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Evaluation of Microbe-Enriched Organic Fertilizer on Three Hybrid Corn (*Zea Mays* L.) Varieties in Swamp Land

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ABSTRACT

Lowland areas are characterized by poor soil fertility and low nutrient content, making them suboptimal for agriculture. However, these lands have the potential to be developed for agricultural purposes, particularly for cultivating hybrid corn plants. To enhance production, organic fertilizers enriched with Azospirilium microbes and Phosphate Solubilizing Bacteria (BPF) are utilized, along with the planting of superior varieties that are tolerant to lowland conditions. Azospirilium microbes play a crucial role in providing nitrogen (N) nutrients through the nitrogenase enzyme, while BPF contributes phosphorus (P) and potassium (K) nutrients through the phosphatase enzyme. This combination of nutrients is essential for hybrid corn plants to thrive and produce effectively. The research conducted in Pulau Semambu Village, North Inderalaya District, Ogan Ilir Regency, from January to April 2023, employed a field experiment method using a Factorial Randomized Block Design with 9 treatment combinations repeated 3 times. The study involved three varieties (Pioneer 21, Bisi 816, Pertiwi) and three organic fertilizer dosages (100 kg/ha, 300 kg/ha, 500 kg/ha). The highest yield was achieved by applying 300 kg/ha of microbe-enriched organic fertilizer in combination with the Bisi 816 variety, resulting in a yield of 4.24 kg/plot or 5.65 tonnes/ha. This result represented a 60% increase compared to the Pioneer 21 variety treated with 100 kg/ha of microbial-enriched organic fertilizer.

Keywords: *Organic Fertilizer Enriched with Azospirillum and MPF, Hybrid Corn, Swamp Land, Soil Microbes*

1. INTRODUCTION

Corn is classified as a cereal crop and is a staple food after rice in Indonesia. Corn is a commodity widely used as animal feed, a substitute for fuel (biofuel), a raw material for industries, and an important commodity traded globally. (Febrianti & Kusmiati, 2022; Komalasari, 2021; Sari et al., 2020).

According to Official Statistical News No. 69/10/Th. XXVI, October 16, 2023 (BPS, 2023) The production of dried corn kernels with 14% moisture content in 2023 is estimated at 14.46 million tons, a decrease of 2.07 million tons or 12.50% compared to the 2022 production of 16.53 million tons. Meanwhile, the harvested area in 2023 is estimated at 2.49 million hectares, a decrease of 0.28 hectares or 10.03% compared to 2022, which was 2.78 million hectares. Corn productivity can be enhanced, for instance, by expanding cultivation areas such as utilizing swampy land intensively as new and productive agricultural land for the community, thereby improving soil fertility (Hadiyanti & Suparwoto, 2023; Nursayuti, 2020; Ritung et al., 2015; Sugiartanti & Sarah, 2020).

Swamp land, also known as suboptimal land, can be utilized for agricultural purposes to contribute to national food security (Wandansari & Pramita, 2019). In Indonesia, the total area of swampland is approximately 25.21 million hectares, with Sumatra accounting for 9.91 million hectares, Papua for 7.44 million hectares, Kalimantan for 7.04 million hectares, Sulawesi for 0.73 million hectares, Maluku for 0.09 million hectares, and a small portion in Java (Ritung et al., 2015). Specifically, the swampland area in South Sumatra spans 3.05 million hectares, comprising 1.35 million hectares of lowland swampland and 1.68 million hectares of tidal swampland (Baiduri, 2023).

However, Lebak swamp land is generally considered unproductive (Dahiri, 2022) due to various limiting factors, including excessive water, poor soil fertility, and the presence of toxic elements (Achmadi et al., 2017; Hutasoit et al., 2020). One practical approach to enhancing lowland swamp land's physical, chemical, and biological properties is to utilize organic (Andreii et al., 2018).

Achieving sustainable plant productivity heavily relies on optimal fertilization, as Rong et al. (2016) emphasized. This result involves the provision of additional plant nutrients through organic fertilizers in appropriate quantities, qualities, and continuity, as highlighted by (Tabrani et al., 2023). By adopting this approach, the reliance on inorganic fertilizers (Agustine et al., 2022; Hartatik et al., 2015; Marlina et al., 2023), which can lead to soil degradation and damage (A'Yunita et al., 2023), as well as environmental pollution due to the residues of inorganic fertilizers (Mukhtar et al., 2018), can be reduced.

Furthermore, the availability of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K) in the soil is predominantly bound within organic molecules, making them less accessible to plants. To overcome this limitation, plants depend on soil microbes, such as bacteria and fungi, which play a crucial role in depolymerizing and mineralizing these nutrients in the soil (Jacoby et al., 2017). The soil harbors various microorganisms, including aerobic bacteria (70%), anaerobic bacteria (13%), Actinomycetes (13%), fungi and algae, protozoa, and viruses (0.2-0.8%) (Singh et al., 2023). Among the abundant bacterial species in soil are Azotobacter, Azospirillum, Clostridium, and Bacillus, which are frequently employed as agents for organic fertilization (Hoorman, 2016; Rahayu & Zulaika, 2017; Yunus et al., 2017). Bacteria are pivotal in maintaining soil health and productivity (Hoorman, 2016).

Soil microorganisms and organic matter in plant cultivation play a crucial role in enhancing nutrient availability and uptake by plants, promoting a well-structured soil, and contributing to various soil processes such as the energy and nutrient cycles, soil aggregation, and overall soil health (Mangungsong et al., 2019). Additionally, soil microorganisms are capable of nitrogen fixation from the atmosphere, as well as the dissolution and mineralization of phosphorus, which can then be utilized as an organic fertilizer to impact plant growth and development positively (Alori et al., 2017; Rosyidhana, 2021). The abundance, diversity, and activity of soil microorganisms serve as key indicators of soil quality and fertility. Furthermore, applying fertilizers can influence soil microorganisms' growth and population dynamic(Abdila et al., 2022; Lori et al., 2017; Purbalisa et al., 2020).

The efficacy of organic fertilizer containing Azospirilium and Phosphate Solubilizing Bacteria (BPF) has been examined in wetlands, with studies conducted on shallots (Marlina et al., 2018), soybeans (Marlina & Gusmiatun, 2020), and peanuts (Marlina et al., 2023), demonstrating notable enhancements in plant growth and productivity. Phosphate Solubilizing Bacteria (BPF) is considered an optimal and eco-friendly approach for meeting plant nutritional requirements (Sharma et al., 2013).

This investigation aims to evaluate the impact of microbial-enriched organic fertilizer on crop yields across three hybrid corn varieties in lowland regions where the application of such fertilizer, containing Azospirilium and BPF, has not been previously explored.

2. MATERIAL AND METHODS

The study was conducted in Pulau Semambu Village, North Inderalaya District, Ogan Ilir Regency, at coordinates 3oS and 104oE, from January to April 2023. The experimental layout in the field employed the field experiment method, utilizing a Factorial Randomized Block Design with 9 treatment combinations that were replicated 3 times. Factor I consisted of 3 varieties: the Pioneer 21 variety, the Bisi 816 variety, and the Pertiwi variety. Factor 2 involved different dosages of organic fertilizer: 100 kg/ha, 300 kg/ha, and 500 kg/ha.

The research commenced by producing organic fertilizer enriched with Azospirillium and BPF (Figure 1). To create the organic fertilizer, the study achieved by blending cow dung and rice straw, which had been ground in a ratio of 10:1. Subsequently, the mixture was incubated for 30 days, with the tarpaulin cover being opened every 5 days to ensure that the temperature remained below 500C. After the 30-day incubation period, 50 ml of Azospirillium and BPF bacteria were added to the mixture in a zigzag manner. In the meantime, the land was cleared of weeds and underwent two rounds of processing to loosen the soil. Following this, 27 plots were established, each measuring 2 m x 3 m.

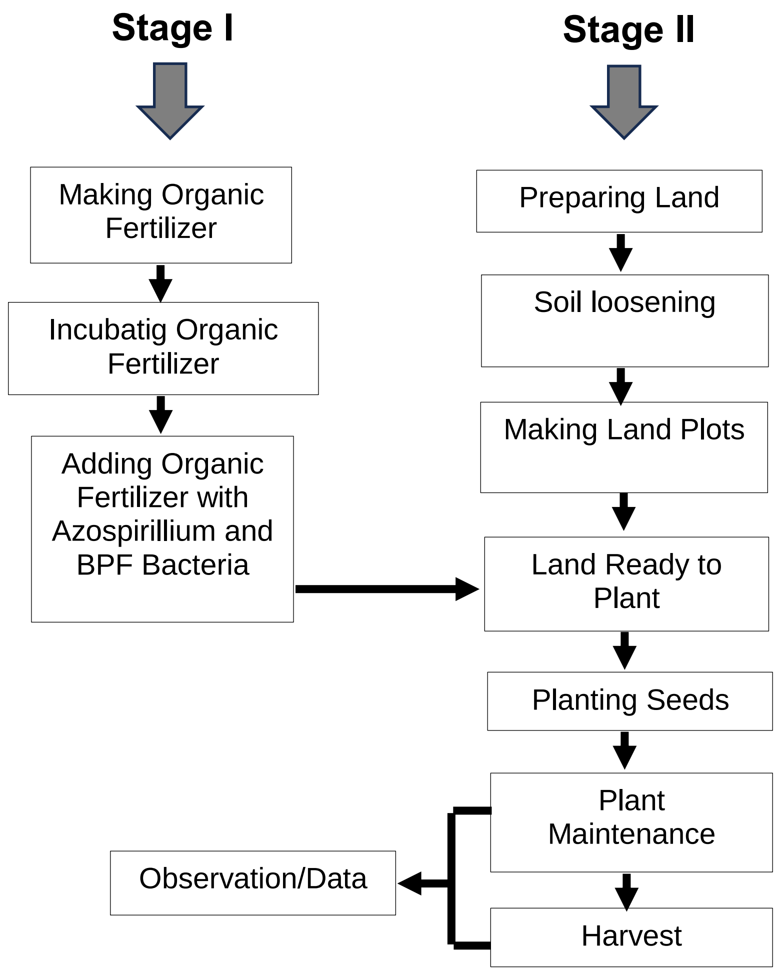

Figure 1. Research Flow

Organic fertilizer is applied one day before planting based on the specific treatment for each plot, while NPK inorganic fertilizer is applied at half of the recommended rate. Two seeds are planted per hole with a 75 x 25 cm spacing. After two weeks, only one fruit is retained per planting hole.

During maintenance, watering is conducted twice daily, in the morning at 07.00 WIT and in the afternoon at 16.00 WIT, unless there is rainfall. Weed control is performed every 2 weeks after planting. Topping occurs when the plants are between 2 to 6 weeks after planting. Harvesting is done when the cob husks turn yellow, the corn kernels are firm, do not release any milk when pressed with the thumb, a black layer forms at the base of the seeds, and the husks are yellow with shiny seeds upon peeling, typically when the plants reach 100 days post-planting.

3. RESULT AND DISCUSSION

The outcomes of this research indicated that the utilization of microbial-enriched organic fertilizer had a notable impact on the development and productivity of three hybrid corn types cultivated on Lebak soil. This result is evident from the analysis of variance, which demonstrates that the treatment involving the three varieties and organic fertilizer had a significant influence on all the variables under observation, such as plant height (cm), number of leaves (strands), cob length (cm), cob diameter (cm), number of seeds per cob (fruit), weight of 1000 seeds (g), cob weight per plant (g), and cob weight per plot (kg). However, no significant interaction was observed from the combination of varieties and organic fertilizers enriched with Azospirillium and BPF, except for the cob diameter (cm) variable, which exhibited a highly significant disparity (Table 1).

Table 1. Results of analysis of variance of organic fertilizer enriched with Azospirillium and BPF with 3 varieties on all observed variables

Observed variables	Treatment			Diversity Coefficient (%)
	Varieties	Organic Fertilizer	Interaction	
Plant height (cm)	36,02**	9,09**	0,28tn	3,59
Number of leaves (pieces)	18,35**	26,82**	0,01tn	3,56
Cob length (cm)	26,70**	32,54**	0,11tn	3,77
Cob diameter (cm)	73,82**	65,73**	5,40**	2,02
Number of seeds per cob	11,08**	17,42**	0,45tn	6,85
(fruit)	23,61**	120,46**	2,76tn	1,64
Weight of 1000 seeds (g)	14,34**	18,93**	0,04tn	5,63
Ear weight per plant (g)	44,75**	42,45**	1,46tn	5,36
Cob weight per plot (kg)				

Note: **= highly significant effect, tn=not significant effect

In the BNJ subsequent analysis, the impact of various treatments and organic fertilizer enhanced with Azospirillium and BPF (Table 2) was examined, revealing that the growth and yield of the Bisi 816 variety surpassed that of Pioneer 21 and Pertiwi. The plant height and leaf count of the Bisi 816 variety exhibited significant differences between Pioneer 21 and Pertiwi, with Pioneer 21 not showing a substantial difference from Pertiwi. Bisi 816 recorded the tallest plant height and highest leaf count at 155.89 cm and 14.44 leaves, respectively, followed by Pertiwi at 140.67 cm and 13.44 leaves and Pioneer 21 at 136.33 cm and 13.11 leaves.

Table 2. BNJ test of the effect of variety treatment and organic fertilizer enriched with Azospirillium and BPF on the observed variables

Treatment	Plant Height (cm)	Number of leaves (pieces)	Cob length (cm)	Cob diameter (cm)	Number of seeds per cob (fruit)	Weight of 1000 seeds (g)	Ear weight per plant (g)	Cob weight per plot (kg)
---Varieties -----								
Pioneer 21	136,33 a	13,11 a	14,41 a	4,32 a	284,89 a	304,22 a	108,89 a	2,92 a
Bisi 816	155,89 b	14,44 b	16,44 c	4,85 c	330,44 b	320,78 c	124,67 b	3,72 c
Pertiwi	140,67 a	13,44 a	15,67 b	4,62 b	318,78 b	313,00 b	112,89 a	3,38 b
BNJ 0,05=	6,32	0,59	0,71	0,11	25,95	6,22	7,90	0,22
----- Azospirillium and BPF enriched organic fertilizer ------								
100 kg/ha	139,56 a	12,89 a	14,44 a	4,33 a	282,22 a	259,78 a	106,56 a	2,99 a
300 kg/ha	149,89 b	14,55 c	16,67 c	4,83 c	341,56 c	332,78 c	125,33 c	3,76 c
500 kg/ha	143,33 a	13,56 b	15,44 b	14,63 b	310,33 b	309,44 b	114,56 b	1,27 b
BNJ 0,05=	6,32	0,59	0,71	0,11	25,95	6,22	7,90	0,22

Note: The same notation in the same column means not significantly different

The Bisi 816 variety exhibits significant differences in ear length, ear diameter, number of seeds per ear, weight of 1000 seeds, ear weight per planting, and ear weight per plot compared to Pioneer 21 and Pertiwi. However, the number of seeds per ear of the Bisi 816 variety is the highest among the three, with 330.44 units, statistically similar to Pertiwi at 318.78 units. At the same time, Pioneer 21 has the lowest count at 284.89 units, showing a significant difference from Bisi 816 and Pertiwi. Notably, the Bisi 816 variety also demonstrates the highest cob weight per plot at 3.72 kg, outperforming Pertiwi and Pioneer 21, which weigh 3.38 kg and 2.92 kg, respectively. These findings suggest that the Bisi 816 variety excels in growth and productivity compared to Pioneer 21 and Pertiwi in lowland regions, as highlighted by Karim et al. (2020) in their study on superior hybrid corn varieties characterized by enhanced vegetative growth and productivity.

Variations in diversity and development among different types of hybrid corn are contingent upon the method of hybridization, stability of pure lines, genetics, and ecosystem adaptability. Hence, it is crucial to carefully choose the appropriate hybrid corn variety based on the prevailing environmental conditions (Aristotle et al., 2019; Garfansa et al., 2022; Tabrani et al., 2023). Dewi et al. (2022) suggest that hybrid varieties exhibit superiority by yielding 15% more than open-pollinated varieties.

The organic fertilizer treatment experiment revealed significant differences in plant height and number of corn leaves when applying 300 kg/ha of organic fertilizer instead of 100 kg/ha and 500 kg/ha. Plant height did not significantly differ between the application of 100 kg/ha and 500 kg/ha, while the number of leaves showed a significant variance. The highest plant height and leaf count were observed with 300 kg/ha organic fertilizer, measuring 149.89 cm and 14.55 leaves, respectively. Subsequently, the plant height and leaf count with 500 kg/ha were 143.33 cm and 13.56 leaves, while the lowest values were recorded with 100 kg/ha organic fertilizer at 139.56 cm and 12.89 leaves.

The data on cob length, ear diameter, number of seeds per ear, weight of 1000 seeds, ear weight per plant, and ear weight per plot demonstrate significant differences between the application of organic fertilizer at 300 kg/ha, 100 kg/ha, and 500 kg/ha.

Notably, the application of 300 kg/ha of organic fertilizer resulted in the highest cob weight per plot, measuring 3.76 kg. In comparison, the application of 100 kg/ha yielded a cob weight of 2.99 kg, while the lowest cob weight of 1.27 kg per planting plot was observed with the application of 500 kg/ha. These findings suggest that using organic fertilizer enriched with Azospirillium and BPF at a rate of 300 kg/ha is most effective in promoting the growth and productivity of corn plants in wetland areas. The presence of Azospirillium and BPF in the organic fertilizer enhances the availability of nitrogen (N) and phosphorus (P) elements, facilitating their absorption by plants and stimulating growth rates.

Soil microbes can enhance the accessibility of nitrogen and phosphorus in the soil. Azospirillium fixes nitrogen from the air, making it easier for plants to absorb and produce Indole Acetic Acid (IAA) hormone, which influences root system and growth. Meanwhile, BPF can increase the availability of phosphorus in the soil. Research by Setiawan (2017) showed that applying IAA on seedlings of loquat root shoots resulted in faster shoot growth by 18 days, with 16.5 shoots, 20.8 leaves, and a low seedling mortality rate of 16.7%.

BPF can enhance and optimize the use of phosphorus directly through the exudation of organic acids and phosphatase enzymes that hydrolyze phosphorus, thereby increasing its availability. Plant response to BPF varies depending on soil temperature, humidity, pH, salinity, insoluble P sources, inoculation methods, energy sources, and the microorganism strains used. (Bargaz et al., 2018; Sharma et al., 2013).

The combination of varieties and organic fertilizers enriched with Azospirillium and BPF on the observed variables showed no significant difference, except for the cob diameter parameter (Table 3).

Table 3. BNJ test of the effect of the combination treatment of varieties and organic fertilizers enriched with Azospirillium and BPF on the observed variables

Combination Treatment	Plant Height (cm)	Number of leaves (pieces)	Cob length (cm)	Cob diameter (cm)	Number of seeds per cob (fruit)	Weight of 1000 seeds (g)	Ear weight per plant (g)	Cob weight per plot (kg)
Pioneer 21 by 100 kg/ha	131,33	12,33	13,33	3,90 a	263,33	284,67	100,73	2,65
Pioneer 21 by 300 kg/ha	141,00	14,00	15,67	4,67 bc	305,33	321,67	119,00	3,18
Pioneer 21 by 500 kg/ha	136,67	13,00	14,33	4,40 b	286,00	306,33	107,33	2,93
Bisi 816 by 100 kg/ha	151,00	13,67	15,33	4,70 c	296,67	302,33	115,00	3,26
Bisi 816 by 300 kg/ha	163,33	15,33	17,67	5,03 d	363,00	342,33	135,00	4,24
Bisi 816 by 500 kg/ha	153,33	14,33	16,33	4,83 cd	331,67	317,67	124,00	3,64
Pertiwi by 100 kg/ha	136,33	12,67	14,67	4,40 b	286,67	300,33	104,33	3,04
Pertiwi by 300 kg/ha	145,33	14,33	16,67	4,80 c	356,33	334,33	122,00	3,84
Pertiwi by 500 kg/ha	140,33	13,33	15,67	4,67 bc	313,33	304,33	112,33	3,27
BNJ 0,05=	TN	tn	tn	0,27	tn	tn	tn	tn

Note: The same notation in the same column means not significantly different

The Bisi 816 treatment exhibited the highest plant height and number of leaves, measuring 163.33 cm and 15.33 pieces, respectively, with an application rate of 300 kg/ha. In contrast, the Pioneer 21 treatment showed the lowest values of 131.33 cm and 12.33 pieces with a lower application rate of 100 kg/ha. These differences are believed to be influenced by physiological and genetic factors in the variety's response to organic fertilizer enriched with Azospirillium and BPF. Azospirillum and BPF are crucial in providing additional nitrogen and phosphate in the soil. At the same time, the variety's reaction to organic fertilizer is essential in stimulating and regulating the growth and productivity of corn plants. Research conducted by Rong et al. (2016) on tea plants has shown that using organic fertilizer in agricultural practices can enhance soil carbon and nitrogen accumulation rates, improving tea plant quality. This result is attributed to the ability of organic fertilizer to shape the microbial community, promote beneficial bacteria, and reduce heavy metal content in the soil (Lin et al., 2019). Furthermore, Behera et al. (2014) highlighted the significance of soil microorganisms in the natural phosphorus cycle for plant growth and enhancing mineral nutrition for optimal plant performance (Jacoby et al., 2017).

Based on the study's findings, it was observed that the Bisi 816 variety treated with 300 kg/ha exhibited the most extended cob length and largest cob diameter at 17.67 cm and 5.03 cm, respectively. On the other hand, the Pioneer 21 variety treated with 100 kg/ha had the shortest cob length and most minor cob diameter at 13.33 cm and 3.90 cm, respectively. The cob diameter of the Bisi 816 variety treated with 300 kg/ha, which had the largest cob diameter, showed significant differences compared to all other treatments except for the Bisi 816 variety treated with 500 kg/ha, where the difference was not important. In contrast, the Pioneer 21 variety treated with 100 kg/ha exhibited substantial differences compared to all other treatments. According to Cahya and Herlina (2018), the length and diameter of cobs are affected by the presence of nitrogen elements in the soil.

The Bisi 816 variety treated with 300 kg/ha also had the highest number of seeds per ear at 363.00 pieces per ear, while the Pioneer 21 variety treated with 100 kg/ha had the lowest number of seeds per ear at 263.33 pieces per ear. Idris et al. (2018) suggested that there is a relationship between the number of leaves, ear length, and seed weight per ear, indicating that a higher number of leaves and longer ears result in increased seed weight per ear. Additionally, the ear diameter is correlated with the seed weight per ear, with wider ear diameters leading to greater bean weight per cob.

The Bisi 816 variety exhibited the highest weight of 1000 seeds and cob weight per plant at 342.33 g and 135.00 g, respectively, when treated with a 300 kg/ha dose. In contrast, the Pioneer 21 variety had the lowest weight of 1000 seeds and cob weight per plant at 284.67 g and 100.73 g, respectively, with a 100 kg/ha dose. When organic fertilizer enriched with Azospirillium and BPF was applied at a rate of 300 kg/ha to the Bisi 816 variety, the cob weight per plot reached 4.24 kg (equivalent to 5.65 tons/ha), representing a 60% increase compared to the Pioneer 21 variety under the same fertilizer dose, which yielded 2.65 kg per plot with 100 kg/ha. These results suggest that the optimal dose for enhancing the growth and productivity of the hybrid corn variety Bisi 816 is 300 kg/ha.

The study conducted by Marlina et al. (2018) revealed that utilizing organic fertilizer combined with Azospirillium and BPF on shallots grown in C-type tidal soil can lead to an 85.33 g increase in growth and production, representing a 38.75% rise. Similarly, the research findings by Marlina and Gusmiatun (2020) demonstrated that the application of Azospirillium and BPF fertilizer on soybean crops cultivated in wetlands resulted in a remarkable yield increase of 201.33% and 228.00% when compared to those without biological fertilizer. Furthermore, the outcomes of the study conducted by Marlina et al. (2023) indicated that the use of organic chicken manure fertilizer supplemented with Azospirillium and BPF at a rate of 400 kg/ha could enhance pod weight per plot of peanut plants by 109.31%.

This study's findings indicate no significant improvement in the growth and yield of hybrid corn varieties when the dose of organic fertilizer is increased to 500 kg/ha compared to a dose of 300 kg/ha. It is suspected that adding microorganisms to the organic fertilizer leads to an abundance of nitrogen, phosphate, and potassium elements, which can impact plant growth. However, this higher dose is economically less viable due to the associated costs. On the other hand, a lower dose of 100 kg/ha may not effectively maximize the production of microorganisms to stimulate plant growth. Fukami et al. (2016) suggest that high doses of Azospirillium in plants can result in the excessive secretion of hormones around the roots, inhibiting growth by affecting the plant's root system. Therefore, the application of organic fertilizer enriched with Azospirillum bacteria and phosphate solubilizing bacteria at a rate of 300 kg/ha is sufficient in providing the necessary nitrogen, phosphate, and potassium nutrients for the Bisi 816 variety of corn plants, meeting their specific requirements.

Considering the significant influence and expenses associated with inorganic fertilizers is crucial. To enhance the productivity of corn crops, reduce production costs, improve soil fertility, and safeguard the environment, it is essential to identify suitable varieties for the specific location and utilize organic fertilizers enriched with Azospirillium microbes and the appropriate dosage of BPF. According to Bargaz et al. (2018) and Safitri et al. (2018), microbial-based biological fertilizers play a pivotal role in enhancing fertilization efficiency, soil fertility and health, plant productivity, and the sustainability of agroecosystems.

4. CONCLUSION

The utilization of organic fertilizer supplemented with Azospirillium and BPF microbes on three different hybrid corn types in a wetland environment exhibited the most favorable growth reaction and productivity in the Bisi 816 variety when applied at 300 kg/ha. This resulted in the highest weight of cobs per plot, amounting to 4.24 kg per plot (equivalent to 5.65 tons/ha), signifying a remarkable increase of 60% compared to the Pioneer 21 variety treated with a dosage of 100 kg/ha, which yielded 2.65 kg per plot.

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