

Optimization of Humic Acid and Vermicompost on the Growth and Yield of Soybean (*Glycine max* (L.) Merrill)

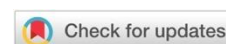
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Abstract:

National soybean productivity tends to decline each year due to land degradation caused by excessive use of synthetic fertilizers. This dependence can be reduced by applying humic acid and vermicompost. This research aims to examine the effect of humic acid and vermicompost on soybean growth and yield. The research was conducted from August to November 2024 at the Jember State Polytechnic research site, using a factorial Randomized Block Design (RAK) with two factors and three replications. The first factor is the dosage of humic acid (10, 20, 25, and 30 kg/ha), and the second factor is the dosage of vermicompost (15 and 20 tons/ha). Data were analyzed using ANOVA, followed by the DMRT test at a 5% or 1% level. The research results showed that the combination of 25 kg/ha humic acid and 20 tons/ha vermicompost significantly affected the number of root nodules (7.17 pieces). Separately, the application of 20 kg/ha humic acid significantly affected the fresh pod weight per sample (2.02 g) and the fresh pod weight per plot (124.89 g). Vermicompost at 20 tons/ha also had a significant effect on plant height (26.69 cm). These findings indicate that humic acid and vermicompost have the potential to improve soil fertility and nutrient availability for soybean plants.



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INTRODUCTION

The demand for soybeans in Indonesia is increasing in line with population growth. Nevertheless, the national demand for soybeans has not been met because domestic production is still insufficient. According to the BPS plot survey results (2024), soybean productivity in Indonesia in 2023 averaged around 14.56 quintals per hectare. This average figure decreased from the previous year, which was 15.43 quintals/ha (BPS, 2023). Therefore, efforts are needed to increase domestic soybean productivity, which is expected to stabilize soybean prices.

Farmers' habit of increasing crop productivity through excessive use of inorganic fertilizers results in less fertile land, making it more difficult for the soil to absorb nutrients. Therefore, there is a need for more environmentally friendly cultivation techniques to improve and maintain soil fertility and optimize the use of inorganic fertilizers. The solution is to use humic acid and vermicompost. This approach effectively reduces the existing impact, as humic acid plays a role in improving soil structure, and vermicompost, as an organic fertilizer, also improves the physical, chemical, and biological properties of the soil, while simultaneously supporting the efficiency of nutrient absorption by plants.

Humic acid is one of the three main components of humic substances, which acts as a component in the formation of humus. Humic acid facilitates the absorption of nutrients such as N, P, K, Cu, Mg, Zn, and Na. Humic acid can release soil nutrients, making them available to plants (Mindari et al., 2018). Vermicompost contains various growth regulators, including gibberellins, cytokinins, and auxins, as well as essential nutrients such as N, P, K, Mg, and Ca. Not only that, but this organic fertilizer also provides important micronutrients for plants, such as Fe, Mn, Cu, Zn, Bo, and Mo (Setyowati et al., 2023). Given the issues presented, it is necessary to conduct research on the optimization of humic acid and vermicompost use for soybean growth and yield. This research is also expected to serve as a follow-up study that will make a greater contribution to increasing soybean production in Indonesia.

METHOD

The research was conducted at Jember State Polytechnic's Research Field between August and November of 2024. Geographical coordinates: -8.157805° S and 113.725867° E; average temperature: 29–33°C; relative humidity: 82%; elevation: about 100 meters above sea level (masl). The research used a Randomized Block Design (RAK) Factorial with two factors. The first factor is the dose of humic acid, which consists of 10 kg/ha, 20 kg/ha, 25 kg/ha, and 30 kg/ha. The second factor is the dose of vermicompost, which consists of 15 tons/ha and 20 tons/ha. There are 8 combinations, each repeated 3 times, resulting in 24 treatment units. Planting was done at a distance of 30 cm × 20 cm, using 2 soybean seeds per hole. Vermicompost is applied 7 days before planting, while humic acid is applied twice, at 15 and 30 days after planting. Maintenance is carried out intensively, including replanting, thinning, watering, weeding, hilling, and pest and disease control. Fertilization is carried out in two times: the first time at planting with 1/3 Urea (16 kg/ha), SP-36 (100 kg/ha), and KCl (75 kg/ha); the second time at 30 days after planting with 2/3 Urea (34 kg/ha). Observations were made on growth and yield variables, including plant height at 14, 28, 42,

and 56 days after planting (DAP), the number of root nodules at 35 and 42 DAP, the fresh pod weight per sample, the fresh pod weight per plot, and the dry seed weight. The research results obtained were analyzed using Analysis of Variance (ANOVA). If the treatment with humic acid and vermicompost shows significant results, it will be further tested using the DMRT Follow-up Test at the 5% level. And if it shows highly significant results, it will be further tested using the DMRT Follow-up Test at the 1% level.

RESULT

This study evaluated the effects of humic acid and vermicompost on soybean growth and yield, including plant height, number of root nodules, fresh pod weight per sample, fresh pod weight per plot, and dry seed weight. The summary of ANOVA results is presented in Table 1.

Plant Height

Plant height was observed at 14, 28, 42, and 56 days after planting (DAP). The ANOVA results showed that vermicompost significantly affected plant height only at 42 DAP ($p < 0.05$), while other observations were not significant. Further analysis using DMRT at the 5% level (Table 2) indicated that the vermicompost dose of 20 tons/ha resulted in significantly higher plant height (26.69 cm) compared to 15 tons/ha (24.50 cm).

Table 1. Recapitulation of the results of variance analysis (ANOVA)

Observed Variables	Humic Acid (A)	Vermicompost (V)	Interaction (A × V)
Plant height			
14 DAP	0.43 ^{ns}	4.33 ^{ns}	0.89 ^{ns}
28 DAP	0.46 ^{ns}	3.75 ^{ns}	1.42 ^{ns}
42 DAP	0.25 ^{ns}	4.77*	1.59 ^{ns}
56 DAP	0.38 ^{ns}	3.23 ^{ns}	1.06 ^{ns}
Number of root nodules			
35 DAP	1.97 ^{ns}	0.69 ^{ns}	1.05 ^{ns}
42 DAP	6.88**	0.06 ^{ns}	5.90**
Fresh pod weight per sample	4.01*	0.69 ^{ns}	1.16 ^{ns}
Fresh pod weight per plot	3.47*	0.37 ^{ns}	2.16 ^{ns}
Dry seed weight	2.36 ^{ns}	2.65 ^{ns}	2.79 ^{ns}

Information: notation shows results not-significant (ns), significant (*), and highly significant (**)

Table 2. The average plant height at 42 days after planting for each dose of vermicompost

Vermicompost Dose (tons/ha)	Plant Height (cm)
15	24.50 b
20	26.69 a

Description: Numbers followed by different letters indicate significant differences in the 5% DMRT test.

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Table 3. Average number of root nodules at 42 HST for each dose of humic acid

Humic Acid Dose (kg/ha)	Vermicompost Dose (tons/ha)	
	15	20
10	7.00 Aa	6.67 Aa
20	7.00 Aa	6.33 Aa
25	6.00 Aab	7.17 Aa
30	6.00 Aa	5.67 ABa

Description: Numbers followed by uppercase letters in the same column and numbers followed by lowercase letters in the same row indicate no significant difference based on the 1% DMRT test.

Number of Root Nodules

Root nodules were observed at 35 and 42 DAP. The ANOVA results showed a highly significant interaction between humic acid and vermicompost at 42 DAP ($p < 0.01$). DMRT analysis at the 1% level (Table 3) revealed that the combination of humic acid at 25 kg/ha and vermicompost at 20 tons/ha produced the highest number of root nodules (7.17 nodules).

Fresh Pod Weight per Sample

Weighing the pods as soon as they were harvested allowed us to observe their weight. The fresh pod weight variable demonstrated a significant effect (*) on humic acid treatment, as indicated by the analysis of variance (ANOVA) shown in Table 1. Consequently, a 5% level DMRT test was carried out. Table 4 presents the findings of this follow-up test.

Table 4. Average weight of fresh pods per sample at each humic acid dosage

Humic Acid Dose (kg/ha)	Fresh Pod Weight per Sample (grams)
10	1.89 ab
20	2.02 a
25	1.36 b
30	1.38 b

Description: Numbers followed by different letters indicate significant differences in the 5% DMRT test.

Fresh Pod Weight per Sample

Humic acid treatment significantly affected fresh pod weight per sample ($p < 0.05$). DMRT results (Table 4) showed that the 20 kg/ha dose produced the highest value (2.02 g), while higher doses resulted in lower values.

Table 5. Average weight of fresh pods per plot at each humic acid dosage

Humic Acid Dose (kg/ha)	Fresh Pod Weight per Sample (grams)
10	109.62 ab
20	124.89 a
25	96.23 b
30	116.36 b

Description: Numbers followed by different letters indicate significant differences in the 5% DMRT test.

Fresh Pod Weight per Plot

Similarly, fresh pod weight per plot was significantly influenced by humic acid treatment ($p < 0.05$). The highest yield was obtained at 20 kg/ha (124.89 g), as shown in Table 5.

Dry Seed Weight

Dry seed weight was not significantly affected by either humic acid, vermicompost, or their interaction ($p > 0.05$).

DISCUSSION

The present study demonstrates that the application of humic acid and vermicompost differentially affects soybean growth and yield components, with significant responses in plant height, root nodulation, and fresh pod weight, but not in dry seed weight. These findings indicate that organic inputs primarily influence early vegetative growth and certain reproductive parameters, while final yield formation remains relatively stable under the tested conditions.

The significant increase in plant height at 42 DAP following vermicompost application underscores the importance of nutrient availability during the active vegetative phase. Vermicompost is known to improve soil fertility by supplying essential macro- and micronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), and by enhancing soil structure and microbial activity. The higher plant height observed at 20 tons/ha suggests that this dose provides an optimal nutrient balance to support cell elongation and division. Nitrogen, in particular, plays a critical role in chlorophyll formation and photosynthesis, thereby promoting biomass accumulation. These findings are consistent with those of Sihaloho et al. (2015), who reported that vermicompost application enhances vegetative growth by improving nutrient supply and soil biological activity. However, the absence of significant effects at other observation times suggests that nutrient release from vermicompost may be gradual, with peak effectiveness occurring at specific growth stages.

A notable finding of this study is the highly significant interaction between humic acid and vermicompost on root nodule formation at 42 DAP. The combination of 25 kg/ha of humic acid and 20 tons/ha of vermicompost produced the highest number of nodules, indicating a synergistic effect between the two inputs. Root nodulation is a critical process in legumes, as it directly influences biological nitrogen fixation. The enhanced nodulation observed in this study may be attributed to improved soil conditions and increased microbial activity. Humic acid has been reported to enhance root development, increase membrane permeability, and stimulate microbial populations in the rhizosphere. In addition, humic substances can chelate nutrients, thereby increasing their availability to plants. The mechanism by which humic acid delays nitrification allows nitrogen to remain in forms more accessible to plant uptake for a longer period, thereby supporting nodule development (Hermanto et al., 2013).

The timing of nodulation is also important. Observations at 42 DAP correspond to the active phase of nodule development before senescence begins. As Adisarwanto (2013) stated, nodules typically become less effective after 50 DAP, which explains why significant differences were observed at 42 DAP but not earlier. The synergistic effect of humic acid and vermicompost suggests that combining organic amendments can create a more favorable rhizosphere environment, enhancing symbiotic interactions between soybean roots and nitrogen-fixing bacteria.

The significant effect of humic acid on fresh pod weight, both per sample and per plot, indicates its role in improving reproductive efficiency. The optimal dose of 20 kg/ha resulted in the highest pod weight, suggesting that humic acid enhances nutrient uptake and assimilation during the reproductive phase. This improvement may be linked to increased photosynthetic efficiency and better translocation of assimilates to developing pods. Humic acid is known to stimulate enzyme activity and hormonal responses in plants, thereby enhancing flowering and fruit development. These results align with Becti et al. (2019), who reported that appropriate doses of humic acid can increase crop yield components.

However, the decline in fresh pod weight at higher doses (25 and 30 kg/ha) indicates that excessive application may have adverse effects. One possible explanation is that high concentrations of humic acid can alter soil pH, potentially increasing acidity and reducing nutrient availability. This condition may inhibit root function and limit nutrient uptake, ultimately reducing plant productivity (Fauziah et al., 2019). This finding underscores the importance of determining optimal dosage levels when applying organic amendments, as both deficiency and excess can negatively impact plant performance.

In contrast, the absence of significant effects on dry seed weight suggests that the treatments were not sufficient to influence final yield accumulation. Seed weight is a complex trait determined by the balance between source (photosynthesis) and sink (seed filling) processes. Although vegetative growth and early reproductive development were enhanced, these improvements did not translate into increased seed dry matter accumulation. This may be due to several factors, including environmental conditions, limited nutrient availability during seed filling, or competition among developing pods. According to Ayunita et al. (2014), seed weight is strongly influenced by water content and organic matter accumulation, which depend on sustained photosynthetic activity and nutrient supply during later growth stages.

Another possible explanation is that the duration of nutrient release from vermicompost and humic acid may not have aligned with the critical period of seed filling. Organic fertilizers typically release nutrients more slowly compared to inorganic fertilizers, which may limit their effectiveness during periods of high nutrient demand. Additionally, the lack of significant interaction effects on most

variables suggests that humic acid and vermicompost may act independently rather than synergistically for certain growth parameters.

From an agronomic perspective, these findings highlight the potential of integrating organic inputs into soybean cultivation systems, particularly in regions with declining soil fertility. The use of humic acid and vermicompost offers a sustainable alternative to synthetic fertilizers by improving soil health, enhancing microbial activity, and promoting nutrient cycling. However, their effectiveness depends heavily on dosage, timing, and environmental conditions.

The novelty of this study lies in evaluating the combined use of humic acid and vermicompost under tropical conditions, particularly in Indonesia, where soil acidity and nutrient limitations are common constraints. The results contribute to the growing body of knowledge on sustainable agriculture by demonstrating that organic amendments can improve specific growth and yield components without negatively affecting overall plant performance.

Nevertheless, this study has several limitations that should be addressed in future research. The absence of a broader range of treatment levels may limit the ability to identify the true optimal dosage. Additionally, environmental factors such as soil type, rainfall, and temperature were not thoroughly analyzed, which may influence soybean plants' responses to organic inputs. Future studies should also consider longer observation periods and additional yield parameters, such as harvest index and nutrient use efficiency, to provide a more comprehensive evaluation.

Overall, the findings suggest that while humic acid and vermicompost can enhance soybean growth, particularly in vegetative development and nodulation, their impact on final yield components remains limited. Therefore, their application should be integrated with other agronomic practices to achieve optimal productivity.

CONCLUSION

The study concludes that the application of humic acid and vermicompost affects soybean growth and yield in a selective manner. The interaction between humic acid at 25 kg/ha and vermicompost at 20 tons/ha significantly increased the number of root nodules, reaching 7.17 nodules. Humic acid at 20 kg/ha significantly improved fresh pod weight per sample (2.02 g) and per plot (124.89 g), while vermicompost at 20 tons/ha significantly increased plant height (26.69 cm). However, no significant effects on dry seed weight were observed, indicating that these treatments did not influence final yield components under the study conditions. These findings suggest that humic acid and vermicompost can be effective organic inputs to enhance soybean growth, particularly during the early and reproductive stages. Further research is recommended to explore a wider range of dosages and to include control treatments to optimize their application and maximize soybean productivity.

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