50-22.50 kg ha^{-1} N-P_2O_5-K_2O and Hyfer Plus foliar fertilizer; N_4, 5 t ha^{-1} vermicompost plus Hyfer Plus foliar fertilizer; and N5, 2.5 t ha^{-1} vermicompost plus 22.50-22.50-22.50 kg ha^{-1} N-P_2O_5-K_2O and Hyfer Plus foliar fertilizer. Each experimental plot measured 4 m × 3 m (12 m²), with 50 cm × 20 cm spacing. Replications were separated by a 1.0-m alley, and a 0.5-m gap was maintained between treatment plots to permit field operations and observations. Data were analyzed using the Statistical Tool for Agricultural Research (STAR), and treatment means were separated with the Honestly Significant Difference (HSD) test.

Soil chemical properties

Before planting, ten soil samples were taken at random from the experimental area at a depth of 0–20 cm. The samples were air-dried, pulverized, and passed through a 2.0-mm sieve before laboratory analysis at the Central Analytical Service Laboratory (CASL), Philippine Root Crops Research Center (PhilRootcrops), VSU, Visca, Baybay City, Leyte. Soil pH, organic matter, total nitrogen, available phosphorus, and exchangeable potassium were determined using the Modified Walkley–Black, Modified Kjeldahl, Modified Olsen, and ammonium acetate procedures, respectively (PCARR, 1980; Olsen & Sommer, 1982). After harvest, soil was again sampled from each treatment at the same 0–20 cm depth. Samples from each treatment plots were taken and the 3 replications were composited and analyzed for the same chemical properties to determine changes in soil condition following crop production.

Application of fertilizers

Organic fertilizers were placed uniformly in furrows and incorporated into the soil two weeks before planting. Treatments N_2 and N_4 received 5 t ha^{-1}, whereas N_3 and N_5 received 2.5 t ha^{-1}. The 14-14-14 complete fertilizer was subsequently placed in furrows 20 days after sowing according to the treatment rates of either 45-45-45 or 22.50-22.50-22.50 kg ha^{-1} N-P_2O_5-K_2O. A liquid foliar fertilizer was sprayed three times, at 25, 35, and 45 days after sowing, at 100 mL per 16 L of water using a knapsack sprayer. The quantities of organic and inorganic fertilizers applied to each 12.0-m² plot (Table 1). Seeds were directly sown at one and two seeds per hill according to the assigned planting-density in each treatment, targeting approximately 100,000–200,000 plants ha^{-1}. Rows were spaced 0.50 m apart and hills were 0.20 m apart. Additional seed was placed beside rows to replace missing hills caused by ants, mole crickets, and birds two days after sowing. Hilling-up was performed four weeks after sowing, before flowering, to support plant establishment, reduce weed growth, and avoid disturbing peg development. Spot weeding was carried out when necessary. The crop was harvested at approximately 110 days after sowing by uprooting the peanut plants.

Table 1 Amount of different fertilizers applied per treatment plot (12 m^2)

Treatments	Amount of fertilizer per plot (12 m^2)
N0: Control (No fertilizer applied)	0 kg
N1: 45-45-45 kg ha^{-1} N, P_2O_5, K_2O	0.386 kg plot^{-1} of complete fertilizer (side-dressed @ 20 DAS)
N2: 5 t ha-1 poultry litters + 1 L foliar fertilizer ha^{-1}	6 kg plot^{-1} poultry litters was applied 2 weeksbefore planting + 1.2 ml Hyfer Plus foliar fertilizer applied at 25, 35 and 45 DAS
N3: 2.5 t ha-1 poultry litters + 22.50 – 22.50 – 22.50 kg N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}	3 kg plot^{-1} poultry litters were applied 2 weeks before planting + 0.192 kg plot^{-1} N, P_2O_5, K_2O (20 DAS) + 1.2 ml Hyfer Plus foliar fertilizer applied at 25, 35 and 45 DAS
N4: 5 t ha^{-1} vermicompost + 1 L foliar fertilizer ha^{-1}	6 kg plot^{-1} vermicompost was applied 2 weeksbefore planting + 1.2 ml Hyfer Plus foliar fertilizer applied at 25, 35 and 45 DAS
N5: 2.5 t ha-1 vermicompost + 22.50 – 22.50 – 22.50 kg N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}	3 kg plot^{-1} vermicompost was applied 2 weeksbefore planting + 0.192 kg plot^{-1} N, P_2O_5, K_2O (10 DAS) + 1.2 ml Hyfer Plus foliar fertilizer applied at 25, 35 and 45 DAS

Data collection

Agronomic performance was assessed using days from sowing to emergence, flowering, and maturity; plant height (cm); number of nodules per plant; and fresh herbage yield (t ha^{-1}). Fresh herbage yield was computed using the formula below:

$$\text{Fresh herbage weight (t ha}^{-1}\text{)} = \frac{\text{Weight (kg plot}^{-1}\text{)}}{\text{Harvestable area (7.2 m}^2\text{)}} \times \frac{10{,}000 \text{ m}^2 \text{ ha}^{-1}}{1{,}000 \text{ kg t}^{-1}}$$

Leaf area index (LAI) was estimated from the following equation:

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area (TLA)}}{\text{Ground area (2500 cm}^2\text{)}}$$

Where TLA = $\sum$ (L × W × 0.552)

Yield and yield components

The yield assessment included pods per plant, seeds per pod, 1,000-seed weight (g), and marketable and non-marketable pod yields (t ha^{-1}). These variables were calculated using the equations presented below:

$$\text{Weight of marketable pods (t ha}^{-1}\text{)} = \frac{\text{Weight of marketable pods (kg plot}^{-1}\text{)}}{\text{Harvestable area (7.2 cm}^2\text{)}} \times \frac{10{,}000 \text{ m}^2 \text{ ha}^{-1}}{1{,}000 \text{ kg t}^{-1}}$$

Shelling recovery (%) was obtained using the following equation:

$$\text{\% Shelling recovery (t ha}^{-1}\text{)} = \frac{\text{Weight of seeds (g)}}{\text{Weight of unshelled pod samples (500 g)}} \times 100$$

Seed yield (t ha^{-1}) was estimated by multiplying total pod yield per hectare by the shelling recovery (%) recorded for the corresponding treatment plot:

$$\text{Seed yield (t ha}^{-1}\text{)} = \frac{\text{Pod yield (t ha}^{-1}\text{)} \times \text{\% Shelling recovery}}{100}$$

Profitability analysis

Profitability analysis was taken by recording all the expenses incurred of the study including labor or land preparation to harvesting and processing, materials and inputs deducted to the gross sales in per hectare basis. Profitability analysis was calculated using the following formula:

Net profit = Gross income - Total cost of production

Return on investment (ROI) was monitored to know the return of investment per peso invested. This was measured using the following formula:

$$\text{Return on investment (ROI) \%} = \frac{\text{Net profit}}{\text{Cost of production}} \times 100$$

Statistical analysis

All observations were subjected to analysis of variance using Statistical Tool for Agricultural Research (STAR), version 2.0.1. Where treatment effects were significant, means were compared using the Honestly Significant Difference (HSD) test.

Results and Discussion

Soil chemical properties

The chemical characteristics of the soil before the experiment and after peanut harvest under different planting-density and nutrient treatments are shown in Table 2. The initial soil had a pH of 6.13, 1.64% organic matter, 0.13% total N, 37.58 mg kg^{-1} available P, and 0.38 me 100 g^{-1} exchangeable K. Based on the interpretation of Landon (1991), the soil was slightly acidic and contained moderate levels of organic matter, total nitrogen, and exchangeable potassium, whereas available phosphorus was relatively high. Under D_1, the N_2 treatment (5 t ha^{-1} poultry litter plus 1 L foliar fertilizer ha^{-1}) resulted in higher final pH, available P, and exchangeable K than the initial soil values, whereas increases in organic matter and total N were not observed. The reduction in total N may reflect plant uptake during vegetative growth and nutrient removal with the harvested crop (Tomada & Cagasan, 2020). For several other treatments, pH, organic matter, total N, and available P remained broadly comparable with the initial values. In contrast, exchangeable K generally increased after treatment application. This may be associated with the gradual release of nutrients from organic materials or the presence of potassium in soil mineral fractions that are not immediately available to plants (Kaiser & Rosen, 2018).

Table 2 Soil chemical properties before and after harvest of peanut as influenced by plant density and integrated nutrient applications

Treatments	pH	OM (%)	Total N (%)	Available P (mg kg^{-1})	Exch K (me 100g^{-1})
Initial soil analysis	6.13	1.64	0.13	37.580	0.38
Planting density					
D1 = 1 plant per hill					
N0	6.20	1.589	0.156	15.320	0.73
N1	6.24	1.571	0.141	18.200	0.78
N2	6.56	1.676	0.138	40.360	1.00
N3	6.31	0.599	0.150	22.820	0.71
N4	6.29	1.642	0.138	21.540	0.82
N5	6.21	1.723	0.135	20.220	0.81
D2 = 2 plants per hill					
N0	6.03	1.627	0.141	17.620	0.80
N1	6.09	1.901	0.159	22.720	0.82
N2	6.65	1.802	0.153	37.200	1.03
N3	6.36	1.560	0.182	22.140	0.88
N4	6.15	1.705	0.141	19.580	0.77
N5	6.26	1.407	0.127	17.700	0.75

N0 = No fertilizer applied; N1 = 45-45-45 kg ha^{-1}N, P_2O_5, K_2O; N2 = 5 t ha^{-1} poultry litters + 1 L foliar fertilizer ha^{-1}; N3 = 2.5 t ha^{-1} poultry litters + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; N4 = 5 t ha^{-1} Vermicompost + 1 L foliar fertilizer ha^{-1}; N5 = 2.5 t ha^{-1} vermicompost + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; OM = Organic matter; N = Total nitrogen; P = Available phosphorus; K = Exchangeable potassium

Agronomic characteristics

Neither planting density nor integrated nutrient treatment produced a significant effect on the number of days required for peanut plants to emerge, flower, and reach maturity, and their interaction was also non-significant (Table 3). The similarity among treatments may reflect the relatively synchronized developmental pattern of the peanut crop from emergence through maturity. Comparable results were reported by Guriqbal et al. (2011), who observed that flowering initiation and maturity were not altered by planting density in peanut. Buttery (1969) also noted that higher plant populations can reduce the proportion of flowers that ultimately develop into mature pods. The measurements of plant height, fresh herbage yield, nodule number, and leaf area index are presented in Table 4.

Planting density did not significantly change plant height, fresh herbage yield, nodule number, or leaf area index. This agrees with Halilou et al. (2016), who found that the relationships among leaf area, plant height, and fresh herbage production were not substantially altered by sowing density. Integrated nutrient management likewise had no significant effect on plant height, fresh herbage

yield, or LAI, but it significantly influenced nodule number. The largest nodule count was recorded with N2, consisting of 5 t ha^{-1} poultry litter plus 1 L foliar fertilizer ha^{-1}, whereas N5, which combined 2.5 t ha^{-1} vermicompost with 22.50-22.50-22.50 kg ha^{-1} N-P_2O_5-K_2O and foliar fertilizer, produced the lowest value. Arangote et al. (2019) reported that poultry litter can enhance nodulation, while Saliga and Skelly (2013) associated poultry manure with substantial supplies of nitrogen, phosphorus, potassium, and organic matter. Foliar nutrient supplementation may also influence nodule development (Bellaloui et al., 2013). Despite the numerical differences, N0, N1, N3, N4, and N5 were statistically comparable with N2 for nodule production. These results are consistent with evidence that combining organic and inorganic nutrient sources can support peanut nodulation (Argaw, 2017). No significant planting-density × nutrient-treatment interaction was detected for plant height, fresh herbage yield, nodule number, or LAI. The absence of interaction may be related to the relatively favorable and stable soil conditions at the experimental site.

Table 3 Number of days from sowing to emergence, from sowing to flowering and from sowing to maturity of peanut as influenced by planting density and integrated nutrient applications

Treatments	Number of days from sowing to		
	Emergence	Flowering	Maturity
Planting density (PD)			
D1 = 1 plant per hill	2.50	29.28	89.28
D2 = 2 plants per hill	2.39	29.33	89.39
F test	ns	ns	ns
Integrated nutrient applications (INA)			
N0	2.67	29.67	89.67
N1	2.33	29.17	89.00
N2	2.50	29.17	89.33
N3	2.33	29.50	89.33
N4	2.33	29.17	89.50
N5	2.50	29.17	89.17
F test	ns	ns	ns
PD × INA	ns	ns	ns
C.V. (a) %	13.64	1.14	0.37
C.V. (b) %	25.14	3.01	0.97

N0 = No fertilizer applied; N1 = 45-45-45 kg ha^{-1}N, P_2O_5, K_2O; N2 = 5 t ha^{-1} poultry litters + 1 L foliar fertilizer ha^{-1}; N3 = 2.5 t ha^{-1} poultry litters + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; N4 = 5 t ha^{-1} vermicompost + 1 L foliar fertilizer ha^{-1}; N5 = 2.5 t ha^{-1} vermicompost + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; C.V. (a) % = Coefficient of variation for Factor A (Planting density); C.V. (b) % = Coefficient of variation for Factor B (Nutrient treatment)

Table 4 Plant height (cm), fresh herbage yield (t ha^{-1}), number of nodules plant$^{-1,}$ and leaf area index (LAI) of peanut as influenced by planting density and integrated nutrient applications

Treatments	Plant height (cm)	Fresh herbage yield (t ha^{-1})	Number of nodules plant^{-1}	Leaf area index
Planting density (PD)				
D1 = 1 plant per hill	73.80	11.81	941.7	1.52
D2 = 2 plants per hill	77.28	10.52	1028.3	1.61
F test	ns	ns	ns	ns
Integrated nutrient applications (INA)				
N0	74.15	11.05	910.3ab	1.42
N1	76.30	11.68	942.7ab	1.88
N2	77.72	10.59	1303.7a	1.75
N3	77.06	12.93	982.5ab	1.55
N4	75.91	11.84	930.0ab	1.43
N5	71.99	9.65	841.0b	1.36
F test	ns	ns	*	ns
PD × INA	ns	ns	ns	ns
C.V. (a) %	22.04	13.33	0.45	12.51
C.V. (b) %	14.16	14.01	0.87	4.26

N0 = No fertilizer applied; N1 = 45-45-45 kg ha^{-1}N, P_2O_5, K_2O; N2 = 5 t ha^{-1} poultry litters + 1 L foliar fertilizer ha^{-1}; N3 = 2.5 t ha^{-1} poultry litters + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; N4 = 5 t ha^{-1} vermicompost + 1 L foliar fertilizer ha^{-1}; N5 = 2.5 t ha^{-1} vermicompost + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; C.V. (a) % = Coefficient of variation for Factor A (Planting density); C.V. (b) % = Coefficient of variation for Factor B (Nutrient treatment)

Yield and yield components

The effects of planting density and nutrient treatment on pods per plant, seeds per plant, and 1,000-seed weight are shown in Table 5. None of these variables differed significantly between the two planting densities. The present results differ from those of Bakal et al. (2020), who reported reductions in pod number, individual-plant weight, and 100-seed weight as plant density increased, although shelling percentage and pod and kernel yields increased. In the current experiment, the nutrient treatments also produced no significant differences in pods per plant, seeds per plant, or 1,000-seed weight. Furthermore, no significant interaction between planting density and nutrient application was detected for any of these yield components.

The lack of significant differences in pod and seed production may have been associated with the heavy rainfall experienced during April, which likely interfered with peg penetration and pod development. Reports summarized by The Peanut Grower (2020) indicate that prolonged wet conditions can contribute to pod deterioration and rot. Depending on the causal organism and environmental conditions, affected pods may develop discoloration and decay, while weakened pegs can leave pods in the soil during harvest. Table 6 shows marketable, non-marketable, and total pod yields under the two planting densities and six nutrient treatments. Planting density and nutrient application did not significantly influence total pod yield, although non-marketable pod yield differed among nutrient treatments. The highest non-marketable yield occurred under the unfertilized control (N0), whereas N2, consisting of 5 t ha^{-1} poultry litter plus 1 L foliar fertilizer ha^{-1}, produced the lowest value and was statistically comparable with N1, N3, N4, and N5. This pattern differs from the general relationship reported by Ngouajio et al. (2011), in which increasing plant density can increase total yield until excessive population density begins to reduce productivity.

The absence of a significant planting-density effect on pod yield may be partly explained by the prolonged and heavy rainfall that saturated the soil during pegging and pod filling. Waterlogged conditions persisted for several days and were associated with peg browning, pod rot, and fungal damage. Nyvall (2013) described extensive soaking of peanut pegs as a condition that can promote rotting and blackened peg tips, while Ginzberg et al. (2010) emphasized the importance of maintaining suitable soil moisture in the pod-development zone during the final weeks of crop growth. The interaction between planting density and nutrient treatment was also non-significant for marketable pod yield, non-marketable pod yield, and total pod yield. Feng et al. (2013) reported that single-seed sowing can perform similarly to the commonly used double-seed practice and may provide advantages through improved root development, root-to-shoot balance, and productivity per plant. Table 7 presents shelling recovery, seed yield and harvest index. Planting density did not significantly alter any of these variables. The relatively favorable soil organic matter and macronutrient status shown in the soil analysis may have contributed to the similarity among treatments. Integrated nutrient applications also failed to produce significant differences in shelling recovery, seed yield, or harvest index, and no significant interaction between planting density and nutrient application was detected. Zhao et al. (2017) similarly reported comparable harvest indices for peanuts established with single- and double-seed planting patterns.

Table 5 Number of pods per plant, number of seeds per plant, and weight (g) 1,000 seeds of peanut as influenced by planting density and integrated nutrient applications

Treatments	Number of pods per plant	Number of seeds per pod	Weight of 1000 seeds (g)
Planting density (PD)			
D1 = 1 plant per hill	26.88	1.91	376.32
D2 = 2 plants per hill	28.43	1.99	401.85
F test	ns	ns	ns
Integrated nutrient applications (INA)			
N0	24.95	1.94	403.81
N1	28.13	1.91	354.84
N2	27.22	1.94	386.83
N3	30.85	1.85	365.13
N4	26.83	2.03	370.08
N5	27.97	2.03	453.84
F test	ns	ns	ns
PD × INA	ns	ns	ns
C.V. (a) %	32.09	8.77	7.97
C.V. (b) %	14.31	6.85	19.65

N0 = No fertilizer applied; N1 = 45-45-45 kg ha^{-1}N, P_2O_5, K_2O; N2 = 5 t ha^{-1} poultry litters + 1 L foliar fertilizer ha^{-1}; N3 = 2.5 t ha^{-1} poultry litters + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; N4 = 5 t ha^{-1} vermicompost + 1 L foliar fertilizer ha^{-1}; N5 = 2.5 t ha^{-1} vermicompost + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; C.V. (a) % = Coefficient of variation for Factor A (Planting density); C.V. (b) % = Coefficient of variation for Factor B (Nutrient treatment)

Table 6 Weight of marketable and non-marketable pod yield (t ha^{-1}) and total pod yield (t ha^{-1}) of peanuts as influenced by planting density and integrated nutrient applications

Treatments	WMPY (t ha^{-1})	WNMPY (t ha^{-1})	Total pod yield (t ha^{-1})
Planting density (PD)			
D1 = 1 plant per hill	1.41	0.23	1.64
D2 = 2 plants per hill	1.42	0.40	1.82
F test	ns	ns	ns
Integrated nutrient applications (INA)			
N0	1.37	0.43a	1.80
N1	1.33	0.37ab	1.70
N2	1.57	0.16b	1.73
N3	1.48	0.28ab	1.76
N4	1.36	0.36ab	1.72
N5	1.38	0.28ab	1.66
F test	ns	**	ns
PD × INA	ns	ns	ns
C.V. (a) %	1.42	17.04	32.45
C.V. (b) %	1.41	38.80	15.52

WMPY = Weight of marketable pod yield (t ha^{-1}); WNMPY = Weight of non-marketable pod yield (t ha^{-1}); TPY = Total pod yield (t ha^{-1}); N0 = No fertilizer applied; N1 = 45-45-45 kg ha^{-1}N, P_2O_5, K_2O; N2 = 5 t ha^{-1} poultry litters + 1 L foliar fertilizer ha^{-1}; N3 = 2.5 t ha^{-1} poultry litters + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; N4 = 5 t ha^{-1} vermicompost + 1 L foliar fertilizer ha^{-1}; N5 = 2.5 t ha^{-1} vermicompost + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; C.V. (a) % = Coefficient of variation for Factor A (Planting density); C.V. (b) % = Coefficient of variation for Factor B (Nutrient treatment)

Table 7 Percent shelling recovery (%), seed yield (t ha^{-1}) and harvest index (HI) of peanuts as influenced by planting density and integrated nutrient applications

Treatments	Percent shelling recovery (%)	Seed yield (t ha^{-1})	Harvest index
Planting density (PD)			
D1 = 1 plant per hill	61.17	1.02	0.42
D2 = 2 plants per hill	64.11	1.17	0.40
F test	ns	ns	ns
Integrated nutrient applications (INA)			
N0	63.83	1.16	0.40
N1	63.17	1.07	0.42
N2	65.67	1.16	0.41
N3	62.83	1.13	0.41
N4	58.83	1.01	0.41
N5	61.50	1.02	0.41
F test	ns	ns	ns
PD × INA	ns	ns	ns
C.V. (a) %	2.12	32.98	9.71
C.V. (b) %	3.41	26.55	12.77

N0 = No fertilizer applied; N1 = 45-45-45 kg ha^{-1}N, P_2O_5, K_2O; N2 = 5 t ha^{-1} poultry litters + 1 L foliar fertilizer ha^{-1}; N3 = 2.5 t ha^{-1} poultry litters + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; N4 = 5 t ha^{-1} vermicompost + 1 L foliar fertilizer ha^{-1}; N5 = 2.5 t ha^{-1} vermicompost + 22.50 – 22.50 – 22.50 kg ha^{-1} N, P_2O_5, K_2O + 1 L foliar fertilizer ha^{-1}; C.V. (a) % = Coefficient of variation for Factor A (Planting density); C.V. (b) % = Coefficient of variation for Factor B (Nutrient treatment)

Conclusion

The study concluded that changing planting density from one to two plants per hill did not significantly alter the measured agronomic traits, yield components, or peanut yield. The two densities (1 and 2 seedlings per hill) therefore produced statistically comparable crop performance under the conditions of the experiment. Integrated nutrient treatments likewise had no significant effect on most growth and yield variables, although they significantly affected nodule number and non-marketable pod yield. No significant interaction between planting density and nutrient application was detected for the measured growth and yield traits. From an economic perspective, D_2 (two plants per hill) generated a net return of PHP 62,480.00 and an ROI of 115%, compared with an ROI of 92% for D_1 (one plant per hill). Among the nutrient treatments, N_0 (no fertilizer) recorded a net return of PHP 104,160.00 and an ROI of 187%, whereas N4 (5 t ha^{-1} vermicompost plus 1 L foliar fertilizer ha^{-1}) resulted in a net loss of PHP 16,463.00 and an ROI of −14%.

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