International Journal on Food, Agriculture, and Natural Resources
Volume 07, Issue 01, Page 35-37
ISSN: 2722-4066
http://www.fanres.org

Original Paper

Effects of Humic Acid and Plant Growth Promoting Rhizobacteria on Growth and Yield of Soybean (*Glycine max L.*)

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Received: 27 January 2026; Revised: 14 March 2026; Accepted: 30 March 2026
DOI: *https://doi.org/10.46676/ij-fanres.v7i1.602*

***Abstract*— Soil degradation and low nutrient availability remain major constraints in soybean production. The use of organic amendments such as humic acid and biological agents such as Plant Growth Promoting Rhizobacteria (PGPR) has been widely promoted as a sustainable strategy to improve soil quality and crop productivity. This study aimed to evaluate the effects of different dosages of humic acid and PGPR on the growth and yield components of soybean (*Glycine max L.*) var. Dering 1. The experiment was conducted from September to December 2024 at the Agrotechnopark, University of Jember, using a randomized complete block design with three treatments (0, 10, and 20 mg) and five replications. Observed parameters included plant height, number of leaves, number of branches, and number of pods. Data were analyzed using analysis of variance (ANOVA) followed by Duncan Multiple Range Test (DMRT) at a 5% significance level. The results showed that humic acid at 10 mg significantly increased plant height, while the 20 mg dosage enhanced branch and pod formation. PGPR application showed a dose-dependent response, with the 20 mg treatment producing the highest values for all observed parameters. These findings indicate that humic acid and PGPR improve soybean growth through different mechanisms and have strong potential to support sustainable soybean cultivation.**

Keywords: Glycine max L, dering 1, humic acid, PGPR, sustainable agriculture, organic fertilizer

I. Introduction

Soybean (*Glycine max L.*) is an important legume crop due to its high protein content and its role in food security and agroindustry. However, soybean productivity in many agricultural areas remains limited by declining soil quality, particularly low organic matter content and reduced nutrient availability [1]. Continuous use of inorganic fertilizers without organic inputs often leads to soil degradation, which negatively affects plant growth and yield.

Humic acid is a major component of soil organic matter and plays an important role in improving soil physical, chemical, and biological properties. Humic substances can enhance soil structure, increase cation exchange capacity, improve water retention, and stimulate nutrient availability for plants [3], [4]. Several studies have reported that humic acid application improves vegetative growth and yield components of soybean when applied at appropriate dosages [5]. However, excessive application may reduce plant performance due to nutrient imbalance or physiological stress [6].

In addition to organic amendments, Plant Growth Promoting Rhizobacteria (PGPR) are beneficial microorganisms that colonize the rhizosphere and stimulate plant growth through various mechanisms. PGPR enhance nutrient uptake through nitrogen fixation, phosphate solubilization, and the production of phytohormones such as indole-3-acetic acid (IAA) [2], [7]. Previous studies have shown that PGPR application can increase soybean growth and yield, although the response depends on inoculum dosage and environmental conditions [8], [9].

Although humic acid and PGPR have been widely studied individually, comparative information on their effects under similar experimental conditions is still limited. Therefore, This study was designed as two independent experiments to separately evaluate the effects of humic acid and PGPR on soybean growth and yield components.

II. Material and Methods

The study was conducted from September to December 2024 at the Agrotechnopark, University of Jember, Indonesia. The experimental site represents typical soybean cultivation conditions in the region. Soybean (Glycine max L.) variety Dering 1 was used as the test plant due to its adaptability and stable yield potential under local conditions [10].

The study consisted of two independent experiments conducted under similar field conditions. The first experiment evaluated the effect of humic acid dosage on soybean growth and yield components, while the second experiment examined the effect of Plant Growth Promoting Rhizobacteria (PGPR) dosage. Each experiment was arranged separately using a Randomized Complete Block Design (RCBD) with three treatment levels (0, 10, and 20 mg) and five replications.

This approach was used to independently assess the response of soybean plants to each input without interaction effects between treatments.. The statistical model followed standard procedures for agricultural field experiments as described by Gomez and Gomez [11].

Humic acid treatments consisted of three dosage levels, namely 0 mg as control, 10 mg, and 20 mg. Humic acid was dissolved in water prior to application and applied by soil drenching to ensure uniform distribution in the root zone. Applications were carried out at three growth stages, namely before planting, 20 days after planting (DAP), and 35 DAP. All plots received the same basal fertilization and irrigation to minimize external variation.

PGPR treatments were also applied at three dosage levels, consisting of 0 mg as control, 10 mg, and 20 mg. The PGPR inoculant contained beneficial rhizobacteria commonly associated with plant growth promotion. The inoculant was applied to the rhizosphere following standard field application procedures to ensure effective microbial colonization around the soybean root system.

Observed parameters included plant height, number of leaves, number of branches, and number of pods per plant. Measurements were conducted periodically, and final observations were recorded at 77 days after planting, when the plants reached the reproductive growth stage.

All collected data were subjected to analysis of variance (ANOVA) at a 5% significance level to determine treatment effects. When significant differences among treatments were observed, mean separation was performed using Duncan Multiple Range Test (DMRT) at the same significance level.

III. Result and Discussion

A. Effects of Humic Acid on Soybean Growth and Yield

Humic acid application significantly affected several growth and yield components of soybean. Differences in plant response were closely related to the dosage applied, indicating a dose-dependent effect of humic acid on soybean growth (Table 1).

TABLE 1. EFFECT OF HUMIC ACID DOSAGE ON SOYBEAN GROWTH AND YIELD COMPONENTS

Treatment	Plant height (cm)	Number of branches	Number of pods
H0 (0 mg)	57.0 ± 3.0 b	6.4 ± 0.5 b	72.4 ± 3.5 c
H1 (10 mg)	59.0 ± 8.5 a	6.2 ± 0.8 b	142.2 ± 9.7 b
H2 (20 mg)	51.4 ± 3.4 c	6.8 ± 0.8 a	147.2 ± 4.4 a

Mean values are presented as mean ± standard deviation (SD). Different letters within the same column indicate significant differences according to DMRT at α = 0.05.

The application of 10 mg humic acid resulted in the highest plant height and differed significantly from the control and the 20 mg treatment. This result suggests that moderate humic acid application enhances vegetative growth by improving nutrient availability and root development. Humic substances are known to increase cation exchange capacity and facilitate the uptake of essential nutrients, particularly nitrogen and potassium, which play key roles in plant height development [3], [4].

In contrast, the 20 mg humic acid treatment reduced plant height but significantly increased the number of branches and pods. This indicates a shift in plant resource allocation from vegetative growth to reproductive development. Similar responses have been reported in previous studies, where higher humic acid dosages stimulated reproductive growth by improving phosphorus availability and metabolic activity during the flowering and pod formation stages [5]. Although the 20 mg treatment resulted in slightly lower plant height, it produced the highest number of branches and pods. This pattern suggests that plant growth may shift from vegetative development toward reproductive structures at higher humic acid dosages. Such responses are commonly associated with improved nutrient availability during the reproductive stage rather than physiological stress. [6].

Overall, these findings confirm that humic acid improves soybean performance when applied at appropriate dosages. Moderate application supports vegetative growth, while higher dosages favor yield-related parameters.

B. Effects of PGPR on Soybean Growth and Yield

PGPR application significantly increased several soybean growth and yield parameters, with a consistent increase observed as PGPR dosage increased (Table 2). Unlike humic acid, PGPR showed a clear linear response across all observed parameters.

TABLE 2. EFFECT OF PGPR DOSAGE ON SOYBEAN GROWTH AND YIELD COMPONENTS

Treatment	Plant height (cm)	Number of leaves	Number of pods
P0 (0 mg)	43.4 ± 3.6 c	16.0 ± 1.4 c	46.0 ± 2.2 c
P1 (10 mg)	51.8 ± 2.5 b	19.0 ± 1.6 b	51.0 ± 2.8 b
P2 (20 mg)	56.0 ± 2.6 a	22.2 ± 2.6 a	56.4 ± 2.7 a

Mean values are presented as mean ± standard deviation (SD). Different letters within the same column indicate significant differences according to DMRT at α = 0.05.

The highest plant height and leaf number were observed in plants treated with 20 mg PGPR. This improvement in vegetative growth is closely related to the role of PGPR in producing phytohormones such as indole-3-acetic acid (IAA), which stimulate cell elongation and leaf expansion [7]. In addition, PGPR enhances nutrient availability through biological nitrogen fixation and phosphate solubilization, leading to improved vegetative growth [2], [8].

The increase in pod number with increasing PGPR dosage indicates improved nutrient uptake during the reproductive stage. Nitrogen and phosphorus availability plays an important role in pod initiation and development, and PGPR-mediated nutrient mobilization supports these processes [9].The consistent superiority of the highest PGPR dosage suggests that higher inoculum levels ensure effective microbial colonization and sustained plant–microbe interactions throughout the growth cycle.

C. Comparative Interpretation of Humic Acid and PGPR Effects

Although both humic acid and PGPR positively affected soybean growth and yield, their patterns of response differed. Humic acid showed an optimal dosage range, with excessive application reducing vegetative growth but enhancing reproductive parameters. In contrast, PGPR application resulted in a steady and positive response across all dosages.

These differences reflect the distinct mechanisms of action of the two treatments. Humic acid primarily improves soil chemical properties and nutrient availability, while PGPR directly influences plant physiology through biological activity in the rhizosphere. The complementary nature of these effects suggests that combining humic acid and PGPR could further enhance soybean productivity, as reported in previous sustainable agriculture studies [1], [2].

IV. Conclusions and Recomendation

The application of humic acid and PGPR significantly affected soybean growth and yield components. Humic acid at 10 mg was optimal for vegetative growth, particularly plant height, while the 20 mg dosage enhanced branching and pod formation. PGPR application showed a dose-dependent response, with the 20 mg dosage consistently producing the highest plant height, leaf number, and pod number. These findings indicate that humic acid and PGPR enhance soybean productivity through different physiological and soil-mediated mechanisms affecting plant growth and nutrient availability. Optimizing dosage is crucial to maximize benefits and avoid negative effects. The findings provide scientific support for the use of organic amendments and biological agents as sustainable alternatives in soybean cultivation.

Acknowledgment

The authors would like to express their sincere gratitude to the Faculty of Agriculture, University of Jember, for providing facilities and technical support during the implementation of this research. Appreciation is also extended to all laboratory staff and students who assisted in the preparation of materials, data collection, and plant maintenance throughout the experimental period. The authors are grateful to colleagues for their valuable discussions and suggestions that contributed to the improvement of this manuscript.

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