Biofilmed biofertilizer and phosphate in NK combined compound fertilizer to reduce basal rot severity and enhance garlic yield on andisol soil

Hadiwiyono Hadiwiyono[1,2*], *Firza Putra* Pradasa[1*], *Susilo Hambeg* Poromarto[2,1], and *Sudadi* Sudadi[3]

[1] Departement of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret (UNS) at Surakarta, Indonesia
[2] Departement of Plant Protection, Faculty of Agriculture, Universitas Sebelas Maret (UNS) at Surakarta, Indonesia
[3] Departement of Soil Science, Faculty of Agriculture, Universitas Sebelas Maret (UNS) at Surakarta, Indonesia

Abstract. Garlic (*Allium sativum* L.) is an important commodity in Indonesia, yet its production remains insufficient to meet market demand. One of the main constraints to garlic productivity is basal rot disease caused by *Fusarium oxysporum* f. sp. *cepae*, which reduces bulb yield and quality. The application of biofilmed biofertilizer (BiO_2) combined with phosphate in NK compound fertilization has the potential to suppress disease severity while improving plant growth and yield. This study aimed to evaluate the effectiveness of BiO_2 and potassium fertilization in controlling basal rot disease and enhancing garlic productivity on Andisol soil in Tawangmangu. The experiment was conducted from May to September 2024 using a Randomized Block Design with four treatments: P0 (100% NK, 0% P + BiO_2), P1 (100% NK, 50% P + BiO_2), P2 (100% NK, 100% P + BiO_2), and P3 (100% NP), each replicated six times. Observations included plant growth, disease incidence and severity, and yield components. The results showed that treatment P2 was the most effective in reducing disease severity while maintaining high yield performance. The application of BiO_2 also increased plant height and leaf number, indicating that integrating BiO_2 with balanced NK fertilization is an effective strategy to enhance garlic productivity on Andisol soils.

1 Introduction

Garlic (*Allium sativum* L.) is a significant commodity in Indonesia, with high demand. In 2023, its production reached 39.25 thousand tons, representing a 28.36% increase compared to 2022 [1]. One of the significant threats to garlic cultivation is basal rot disease (BRD) caused by *Fusarium oxysporum* f. sp. *cepae* (FOCe) [2], which has been spreading continuously since 2000 in Tawangmangu, Central Java, Indonesia, and has become a serious

*Corresponding author: hadiwiyono@staff.uns.ac.id; firzaputra@student.uns.ac.id;

concern for farmers [3]. FOCe is a soil-borne pathogen that causes basal rot and infects approximately 150 plant species. FOCe spread easily and widely through soil, water, air, and agricultural equipment. FOCe is challenging to control due to its ability to form chlamydospores, and it can reduce yields by up to 50% in the field and 30% during storage [5].

The genus Fusarium is a weak pathogen whose attack increases in weakened plants [6]. Therefore, control through improved plant growth, such as through the application of biofilmed biofertilizer (BiO_2), is promising. One important macrofertilizer is phosphate. The combination of biofertilizers and phosphate has been reported to increase phosphorus uptake by up to 28.44% and improve plant growth by 44.83% [7], while BiO_2 contains functional microorganisms that contribute to increased crop yield [8]. Therefore, this study aimed to determine the most effective dosage of P balanced by BiO2 for suppressing the intensity of basal rot disease and increasing garlic yield.

2 Materials and Methods

2.1 Location and Time

The study was conducted from May to September 2024 in Pancot Village, Tawangmangu District, Karanganyar Regency, Central Java, at coordinates 7°39' South Latitude and 111°08' East Longitude. The experiment took place at an altitude of 1,200 meters above sea level. The soil type in the study area is Andisol.

2.2 Materials and Equipment

The materials used in this study included garlic seeds of the Tawangmangu Baru variety, Urea, SP-36, KCl fertilizers, and Biofilmed Biofertilizer (BiO_2). The tools used in the field included a hoe, measuring tape, digital scale, camera, and stationery. In the laboratory, a pH meter, oven, analytical balance, microscope, autoclave, and glassware, including Erlenmeyer flasks, test tubes, and Petri dishes, were used.

2.3 Research Implementation

The study used a Randomized Block Design (RBD) with a single factor consisting of four treatments: P0: 100% NK, 0% P + BiO_2; P1: 100% NK, 50% P + BiO_2; P2: 100% NK, 100% P + BiO_2; P3: 100% NPK (control). Each treatment was replicated six times, resulting in a total of 24 experimental units. Land preparation was carried out by removing weeds, tilling the soil, and making planting beds measuring 1.2 × 10 m. Garlic cloves were planted at a spacing of 10 × 15 cm and a depth of 2–3 cm. BiO_2 was applied weekly starting from three weeks after planting until just before harvest at a dosage of 2 L/ha. Nitrogen and potassium fertilizers were applied three times (at 30, 60, and 80 days after planting) at fixed dosages, while phosphorus fertilizer was applied according to the treatment. Crop maintenance included watering, weeding, and pest and disease control as needed. Harvesting was carried out at approximately 120 days after planting, indicated by the yellowing of the leaves.

3 Result and Discussion

3.1 Soil Analysis

The soil type in the study area is Andisol. Andisol is characterized by its black color, porous structure, high organic matter content, and amorphous clay minerals, such as allophane, with small amounts of silica, alumina, or iron hydroxides. Soil analysis of the research field is presented in Table 1.

Table 1. The Analysis Results of Soil Treated by BiO2, N, K, and Variation Dosage of P

Treatment	N Total (%)	P is availible (ppm)	K is availible (cmol(+)kg^{-1})	C Organik (%)	pH	C/N Ratio
Before Treatment	0.23	9.42	0.48	1.27	6.51	5.42
P0 (100% NK, 0% P + BiO_2)	0.64	129.55	0.40	4.52	6.67	7.12
P1 (100% NK, 50% P + BiO_2)	0.71	149.28	0.37	4.83	6.38	6.86
P2 (100% NK, 100% P +BiO_2)	0.51	239.51	1.14	4.34	6.61	8.49
P3 (100% NPK (control))	0.49	150.43	0.42	4.49	6.37	8.49

Based on Table 1, the application of a combination of chemical fertilizer and BiO_2 was able to increase the macronutrient content of Andisol soil in Tawangmangu. The analysis showed an increase in total nitrogen (N-total) from 0.23% to 0.28–0.71%, with the highest value observed in the treatment of 100% NK and 50% P + BiO_2. Available phosphorus (P) also increased from 9.42 ppm to 239.51 ppm in the 100% NK and 100% P + BiO_2 treatment, while available potassium (K) rose from 0.48 cmol(+) kg^{-1} to 1.14 cmol(+)kg^{-1}. This improvement was attributed to the activity of phosphate-solubilizing microorganisms in BiO_2, which enhances phosphorus dissolution and availability in the soil, while also supporting biological processes such as nitrogen fixation and organic matter decomposition. In addition, soil organic carbon (C-organic) increased from 1.27% to 4.83%, indicating improved soil structure and microbial activity. Overall, the combination of fertilizer and BiO_2 plays an important role in enriching soil macronutrients (N, P, K, and C-organic), enhancing soil biological activity, and supporting the growth and productivity of garlic plants [9].

3.2 Desease Variable

The balance of phosphate fertilizer and biofilmed biofertilizer had a significant effect on the severity of wilt and basal rot in garlic. The severity of wilt in garlic plants with different balances of phosphate fertilizer and Biofilmed Biofertilizer (BiO_2) can be seen in Figure 1.

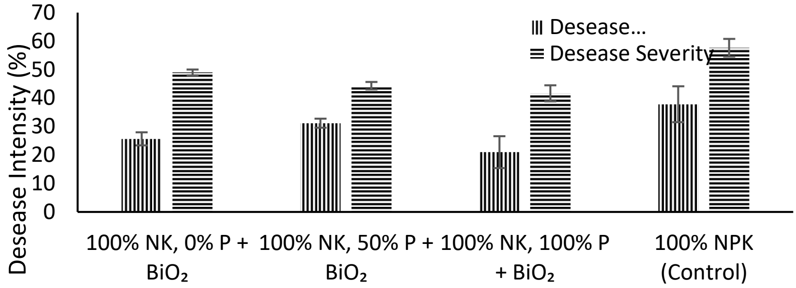

Fig 1. Effect of BiO2, N, K, and Variation Dosage of P on Desease Insidence and Severity of Basal Rot of Garlic

Based on Figure 1, the disease incidence in garlic differed significantly among treatments. The treatment of 100% NK and 100% P + BiO_2 was the most effective in suppressing disease incidence, with a percentage of 21.00%. Based on the DMRT test at a 5% significance level, the treatments of 100% NK and 50% P + BiO_2 increased resistance to basal rot disease in garlic, although they were not significantly different from the 100% NK and 100% P + BiO_2 treatments. The intensity of basal rot in garlic plants under the 100% NK, 50% P + BiO_2, and 100% NK, 100% P + BiO_2 treatments showed no significant difference in the average severity of basal rot. However, from an economic perspective, the 100% NK, 50% P + BiO_2 treatment is recommended as the most efficient option for reducing the severity of basal rot disease in garlic. The application of BiO_2 plays an essential role in enhancing plant growth and resistance by improving soil fertility, increasing nutrient uptake, and suppressing pathogens that cause basal rot in garlic. BiO_2 contains functional microorganisms such as *Bacillus* sp., *Pseudomonas*, and *Rhizobium*, which are capable of fixing nitrogen, solubilizing phosphate, producing growth hormones, and generating antimicrobial compounds that inhibit pathogen development [10]. Other biological agents, such as *Bacillus subtilis* and non-pathogenic FOCe, have also been proven effective in reducing disease incidence. Therefore, the combination of phosphorus fertilizer and biofertilizer serves as a strategic approach to improve soil health and enhance garlic resistance against basal rot disease.

Phosphorus (P) is an essential element for plant metabolism, including in garlic; however, its efficiency is relatively low, as only about 10–30% can be absorbed by plants, while the remainder becomes bound in insoluble forms. The use of phosphate-solubilizing bacteria, such as those contained in BiO_2, can enhance phosphorus solubility and fertilizer efficiency. Phosphate-solubilizing microbes, including both bacterial and fungal groups, play a crucial role in converting organic phosphate into inorganic forms, thereby making it more available to plants. The combination of P fertilizer and BiO_2 not only accelerates plant growth and resistance but also suppresses pathogen development through biological and chemical mechanisms. Pseudomonas sp. and Bacillus sp. are known to be effective as biofertilizers because they can solubilize phosphate bound to Ca, Mg, Fe, and Al elements, thereby enhancing plant growth. The combination of phosphorus (P) fertilizer and BiO_2 effectively controls garlic basal rot disease (Fusarium oxysporum) while improving growth and yield. Phosphorus strengthens root systems and supports plant metabolism, whereas BiO_2, containing PGPR such as *Bacillus* sp. and *Pseudomonas* sp., solubilizes phosphate, produces antibacterial compounds, and induces plant defenses [11].

3.3 Yield Parameters (Bulb Weight & Dry Weight)

The taller the plant and the greater the number of leaves formed, the higher the fresh biomass weight of the plant will be. A good photosynthesis rate in a plant can be indicated by rapid growth and development, resulting in a greater accumulation of photosynthates in the biomass of roots, stems, and leaves.

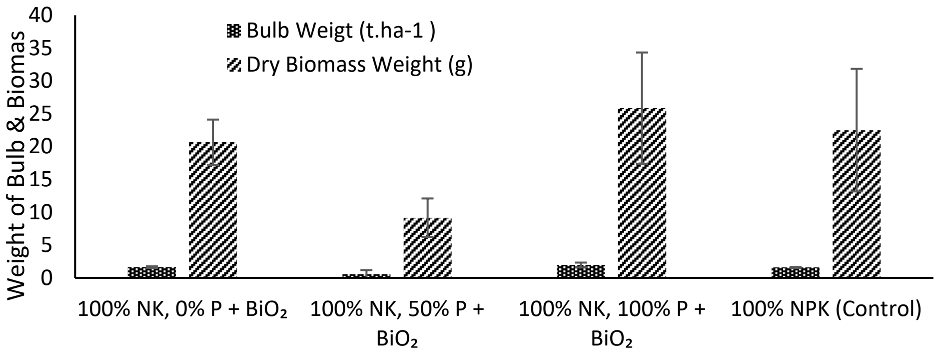

Fig 2. Effect of BiO2, N, K, and Variation Dosage of P on Weight of Bulb and Dry Biomass of Garlic

Based on Figure 2, the combination treatment of P fertilizer and BiO2 showed no significant effect among treatments. However, statistically, the combination of 100% NK and 100% P + BiO_2 (1.96 t.ha-1) resulted in a higher yield compared to other treatments. The dry biomass with 100% NPK (22.50 g) was not significantly different from the 100% NK, 0% P + BiO_2 and 100% NK, 100% P + BiO_2 treatments. Nevertheless, from an economic perspective, the 100% NPK treatment is recommended for improving the dry biomass weight of garlic plants. Garlic yields can be improved through fertilization, particularly with phosphorus (P) fertilizer, which plays a crucial role in root and bulb formation. Nitrogen (N) absorption also supports the uptake of other essential nutrients. To reduce the use of chemical fertilizers, P fertilizer can be combined with biofertilizers such as BiO_2, which contains phosphorus-solubilizing and nitrogen-fixing microbes [12]. This combination creates an ideal nutrient environment, enhances nutrient uptake efficiency, and maintains soil microbial balance, thereby contributing to an increase in garlic bulb weight per hectare.

The application of phosphorus (P) fertilizer plays an important role in increasing the fresh and dry biomass weight of garlic. The use of BiO_2 in combination with P fertilizer yields a synergistic effect, enhancing the availability and uptake of essential nutrients, particularly nitrogen and phosphorus, which are crucial for vegetative plant growth. Phosphorus is an important element involved in photosynthesis, respiration, and energy metabolism. BiO_2, which contains PGPR (Plant Growth-Promoting Rhizobacteria), such as Bacillus and Pseudomonas, can enhance microbial activity in the rhizosphere, extend root length, and increase the number of root branches and root hairs, thereby improving nutrient absorption efficiency. In general, the application of PGPR can increase plant biomass by converting unavailable nutrients into forms that plants more easily absorb.

3.4 Plant Growth Variable

Plant height was observed to determine vegetative growth. Observations of plant height were carried out for 10 weeks. After 10 weeks, the garlic plants entered the generative phase, which was characterized by a decrease in leaf growth rate and changes in leaf color, beginning to turn yellow and wilt.

Table 2. Height of garlic plants and number of leaves with the balance of phosphate fertilizer starting to turn yellow and wilt.

Treatment P fertilizer and BiO_2	Plant Height	Numbers of Leaves
100% NK, 0% P + BiO_2	47.89±2.10a	11.20±1.25c
100% NK, 50% P + BiO_2	46.40±3.16a	12.43±2.12d
100% NK, 100% P + BiO_2	60.09±6.52b	7.60±1.30b
100% NPK	49.09±1.25a	6.50±2.07a
Significance	<0.05%	<0.05%

Table 2, plant height at 10 weeks after planting (60.09 cm) with the treatment of 100% NK and 100% P + BiO_2 was significantly different from other treatments. The treatment of 100% NK and 50% P + BiO_2 also showed a significant difference in the number of garlic leaves at 10 weeks after planting, producing an average of 12.43 leaves. Phosphorus plays an important role in root and bulb formation as well as in the photosynthesis process of garlic. Therefore, phosphorus deficiency can inhibit plant growth. The combination of phosphorus fertilizer and BiO_2 increases plant height because microorganisms such as Bacillus sp. and Trichoderma sp. in BiO_2 solubilize phosphate and produce metabolites such as phytohormones and siderophores that support plant growth [13]. NPK fertilizer and BiO_2 also play an important role in enhancing the vegetative growth of garlic, including leaf number, bulb diameter, and fresh and dry weight. NPK elements support root and shoot formation, as well as photosynthesis and metabolism processes, while BiO_2 improves soil conditions and enhances beneficial microbial activity. Microorganisms such as Bacillus sp. in BiO_2 can produce auxin, gibberellin, and cytokinin hormones that stimulate cell division and root growth, leading to more optimal nutrient absorption [14]. In addition, bacterial chemotaxis toward the roots aids the colonization process, strengthening the root system and increasing nutrient uptake efficiency [15].

4 Conclusions

Biofilmed biofertilizer (BiO_2) has the potential to improve soil fertility and significantly enhance the growth and health of garlic plants. The combination of BiO_2 and phosphate fertilizer was effective in increasing plant height, number of leaves, and reducing the severity of basal rot compared to the control treatment, which used only 100% NPK without BiO_2.

The treatment of 100% NK and 100% P + BiO_2 showed the best results for plant height, while 100% NK and 50% P + BiO_2 were the best treatments for the number of leaves. Meanwhile, 100% NK and 100% P + BiO_2 were the most effective in suppressing root rot disease. This study suggests that BiO_2 plays a crucial role in supporting garlic growth and productivity, even with a reduced phosphate fertilizer dose.

5 Suggestion

My recommendation is that further research should be conducted on the use of Biofilmed Biofertilizer (BiO_2) combined with organic phosphate fertilizer, such as that derived from livestock manure, to reduce the severity of garlic basal rot disease while also evaluating its effects on soil fertility and plant productivity.

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