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STAGE-SPECIFIC BLACK SOYBEAN RESPONSES TO QUAIL MANURE AND SP-36 FERTILIZATION

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ABSTRACT

Black soybean productivity depends on nutrient management that can support both soil fertility and reproductive development, yet the combined response to animal manure and mineral phosphorus is not always expressed uniformly across growth stages. This study evaluated the individual and interactive effects of quail manure and SP-36 fertilizer on black soybean (Glycine max (L.) Merr.) under polybag cultivation. A 3 x 3 factorial randomized block design with three replications was conducted in Medan Deli, North Sumatra, from February to June 2026. Quail manure was applied at 0, 320, and 480 g polybag-1, while SP-36 was applied at 0, 3.6, and 4.0 g polybag-1. Plant height, stem diameter, branch number, flowering time, final soil pH, post-harvest soil phosphorus, and seed weight per plant were evaluated by analysis of variance followed by Duncan's Multiple Range Test at 5%. Most vegetative traits were not significantly affected. SP-36 significantly increased stem diameter at 4 weeks after planting, with 4.0 g polybag-1 producing 4.35 mm. Both factors significantly increased post-harvest soil phosphorus, reaching 13.13 mg kg-1 under 480 g manure and 14.91 mg kg-1 under 4.0 g SP-36. The clearest response occurred in seed weight: both main effects and their interaction were highly significant, and P2S2 produced 71.48 g plant-1 compared with 11.18 g plant-1 in the unfertilized control. These findings reveal a stage-specific response in which co-fertilization primarily strengthened reproductive output rather than uniformly stimulating vegetative growth.

Keywords: Black soybean; Quail manure; Phosphorus fertilization; Seed yield; Nutrient synchronization.

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INTRODUCTION

Black soybean (Glycine max (L.) Merr.) is a nutritionally and economically important soybean type in Indonesia. Its dark seed coat contains anthocyanins and other phenolic compounds that contribute to antioxidant activity, while Indonesian black-soybean breeding has increasingly emphasized yield stability and adaptation across environments (Malenčić et al., 2012; Susanto et al., 2023). For crop management, however, genetic potential can only be expressed when soil nutrient supply is synchronized with crop demand. Phosphorus (P) is especially important in soybean because it supports root growth, biological nitrogen fixation, energy transfer, reproductive development, and seed filling. Recent field calibration work further shows that soybean response to fertilizer P depends strongly on soil-test P and the production environment, so blanket application rates can be inefficient (Parvej et al., 2026).

Phosphorus management is challenging because soil P is relatively immobile and readily interacts with mineral surfaces. Fertilizer placement, soil buffering, root architecture, and the spatial distribution of available P determine how much applied P is actually acquired by plants (Havlin et al., 2014; Williams et al., 2022). Long-term work with soybean also demonstrates that P distribution within the soil profile influences root proliferation, P acquisition, and grain yield (Nunes et al., 2021). In Indonesia, increasing SP-36 rates has been associated with greater soybean biomass and seed yield, although the magnitude of response varies with dose and accompanying nutrient management (Harahap et al., 2024). These findings suggest that P fertilization should be evaluated not only through early vegetative growth but also through reproductive yield and post-harvest soil nutrient status.

Organic amendments provide a complementary pathway for nutrient management. Livestock manure supplies nutrients and organic carbon, can improve soil physical and biological properties, and may alter P retention and release. Reviews of manure-derived fertilizers emphasize that agronomic P efficiency depends on material characteristics and soil reactions rather than on total P content alone (Persson & Rueda-Ayala, 2022). Quail manure is of particular interest because it is nutrient-dense and locally available in areas with intensive quail production. Studies in different crops have reported positive growth or yield responses to quail manure, although effective rates and response traits vary by crop and production system (Honorato et al., 2024; Latif et al., 2023; Parna et al., 2025; Ramadani & Baharuddin, 2025). This variability makes it inappropriate to assume that organic and mineral fertilizers will automatically produce additive effects on every plant trait.

A more informative question is whether organic manure and mineral P modify different stages of crop performance. Soybean studies show that P sources and P-solubilizing strategies can increase seed weight and yield even when some vegetative traits respond weakly (Goudanavar et al., 2021), while soil chemical constraints and biological interactions can substantially change the apparent benefit of applied P (Adeyemi et al., 2021; Dabesa & Tana, 2021). In black soybean specifically, phosphorus dosage has been shown to influence selected growth and yield components, and interactions with biological inputs may appear only in particular traits (Tyas et al., 2025). Therefore, separating vegetative, soil, and reproductive responses is essential for identifying the actual agronomic value of a fertilizer combination.

The present study examined quail manure and SP-36 in a factorial design on black soybean cv. Malika. The novelty of the article lies in interpreting the treatment response as a stage-specific pattern rather than assuming a uniform growth-promoting effect: the same fertilizer combination that produced limited changes in plant height, branching, flowering, and final soil pH generated strong differences in post-harvest soil P and, most importantly, seed weight. The study aimed to determine (1) the main effect of quail manure, (2) the main effect of SP-36 fertilizer, and (3) their interaction on black soybean growth, soil response, and seed production.

RESEARCH METHODS

The experiment was conducted from February to June 2026 in Mabar, Medan Deli District, North Sumatra, Indonesia, at approximately 26 m above sea level. Black soybean cv. Malika was grown in 35 x 35 cm polybags containing topsoil. The materials used in the field included black-soybean seed, quail manure, SP-36 fertilizer, rice-husk charcoal, and crop-protection inputs. SP-36 contained approximately 36% P2O5 according to the product specification reported in the thesis.

A factorial randomized block design was used with two factors and three replications. Factor P was quail manure at P0 = 0 g polybag-1, P1 = 320 g polybag-1 (equivalent to 20 t ha-1), and P2 = 480 g polybag-1 (30 t ha-1). Factor S was SP-36 at S0 = 0 g polybag-1, S1 = 3.6 g polybag-1 (225 kg ha-

1), and S2 = 4.0 g polybag-1 (250 kg ha-1). The 3 x 3 combination generated nine treatments and 27 experimental plots. Each plot contained five plants, three of which were sampled, giving 135 plants in total and 81 sample plants. Factorial randomized block designs are commonly used to separate main and interaction effects in agronomic studies published in Algebra, including experiments on beet, cherry tomato, and coconut seedlings (Hasibuan et al., 2024; Revina Azhari et al., 2025; Milala et al., 2026).

Quail manure was incorporated into the topsoil during preparation of the planting medium. SP-36 was applied in two split applications: the first at one week after planting (WAP) and the second at three WAP, before flowering. Routine maintenance included daily watering, manual weed control, and crop protection when required. Plant height, stem diameter, and number of primary branches were recorded at 2, 4, and 6 WAP. Flowering time was recorded when plants in each plot initiated flowering. Final soil pH was measured after treatment, and post-harvest soil samples were composited by treatment for phosphorus analysis. Seed production was expressed as seed weight per plant (g).

The original thesis used Bray extraction for the initial soil-P determination and a different laboratory workflow for the post-harvest analysis. Because the baseline and final P values were not generated by an identical analytical procedure, this article does not interpret their numerical difference as a temporal depletion or accumulation rate. Instead, the inferential analysis focuses on treatment differences in post-harvest soil P. This approach avoids attributing analytical-method differences to fertilizer effects.

Data were analyzed using the linear model Yijk = mu + rho_i + alpha_j + beta_k + (alpha beta)_jk + epsilon_ijk, where rho_i represents block effects, alpha_j the quail-manure effect, beta_k the SP-36 effect, and (alpha beta)_jk their interaction. Analysis of variance was conducted for each response variable. When the F-test indicated significance, treatment means were separated using Duncan's Multiple Range Test (DMRT) at alpha = 0.05. Results are reported as non-significant (ns), significant (*) or highly significant (**), following the significance classifications in the thesis ANOVA tables.

Table 1. Factorial treatment structure used in the experiment

Factor	Level	Field-equivalent dose	Polybag dose
Quail manure	P0	0 t ha-1	0 g
	P1	20 t ha-1	320 g
	P2	30 t ha-1	480 g
SP-36	S0	0 kg ha-1	0 g
	S1	225 kg ha-1	3.6 g
	S2	250 kg ha-1	4.0 g

Note. Nine treatment combinations were arranged in three blocks, producing 27 experimental plots.

RESULTS AND DISCUSSION

Overall Response Pattern

The treatment response was strongly trait-dependent. Plant height at 2, 4, and 6 WAP; branch number at 2, 4, and 6 WAP; flowering time; and final soil pH were not significantly affected by quail manure, SP-36, or their interaction. Stem diameter was also generally stable, except at 4 WAP, when the SP-36 main effect was significant. In contrast, post-harvest soil P responded highly significantly to both fertilizer factors, and seed weight per plant showed the strongest response, with highly significant main effects and a highly significant P x S interaction (Table 2). This pattern is central to the interpretation of the experiment: fertilizer effects were more evident in nutrient status and reproductive output than in broad vegetative expansion.

Table 2. Summary of treatment significance across measured variables

Response variable	Quail manure (P)	SP-36 (S)	P x S
Plant height, 2 WAP	ns	ns	ns
Plant height, 4 WAP	ns	ns	ns
Plant height, 6 WAP	ns	ns	ns
Stem diameter, 2 WAP	ns	ns	ns
Stem diameter, 4 WAP	ns	*	ns
Stem diameter, 6 WAP	ns	ns	ns
Primary branches, 2-6 WAP	ns	ns	ns
Flowering time	ns	ns	ns

Final soil pH	ns	ns	ns
Post-harvest soil P	**	**	ns
Seed weight per plant	**	**	**

*Note. ns = non-significant; * = significant; ** = highly significant according to the ANOVA classifications reported in the thesis. WAP = weeks after planting.*

Stem Diameter and Post-Harvest Soil Phosphorus

At 4 WAP, mean stem diameter increased from 3.74 mm under S0 to 4.06 mm under S1 and 4.35 mm under S2. The difference between S2 and S0 was significant at the 5% level, whereas quail-manure treatments did not significantly change stem diameter. By 6 WAP, the SP-36 effect was no longer significant. A temporary stem-diameter response is biologically plausible because P availability can support early root function and carbon-energy metabolism, but later stem dimensions may become more strongly regulated by genotype, canopy competition, water status, and other nutrients. Similar non-uniform responses across growth stages are common in factorial agronomic studies, where a treatment can affect a specific observation period without producing a persistent effect on all later measurements (Revina Azhari et al., 2025).

Both quail manure and SP-36 produced clear differences in post-harvest soil P. For the manure factor, mean soil P increased across P0, P1, and P2 from 11.81 to 12.35 and 13.13 mg kg-1, respectively. For SP-36, the increase was larger: S0, S1, and S2 produced 8.93, 13.46, and 14.91 mg kg-1, respectively (Table 3). The P x S interaction for this variable was not significant, indicating that the factors changed post-harvest soil P largely through separable main effects. This agrees with the general understanding that mineral P provides a directly soluble P source, whereas organic amendments may influence retention, mineralization, microbial activity, and sorption reactions (Persson & Rueda-Ayala, 2022; Williams et al., 2022).

Table 3. Selected main-effect means for significant response variables

Treatment	Stem diameter at 4 WAP (mm)	Post-harvest soil P (mg kg-1)	Seed weight (g plant-1)
P0	4.16	11.81 c	28.80 c
P1	4.00	12.35 b	43.32 b
P2	3.99	13.13 a	60.85 a
S0	3.74 b	8.93 c	29.24 c
S1	4.06 ab	13.46 b	43.70 b
S2	4.35 a	14.91 a	60.03 a

Note. Within each fertilizer factor and response variable, means followed by different letters differ at the 5% level by DMRT. Stem-diameter means for P0-P2 were not significantly different.

Seed-Weight Interaction and Stage-Specific Response

The reproductive response was substantially stronger than the vegetative response. Quail manure increased mean seed weight from 28.80 g plant-1 in P0 to 43.32 g plant-1 in P1 and 60.85 g plant-1 in P2. SP-36 increased mean seed weight from 29.24 g plant-1 in S0 to 43.70 g plant-1 in S1 and 60.03 g plant-1 in S2. Relative to their respective controls, the highest manure and SP-36 levels increased mean seed weight by approximately 111% and 105%. These results are consistent with soybean studies in which improved P supply increased seed weight or grain yield through better reproductive nutrient support (Goudanavar et al., 2021; Harahap et al., 2024). They also support the principle that the agronomic value of P should be assessed at yield formation rather than inferred solely from early plant height or branch number (Morales et al., 2023; Parvej et al., 2026).

Most importantly, seed weight displayed a highly significant interaction between quail manure and SP-36. The unfertilized combination P0S0 produced 11.18 g plant-1, whereas P2S2 produced 71.48 g plant-1, equivalent to an approximately 539% increase over P0S0. The interaction means followed a clear upward response overall, but the pattern was not simply proportional at every dose (Table 4 and Figure 1). For example, the addition of SP-36 at S2 markedly improved P0 seed weight, while the manure response under S0 also increased strongly from P0 to P2. This statistical interaction indicates that the reproductive effect of one input depended on the level of the other input, even though such dependence was not detected for most vegetative traits.

This result provides a more informative interpretation than a general statement that the fertilizer combination had no interaction. The detailed ANOVA for seed weight indicates a significant P x S effect, so the reproductive endpoint should be treated separately from traits where the interaction was genuinely non-significant. Agronomically, the result is compatible with complementary nutrient

functions: manure can contribute nutrients and improve the soil biological and physicochemical environment, while SP-36 supplies readily available P during critical stages. Quail-manure studies in other crops similarly show that yield-related traits may respond more strongly than some vegetative traits (Parna et al., 2025; Ramadani & Baharuddin, 2025), and work with fermented quail manure confirms that dose strongly influences nutrient-mediated biomass responses (Latif et al., 2023).

Table 4. Interaction means for seed weight per plant

Quail manure	S0: 0 g SP-36	S1: 3.6 g SP-36	S2: 4.0 g SP-36
P0: 0 g	11.18 f	24.48 e	50.73 cd
P1: 320 g	26.43 e	45.67 d	57.87 bc
P2: 480 g	50.11 cd	60.96 b	71.48 a

Note. Means followed by different letters differ at the 5% level by DMRT.

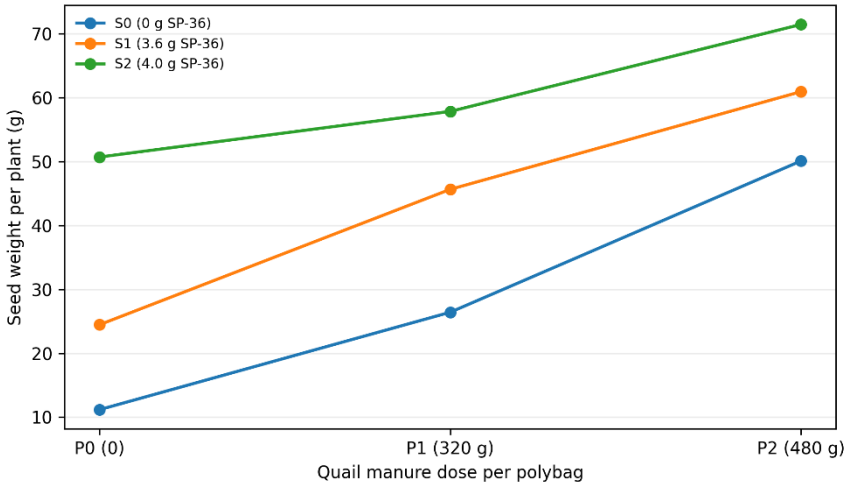


Figure 1. Seed-weight response to the interaction between quail manure and SP-36 fertilizer.

The absence of significant changes in plant height and branch number should not be interpreted as treatment failure. Soybean partitioning changes substantially from vegetative growth to pod and seed filling, and P demand is closely associated with reproductive metabolism and assimilate transfer. Studies under P-deficient conditions have shown that improved P acquisition can raise soybean grain yield and P uptake even when the response of individual vegetative variables is not uniform (Adeyemi et al., 2021; Dabesa & Tana, 2021). In black soybean, Tyas et al. (2025) likewise reported that phosphorus dosage affected selected growth variables rather than every measured trait. Thus, the present experiment suggests a decoupling between visible vegetative expansion and final reproductive benefit.

From a nutrient-management perspective, the highest treatment combination (480 g quail manure plus 4.0 g SP-36 per polybag) was the most productive within the tested range. However, this result should not be converted directly into a field recommendation without verification. Polybag conditions restrict root volume, fertilizer placement, and nutrient movement compared with field soil. In addition, fertilizer P recommendations should be calibrated against soil-test P and yield response to avoid unnecessary P accumulation or inefficient input use (Morales et al., 2023; Parvej et al., 2026). Future field trials should therefore test the same integrated nutrient concept across soil-P classes and seasons, and should use identical analytical methods for pre- and post-experiment soil P.

The study contributes a practical and conceptual point to black-soybean fertilization. Practically, it identifies a combination that substantially increased seed weight under the tested conditions. Conceptually, it demonstrates that fertilizer evaluation can be misleading when conclusions are based mainly on vegetative traits or when all endpoints are summarized under a single interaction statement. The combination of organic and mineral nutrient sources may express its clearest benefit at a specific developmental stage or yield component. This stage-specific perspective is consistent with the broader literature on P acquisition, root-soil interactions, and integrated nutrient management (Nunes et al., 2021; Honorato et al., 2024).

CONCLUSIONS

Quail manure and SP-36 did not uniformly stimulate all black-soybean growth traits. Plant height, branch number, flowering time, and final soil pH were largely unchanged, while SP-36 significantly increased stem diameter only at 4 WAP. Both quail manure and SP-36 significantly increased post-

harvest soil phosphorus. The most important finding was the reproductive response: quail manure and SP-36 each increased seed weight, and their interaction was highly significant. The P2S2 combination (480 g quail manure plus 4.0 g SP-36 per polybag) produced the highest seed weight, 71.48 g plant-1, compared with 11.18 g plant-1 in P0S0. Therefore, the novelty of the study is the identification of a stage-specific fertilization response in which integrated organic-mineral nutrition was expressed more strongly in reproductive output than in vegetative growth. Field-scale validation across different soil-P conditions is recommended before translating the polybag doses into farm recommendations.

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