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Efficacy of BioNiKPhos Bio-Fertilizer (NARO BHL BF) on Maize Growth and Yield

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Abstract. This study evaluated the effects of BioNiKPhos Bio-fertilizer (NARO BHL BF) on maize growth and yield, with a focus on determining optimal application rates and economic benefits. The research was conducted at NARL Kawanda and AbiZARDI in Arua, using a randomized complete block design (RCBD). Seven treatment levels were applied (T1: control, T2: 5ml, T3: 10ml, T4: 15ml, T5: 20ml, T6: 25ml, T7: 30ml) per 20L of water, across three replications, over two seasons at NARL and one season at AbiZARDI. BioNiKPhos was applied five days before planting to promote bacterial colonization in the soil. The results revealed that application of BioNiKPhos at 20ml per 20L of water significantly improved maize height, leaf length, dry biomass, grain yield, and 1000-seed weight compared to the control, with a remarkable 32% increase in grain yield. Thus, pre-planting application of BioNiKPhos at 20ml per 20L of water was found to be effective in enhancing maize yield by improving soil conditions. Highest value cost ratio (VCR) was obtained from BioNiKPhos at 20ml per 20L of water (2.58). The study recommended application of BioNiKPhos at 20ml per 20L of water as the most agronomically and economically optimum for maize compared to the control.

Keywords: BioNiKPhos, Bio-fertillizer, maize growth, yield, economic benefit.

Introduction

Maize (Zea mays L.) is one of the most important staple crops globally, providing a significant portion of human and animal nutrition. In sub-Saharan Africa, and Uganda in particular, it is the third largest crop cultivated as measured by production volume, trailing only plantains and cassava (UBOS, 2015) Maize also serves as a vital food source, contributing to food security and income generation. However, despite its significance, the productivity of maize is often constrained by soil fertility limitations, particularly the deficiency of essential nutrients like nitrogen and phosphorus (Rusinamhodzi *et al*., 2021). Maize production is dominated by peasant farmers, with 75% of the country's output grown on plots of land that are between 0.2-0.5 hectares (USAID, 2010; Joughin, 2012).

The conventional use of chemical fertilizers, while effective in boosting maize production, has raised concerns due to high costs, environmental degradation, and the depletion of soil health. Smallholder farmers often struggle with these issues, leading to declining maize yields

(Tadesse *et al*., 2020). In this context, there is a growing need to explore eco-friendly and cost-effective alternatives. In an effort to address these challenges, bio-fertilizers have emerged as a sustainable alternative to chemical fertilizers, promoting the uptake of key nutrients while reducing environmental impacts. Through effective research and technology, Bumi Hijau Limited obtained useful micro-organisms primarily Microbe/bacterium Acinetobacter *sp* leading to a soil-friendly, organic solution for improving soil fertility. This micro-organism has the ability to fix atmospheric nitrogen, solubilize phosphorus, and mobilize potassium. This micro-organism is therefore important in the betterment of the soil, environment, and plants. The phosphorus-solubilizing bacteria convert insoluble forms of phosphorus in the soil into soluble forms, facilitating greater plant uptake (Bhattacharyya *et al*., 2020). Recent studies have highlighted the role of bio-fertilizers in sustainable agriculture, showing positive impacts on crop growth and soil health (Mahanty *et al*., 2017; Kumar *et al*., 2022). Specifically, phosphorus-solubilizing bio-fertilizers have been shown to improve phosphorus availability, leading to better crop performance (Sarkar *et al*., 2021).

However, the efficacy of these products can vary depending on soil type, crop variety, and environmental conditions, making field-specific evaluations essential. The study was designed to evaluate the efficacy of BioNiKPhos bio-fertilizer (NARO BHL BF) on the growth and yield of maize under different field conditions. It was to determine the optimal rate of application, growth and yield components and the economic benefits of using BioNiKPhos in maize production.

The study hypotheses that, the application of BioNiKPhos bio-fertilizer will significantly enhance maize growth, yield and profitability compared to control. By conducting this study, we aim to contribute valuable insights into the role of BioNiKPhos in promoting sustainable maize production and enhancing food security in Uganda where soil fertility is a major constraint.

Materials and Methods

Study Site

The study was conducted at two locations in Uganda: The National Agricultural Research Laboratory (NARL) Kawanda and AbiZARDI. At NARL, the experiment ran for two seasons: September–December 2019 and March–June 2020. Kawanda is situated at 0°25'14"N and 32°32'26"E, with an elevation of 1,300 meters above sea level. The area experiences a bimodal rainfall pattern with an average of 1,100 mm annually and temperatures ranging from 18°C to 27°C. The soil type in Kawanda is classified as Haplic Nitisols. AbiZARDI hosted the experiment from March to June 2021. It is located at 3.077044°N and 30.945122°E, at an elevation of 1,207 meters above sea level. AbiZARDI experiences a unimodal rainfall pattern, with a wet season lasting from April to November and an average annual rainfall of 1,200 mm. The average temperature is around 30°C. The soil type in this region is Albic Plinthosols.

Field Establishment

The experimental fields were prepared by clearing with local tools, followed by primary and secondary tillage using a disc harrow to create a fine seedbed for planting maize. The experiment followed a randomized complete block design (RCBD) with seven treatments, replicated three times. The factors under study were the dosage of BioNiKPhos application and the profitability. The treatments included T1: Control, T2: 25% (5 ml/20 l) BioNiKPhos, T3: 50% (10 ml/20 l), T4: 75% (15 ml/20 l), T5: 100% (20 ml/20 l), T6: 125% (25 ml/20 l), and T7: 150% (30 ml/20 l). Each plot measured 2 x 3 meters, with a 1-meter gap between plots. The Bio-fertillizer was applied five days before planting to allow for colonization. Each hole received approximately 50ml of diluted BioNiKPhos Bio-fertillizer. The maize seeds (Longe 5 variety) were sourced from FICA Seeds Limited with 85% germination rate according to the seed certification card.

Field Management

Weeding was done by hand twice, once when plants were at knee height and again before the tasseling stage. Weekly field scouting was performed to monitor for pests, with Nugro Bio activator applied at 20 ml/20 litres of water to control fall armyworm infestations.

Data Collection

Growth and yield parameters were recorded monthly from 30 days after sowing until harvest. Five plants were tagged per plot, excluding border plants to minimize environmental variations. Measurements included plant height, leaf length, and leaf width. Plant height was measured vertically based on the distance from the stem base to the highest growing point of leaf segregation. The leaf length was measured from the apex of the blade to the base of the petiole, and width was measured at the widest point perpendicular to the longitudinal axis of the leaf using a ruler with 0.1 cm precision. Yield parameters such as cob weight, grain weight, and 1,000 seed weight were recorded after harvest from the tagged plants. Dry matter production was also measured, and yield was converted to per hectare estimates.

Analysis

The economic analysis followed CIMMYT (1988) procedures. Costs for different levels of BioNiKPhos and income from the treatments were calculated based on prevailing market values during the trials. The net return was obtained by subtracting total variable costs from gross returns. A value cost ratio was computed by dividing total gross returns by total variable costs. Data were statistically analysed using Genstat 64-bit Release 18.2. Analysis of variance (ANOVA) was used to determine overall significance, and the least significant difference (LSD) test ($P = 0.05$) was applied to compare treatment means.

Results

Growth Components

A conclusive trend was observed among the treatments that showed differences, with the control having the lowest maize plant height, leaf length, and leaf diameter. The plant height, leaf length, and leaf diameter significantly ($P < 0.05$) differed between the treatments, where the highest was under T5; application of Bio-fertilizer at 20ml per 20L of water, while the lowest was under control (Table 1). Treatments T6 (25ml) and T7 (30ml) did not significantly enhance plant height, leaf length, or leaf diameter compared to T5 (20ml). This indicates that increasing the Bio-fertilizer application beyond 20ml per 20L of water did not yield additional benefits for these specific growth parameters. Overall, the optimal application rate for promoting maize growth appeared to be 20ml per 20L of water.

Yield Components

The application of treatments positively and notably influenced the grain yield and yield components of maize (Table 2). Total biomass production ranged from 14,183 to 27,867 kg/ha, with the highest recorded under T5 application of BioNiKPhos at 20 ml per 20 L of water, and the lowest recorded under T1 control. The highest grain yield was also noted under T5 application of BioNiKPhos at 20 ml per 20 L of water (5,453 kg/ha). This yield differed significantly ($p < 0.05$) from those recorded at T2, T3, T4 as well as T1 control. Additionally, the 1000 seed weight was highest under T5 application of BioNiKPhos at 20 ml per 20ml of water which significantly differed ($p < 0.05$) compared to the treatments of T2, T3, T4 as well as T1 control. Overall, the dry biomass, grain weight, and 1000-seed weight per plant are important traits that significantly differed due to the treatments, with the highest values recorded under the application of BioNiKPhos at 20 ml per 20 L of water.

Economic Analysis

The economic analysis of the performance of different levels of BioNiKPhos for maize is presented in Table 3. The per hectare expenditure on various levels of BioNiKPhos treatments showed the highest expenditure value of 1,518,300 UGX for BioNiKPhos at 30 ml per 20 L of water (T7), followed by 1,492,600 UGX for BioNiKPhos at 25 ml per 20 L of water (T6). The lowest expenses were recorded at 1,235,000 UGX for BioNiKPhos at 5 ml per 20 L of water (T1), 1,330,000 UGX for BioNiKPhos at 10 ml per 20 L of water (T2), and 1,390,000 UGX for BioNiKPhos at 15 ml per 20 L of water (T3). The maximum income of 3,817,100 UGX was obtained from the application of BioNiKPhos at the rate of 20 ml per 20 L of water (T5), as it yielded the highest grain yield. This was followed by T6 (25 ml per 20 L of water) with an income of 3,623,900 UGX. The lowest income was recorded from the control treatment (T1), which yielded 2,473,100 UGX. The net profit was highest with BioNiKPhos at 20 ml per 20 L of water (T5), amounting to 2,334,900 UGX, while the lowest profit was observed with the control (T1), at 1,238,100 UGX. Additionally, the value (total income) to cost (total expenditure) ratio (VCR) was determined to compare various BioNiKPhos levels (Table 3). The data showed that the highest VCR was obtained from BioNiKPhos at 20 ml per 20 L of water (2.58), while the lowest was from the control (2.00).

Table 1. Combined Maize Growth Parameters under different doses of BioNiKPhos

		Plant Height (cm)	Leaf Length (cm)	Leaf Diameter (cm)
T1	Control	167.5 a	81.78 a	8.94 a
T2	5 ml BioNiKPhos	181.8 b	90.85 b	10.50 b
T3	10 ml BioNiKPhos	191.3 bc	93.44 bc	10.90 bc
T4	15 ml BioNiKPhos	199.8 cd	99.30 cd	11.19 cd
T5	20 ml BioNiKPhos	210.7 d	105.44 e	11.99 e
T6	25 ml BioNiKPhos	206.0 d	101.85 de	11.45 cde
T7	30 ml BioNiKPhos	206.1 d	101.81 de	11.58 de
Mean		194.7	96.35	10.937
s.e		4.98	1.79	0.4812
CV %k.		2.6	1.9	4.4

Mean values followed by different letters in a column are significantly different (P<0.05).

Table 2. Combined Maize Yield Parameters under different doses of BioNiKPhos Bio-fertillizer

		Dry Biomass (kg/ha)	Grain weight (kg/ha)	1000 seed weight (gm)
T1	Control	14183 a	3533 a	318.1 a
T2	5 ml BioNiKPhos	17459 b	4144	349.0 b
T3	10 ml BioNiKPhos	19581 c	4389 bc	363.2 bc
T4	15 ml BioNiKPhos	21739 d	4714 cd	380.7 cd
T5	20 ml BioNiKPhos	27867 f	5453 e	380.7 cd
T6	25 ml BioNiKPhos	25225 e	5177 de	411.5 ef
T7	30 ml BioNiKPhos	24538 e	4984 de	396.9 de
Mean		21,513	4628	378.5
s.e		789.1	79.1	12.68
CV %		3.7	1.7	3.4

Mean values followed by different letters in a column are significantly different (P<0.05).

Table 3. The Economic Comparison of Different levels of BioNiKPhos Bio-fertilizer for Maize Production.

Treatments	Variable costs (UGX/ ha^{-1})	Grain yield (kg/ha^{-1})	Gross return (UGX/ha^{-1})	Net return (UGX/ha^{-1})	Value cost ratio
T1: Control	1,235,000	3,533	2,473,100	1,238,100	2.00
T2: 5ml BioNiKPhos	1,330,000	4,144	2,900,800	1,570,800	2.18
T3: 10ml BioNiKPhos	1,390,000	4,389	3,072,300	1,682,300	2.21
T4: 15ml BioNiKPhos	1,421,000	4,714	3,299,800	1,878,800	2.32
T5: 20ml BioNiKPhos	1,482,200	5,453	3,817,100	2,334,900	2.58
T6: 25ml BioNiKPhos	1,492,600	5,177	3,623,900	2,131,300	2.43
T7: 30ml BioNiKPhos	1,518,300	4,984	3,488,800	1,970,500	2.30

Discussion

The increase in growth components compared to the control may be attributed to the effect of Microbe/bacterium Acinetobacter sp in the BioNiKPhos Bio-fertillizer, which colonize the soil, thereby directly releasing nutrients or enhancing the availability of nutrients for plants. This aligns with Vessey (2003), who defined Bio-fertilizers as substances that contain living microorganisms. When applied to seeds, plant surfaces, or soil, they colonize the soil and promote growth by increasing nutrient availability. Similarly, Ali et al. (2012) reported that the application of plant growth-promoting rhizobacteria increased plant height and biological yield. The growth observed in maize may be attributed to enhanced nutrient uptake and increased seed yield, as reported by Etesami et al. (2021) in the presence of Bio-fertilizers.

The positive effect of BioNiKPhos Bio-fertillizer may stem from its ability to increase nitrogen availability and the availability of phosphorus and other nutrients. The increase in 1000-seed weight can be attributed to better transfer of photosynthetic substances under the Bio-fertillizer treatment. It can be concluded that the photosynthetic capacity of plants increased due to enhanced nitrogen and phosphorus nutrition, as reported by Etesami et al. (2020). Significant increases in grain yield and biomass yield were observed across all treatments compared to the control.

The net benefit illustrates the relationship between the varying cost of production and the net benefit obtained from the treatments, revealing how benefits from an investment increase. The results indicated that BioNiKPhos at 20 ml per 20 L of water provided the best economic benefit compared to other levels and the control. These findings are supported by Rout et al. (2001), who found that Azotobacter, Azospirillum, and their combinations yielded more than untreated maize.

Microbial communities play an important role in agricultural systems due to their involvement in various soil processes and functions. Recently, beneficial plant-microbiome associations have been exploited to improve crop production. Beneficial plant microbes enhance soil properties, increase the availability of soil nutrients, improve resistance to pathogens, and produce plant growth-stimulating hormones, as noted by Wasai and Minamisawa (2018).

Conclusion

The application of BioNiKPhos Bio-fertillizer significantly enhanced the growth and yield components of maize, as compared to the control. This improvement can be attributed to the role of microorganisms in the Bio-fertillizer, which enhance nutrient availability and uptake. The results demonstrated that BioNiKPhos at a rate of 20 ml per 20 L of water was the most effective, producing the highest grain yield, 1000-seed weight, and overall biomass. Economic analysis showed that this level of application also provided the best net benefit and value-to-cost ratio, making it a cost-effective solution for improving maize production. The findings align with previous studies that highlight the positive impact of plant growth-promoting rhizobacteria, such as Azotobacter and Azospirillum, in promoting crop growth and development.

In conclusion, BioNiKPhos Bio-fertillizer, especially at the 20 ml per 20 L application rate, is a promising sustainable input for maize production, enhancing both yield and economic returns while promoting healthier soil ecosystems.

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