Effect of BioNiK-Phos and Phosphorus-based fertilizers on yield of hybrid sunflower in Northern Uganda

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Abstract

The sunflower oil seed industry is one of the promising business sectors in Uganda for both domestic and export markets. Both open-pollinated varieties and hybrids are grown in Uganda. Average yields of open-pollinated varieties in farmers' fields range from about 750-900 kg ha^{-1} and hybrids about 2,000 kg/ha. For high production and productivity, sunflower requires fertilizers. The objective of this study was to establish the effects of BioNik-Phos and di-ammonium phosphate (DAP) fertilizers micro-dosing on yield of sunflower hybrid (PAN 5057) in Northern Uganda in 2021b and 2022a seasons. Field experiments were laid using a randomized complete block design (RCBD) with 4 replications per location in 3 locations in Alebtong District (Abako, Aloi and Angeta). There were significant ($P \leq 0.05$) differences in sunflower yields across treatments in all the three locations (Abako: 1,250-3,524 kg ha^{-1}, Aloi: 1,274-3,488 kg ha^{-1} and Angeta: 1,238-3,369 kg ha^{-1}) in 2021 with or without micro-dosing with BioNiK-Phos and DAP fertilizer. A similar trend was recorded for 2022a season (Abako: 1,268-3,500 kg ha^{-1}, Aloi: 1,357-3,607 kg ha^{-1} and Angeta: 1,286-3,417 kg ha^{-1}). The effect of DAP fertilizer micro-dosing on sunflower hybrid productivity was three folds in both years. BioNiK-Phos effect was, however, not significantly different ($P \leq 0.05$) from the control. This is the first report of the effect of BioNiK-Phos and DAP fertilizers micro-dosing of sunflower in Northern Uganda.

Keywords: bioNiK-Phos, di-ammonium phosphate, fertilizer, sunflower, micro-dosing.

Efeito de fertilizantes à base de BioNiK-Phos e Fósforo na produção de girassol híbrido no Norte de Uganda

Resumo

A indústria de sementes de óleo de girassol é um dos sectores empresariais promissores no Uganda, tanto para o mercado interno como para o de exportação. Tanto variedades de polinização aberta como híbridos são cultivados em Uganda. Os rendimentos médios das variedades de polinização aberta nos campos dos agricultores variam entre cerca de 750-900 kg ha^{-1} e os híbridos cerca de 2.000 kg ha^{-1}. Para alta produção e produtividade, o girassol necessita de fertilizantes. O objetivo deste estudo foi estabelecer os efeitos da microdosagem de fertilizantes BioNik-Phos e fosfato diamônico (*DAP*) no rendimento do híbrido de girassol (PAN 5057) no Norte de Uganda nas temporadas 2021b e 2022a. Os experimentos de campo foram realizados usando um desenho de blocos completos aleatórios (DBCA) com 4 repetições por local em 3 locais no distrito de Alebtong (Abako, Aloi e Angeta). Houve diferenças significativas ($P \leq 0,05$) na produção de girassol entre os tratamentos em todos os três locais (Abako: 1.250-3.524 kg ha^{-1}, Aloi: 1.274-3.488 kg ha^{-1} e Angeta: 1.238-3.369 kg ha^{-1}) em 2021 com ou sem microdosagem com BioNiK-Phos e fertilizante *DAP*. Uma tendência semelhante foi registada para a época 2022a (Abako: 1.268-3.500 kg ha^{-1}, Aloi: 1.357-3.607 kg ha^{-1} e Angeta: 1.286-3.417 kg ha^{-1}). O efeito da microdosagem de fertilizante *DAP* na produtividade do híbrido de girassol foi três vezes maior em ambos os anos. O efeito BioNiK-Phos, no entanto, não foi significativamente diferente ($P \leq 0,05$) do controle. Este é o primeiro relato do efeito da microdosagem de fertilizantes BioNiK-Phos e *DAP* em girassol no Norte de Uganda.

Palavras-chave: bioNiK-Phos, fosfato di-Amônio, fertilizante, girassol, microdosagem.

1. Introduction

Sunflower (*Helianthus annuus* L.) is the world`s fourth largest oil seed crop (Adeleke; Babalola, 2020). Global production has been growing steadily in the last 35 years. The largest producers in 2019 were Ukraine, Russia, Argentina and Romania, and the largest producer in Africa was Tanzania (Khondoker et al., 2022). In Uganda, sunflower is an important oil crop. The crop is cultivated in the eastern and northern parts of Uganda. The sunflower sub-sector presents good business opportunities in Uganda (Kamoga, 2011). Land under sunflower production in Uganda is approximately 593,000 acres.

In Uganda, the area under sunflower production has been increasing (Elobu et al., 2013). Sunflower yield, however, has remained low in the country, despite the increase in production. A number of factors have been reported to be responsible for the low yield including poor agronomic practices and lack of high-yielding varieties (Anyanga, 2003). On-station yields of open-pollinated varieties range from 1,500-1,800 kg/ha, while the average on-farm yield ranges from 750-900 kg ha^{-1} (Anyanga, 2003). Currently, there are a number of high yielding sunflower hybrids in Uganda, but their yields in farmers` gardens are low due to poor agronomic practices and declining soil fertility.

It has been reported that fertilization with phosphorous-based fertilizer increases growth and yield in sunflower (Abbadi et al., 2011; Sadozai et al., 2013). According to Soomro et al. (2018), lack of phosphorous in sunflower causes reduced growth rate, delay in flowering, poor filling of achenes, and reduction oil content. The effect is worse if the phosphorous deficiency occurs at the beginning of the vegetative cycle (Prado et al., 2006). It is, therefore, important to test the soil for phosphorous to guide the amount of phosphorous-based fertilizer to be used in sunflower growing. The application of phosphorous should however, focus on use efficiency (Veneklaas et al., 2012) to reduce the environmental impacts which can result from excessive use of this fertilizer (Godfray et al., 2010).

Phosphorous availability to plants is a key factor for sustainable agriculture (2010). According to McGill (2012), agriculture is highly dependent on phosphorus, a non-renewable resource. Hence, phosphorous use in agriculture should target maximizing efficiency. For Northern Uganda, studies on the response of sunflower hybrid to phosphorous-based fertilizer micro dosing under field conditions is needed. BioNiK-Phos contains biofertilizer microbe/bacterium *Acinetobacter* spp, with ability to fix atmospheric nitrogen and dissolve phosphate in the soil for plant usage. Thus, we hypothesized that BioNiK-Phos and Di-Ammonium Phosphate fertilization increase sunflower seed yield.

2. Materials and Methods

2.1 Study area

The study was conducted in 2021b (August to November) and 2022a (April to July) seasons in 3 Sub-counties (locations) in Alebtong District. The 3 Sub-counties were Aloi, Abako and Angeta, Uganda. The three Sub-counties were used in both growing seasons.

2.2 Plant materials

Certified seed of hybrid sunflower (PAN 5057) and Di-Ammonium Phosphate (DAP) fertilizer were procured from Agro Wonders input shop in Lira City. In addition, BioNiK-Phos fertilizer was sourced from NARO Holdings Ltd. 200 mL of BioNiK-Phos was added to 20 L of water, mixed well and the mixture was transferred into clean containers.

2.3 Experimental design

A randomized complete block design with 3 replications was adopted for the field experiments. Three treatments: 40 kg ha^{-1} DAP fertilizer, 6.0 L ha^{-1} of BioNiK-Phos and no treatment with DAP or BioNiK-Phos as a control were randomly assigned to plots within each block. The plot size was 20 m by 10 m and sunflower spacing of 75 cm by 30 cm was used. DAP fertilizer was broadcasted at planting time at the rate of 40 kg ha^{-1} to represent the micro-dosed plots, BioNiK-Phos was applied evenly on planting holes immediately after planting using a watering can.

One plot in each block was left without DAP micro-dosing or BioNiK-Phos to act as a control. DAP fertilizer broadcast was done between lines of sunflower. The choice to use DAP as a fertilizer for this study didn’t result from soil testing, but from the results of cowpeas and groundnut study using DAP in the same region which indicated that phosphorus is a major limiting nutrient in soils within Northern Uganda (Nyamaizi et al., 2020; Abaca et al., 2023). BioNiK-Phos fertilizer was included because it contains biofertilizer bacterium, *Acinetobacter* species, with ability to fix atmospheric nitrogen and dissolve phosphate in the soil for plant usage. 2021b season experiment was planted in April 2021 and 2022b season experiment in August 2018. Recommended agronomic practices were followed. Data was collected on plot yield. Plot yield data was used to estimate yield in kg ha^{-1}.

2.4 Statistical analysis

Data on sunflower yield in kg/ha was analysed by analysis of variance (ANOVA) assuming normal distribution. Data analysis was performed using GENSTAT statistical package 16th edition. The data was subjected to ANOVA, and residual plots were used to check ANOVA assumptions. Hypotheses were rejected at $P \leq 0.05$ and means compared by Turkey's test. Mean values of results were presented.

3. Results

The result of the effect of BioNik-Phos bio-fertilizer and DAP fertilizer micro-dosing is presented in (Table 1). There were significant ($P \leq 0.05$) differences in sunflower yields across treatments in all the three locations (Table 1).

Table 1. ANOVA for the effect of BioNik-Phos bio-fertilizer and DAP fertilizer micro-dosing on yield of hybrid sunflower (PAN 5057).

Source of variation	2021 Trial					2022 Trial			
	d.f	s.s.	m.s.	v.r.	F pr.	s.s.	m.s.	v.r.	F pr.
Replication	3	328231	109410	9.34		190271	63424	2.53	
Location	2	64374	32187	2.75	0.084	54453	27227	1.09	0.353
Treatment	2	37658478	18829239	1607.17	<.001	36306154	18153077	724.27	<.001
Location* treatment	4	25195	6299	0.54	0.709	46926	11732	0.47	0.759
Residual	24	281179	11716			601537	25064		
Total	35	38357458				37199342			

Note: d.f = degrees of freedom, s.s = sum of squares, m.s = mean square, v.r = variation, Fpr = F-statistics.

Hybrid PAN 5057 treated with DAP fertilizer yielded 3,524 kg ha^{-1}, 3,488 kg ha^{-1} and 3,369 kg ha^{-1} in Abako, Aloi and Angeta, respectively in 2021. Again in 2022, hybrid PAN 5057 micro-dozed with DAP fertilizer had the highest yield across locations with 3,500 kg ha^{-1}, 3,607 kg ha^{-1} and 3,417 kg ha^{-1} in Abako, Aloi and Angeta, respectively. Bio-NikPhos treatment effect was, however, not significantly different ($P \leq 0.05$) from the control across locations (Table 2).

Table 2. Variation in yields of sunflower hybrid (5057) treated with or without DAP and BioNik-Phos fertilizers across locations.

Location	2021 Trial				2022 Trial			
	Estimated yield per hectare in kg				Estimated yield per hectare in kg			
	Bio-fert	DAP	Control	LSD (5%)	Bio-fert	DAP	Control	LSD (5%)
Abako	1393	3524	1250	243.7	1500	3500	1268	321.1
Aloi	1333	3488	1274	143.4	1452	3607	1357	265.9
Angeta	1262	3369	1238	126.6	1429	3417	1286	183.7
LSD (5%)	NS	NS	NS		NS	NS	NS	
CV (%)	11	3.5	7.5		2.8	5.4	7.3	

Note: Bio-fert = BioNiK-Phos fertilizer, DAP = Di-Ammonium Phosphate fertilizer, LSD = Least Significant Difference, CV=Coefficient of variation, NS = Not significant, Control=Not treated with either BioNiK-Phos or Di-Ammonium Phosphate fertilizer.

The yield of plants treated with Bio-NikPhos were 1,393 kg ha^{-1}, 1,333 kg ha^{-1} and 1,262 kg ha^{-1} in Abako, Aloi and Angeta respectively in 2021, and 1,500 kg ha^{-1}, 1,452 kg ha^{-1} and 1,429 kg ha^{-1} in Abako, Aloi and Angeta respectively in 2022. The yield performance of untreated control across the three locations in 2021 were 1,250 kg ha^{-1}, 1,274 kg ha^{-1} and 1,238 kg ha^{-1} in Abako, Aloi and Angeta, respectively, and 1,268 kg ha^{-1}, 1,357 kg ha^{-1} and 1,286 kg ha^{-1} respectively in 2022. Overall, The effect of DAP fertilizer micro-dosing on sunflower hybrid (PAN 5057) yield was three folds. There were no significant differences in yield response within locations for BioNiK-Phos, DAP and untreated control.

4. Discussion

Sunflower yield varied significantly ($P \leq 0.05$) across treatments. The highest yield in all the test locations was recorded for DAP fertilizer. The average yield of sunflower hybrid PAN (5057) was 3460 kg ha^{-1} and 3.508 kg ha^{-1} in 2021b season and 2022b season, respectively. Application of DAP fertilizer in sunflower hybrid (5057) at a rate of 40 kg ha^{-1} at planting time increased yield in the three test locations three folds. The increase in yield could be attributed to the release of PO^{3-} and NH^{4+} in the soil.

The increase in yield in crops following P-fertilizer applications has been reported for groundnuts (Abaca et al., 2022) and maize (Murendo; Wollni, 2015). This finding suggests sunflower hybrid PAN 5057 is adapted to these locations, only that its yield was being limited by the soil nutrients including Phosphorous. The implication of this finding is that soil testing, soil fertility management and improvement could be used as a strategy for increasing hybrid sunflower productivity in northern Uganda.

Oliveira et al. (2022) described the benefits of Phosphorus fertilization for sunflower. Other studies have also shown that phosphorus application promotes growth and increases sunflower yield (Abaca et al., 2022; Sadozai et al., 2022). Lack of Phosphorus has also been reported to affect growth, delay flowering and cause less filling of the achenes (Padro, 2006; Soomro et al., 2018). There is, therefore, the need to promote the use of P-based fertilizer micro-dosing in sunflower growing in dry areas of Northern Uganda, where declining soil fertility is a major constraint to sunflower production.

The high efficiency of phosphorus use in a low dose (40 kg ha^{-1}) in the current study indicates that the hybrid sunflower (PAN 5057) has greater adaptation to conditions of low phosphorus concentration. Plant response to phosphate fertilization is related to its availability in the soil. Applications of large doses of Phosphorous-based fertilizers have been reported to result in sorption, making Phosphorous unavailable to plants. Hence, the need to apply Phosphorous in small doses to make it available to plants.

BioNiK-Phos used in the current study contains bio-fertilizer bacterium, *Acinetobacter* species, a plant-growth promoting rhizobacteria. Several studies have demonstrated the multiple functional traits of bacteria of the genus *Acinetobacter* for plant growth promotion including siderophore production, calcium phosphate solubilization, auxin synthesis and antibiosis and (Oliveira-Longatti et al., 2014; Kandel et al., 2017). Velázquez et al. (2008), reported occurrence of *Acinetobacter* in association with the rhizosphere and as endophytic bacteria of sugarcane roots stems and leaves.

In the current study BioNiK-Phos did not significantly increase yield of sunflower. The lack of effect of BioNiK-Phos on sunflower yield is an indication of lack of interaction between the *Acinetobacter* spp. in the BioNiK-Phos and the sunflower hybrid (PAN 5057). This could have been due to failure of the *Acinetobacter* spp. to adhere to hybrid sunflower (PAN 5057) roots, as a result the bacteria population applied failed to survive under micro-propagation conditions. More research, however, is needed to study the interaction between BioNiK-Phos and sunflower hybrids under controlled conditions.

5. Conclusions

Di-Ammonium Phosphate fertilizer micro-dosing (40 kg ha^{-1}) increased the seed yield of sunflower hybrid (PAN 5057) by three folds. This finding illustrates the role of soil fertility management in enhancing sunflower hybrid productivity. Thus, sunflower micro-dosing with Di-Ammonium Phosphate, combined with good agronomic practice can be used to increase sunflower production in Northern Uganda. More studies are however, still needed to compare the effect of Di-Ammonium Phosphate with other Phosphorus-based fertilizers in Uganda.

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7. Authors' Contributions

Kumakech Alfred: responsible for the ideas, formulation, carrying out experiments, statistical analysis and writing the original draft. Laban. *Frank Turyagyenda*: supervision and review of the research work.

8. Conflicts of Interest

No conflicts of interest.

9. Ethics Approval

Not applicable.

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