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EFFECTS OF PROPAGATION METHODS AND NITROGEN FERTILIZER ON PERFORMANCE OF GINGER (*Zingiber officinale* L.) IN THE SOUTHERN GUINEA SAVANNAH AGROECOLOGY OF NIGERIA

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ABSTRACT

A field experiment was conducted to evaluate the effects of propagation method and nitrogen source on growth and yield of ginger (*Zingiber officinale*). Two propagation methods rhizome seeds and rhizome seedlings raised from rhizome seeds for one month—were combined with four nitrogen sources: 100% NPK (15:15:15) at 933 kg ha^{-1}; Supergro organic liquid fertilizer at 2.9 mL L^{-1}; 100% *Tithonia* compost at 5.2 t ha^{-1} and a 50:50 combination of *Tithonia* compost and NPK (2.6 t ha^{-1} + 466.5 kg ha^{-1}). Each treatment supplied 140 kg N ha^{-1}, while the control received no nitrogen fertilizer. The 2 × 5 factorial experiment was arranged in a randomized complete block design with three replications. Rhizome seeds produced superior results compared to rhizome seedlings in plant height (63.70 cm and 35.84 cm), number of leaves/tiller (24.89 and 16.47), leaf area (51.59 cm^2 and 31.02 cm^2), number of tillers/plant (14.52 and 6.86), fresh rhizome yield (9.92 t ha^{-1} and 7.77 t ha^{-1}), dry rhizome yield (0.12 t ha^{-1} and 0.10 t ha^{-1}) and dry matter accumulation (1.17 g m^{-2} day^{-1} and 0.90 g m^{-2} day^{-1}). Among the nitrogen sources, the 50% *Tithonia* compost + 50% NPK treatment showed the highest values for plant height (57.83 cm), number of leaves/tiller (24.75), leaf area (57.93 cm^2), number of tillers/plant (13.65), fresh yield (15.91 t ha^{-1}), dry yield (0.20 t ha^{-1}), and dry matter accumulation (2.03 g m^{-2} day^{-1}). The interaction of propagation method and nitrogen source was significant for all parameters except for dry matter accumulation. It is recommended that 25–30 g rhizome seed fertilized with 50% *Tithonia* compost and 50% NPK be used for optimum growth and yield of ginger in the study area.

Keywords: Ginger; Growth; Compost; Nitrogen supply; Multiplication method.

INTRODUCTION

Ginger (*Zingiber officinale* L.) is an economically and nutritionally important crop widely cultivated in the tropical and subtropical regions, including Nigeria, where it contributes significantly to household incomes and export revenues (Okwuowulu *et al*., 2021). The productivity of ginger in Nigeria however remains suboptimal due to poor agronomic practices, including ineffective propagation techniques and improper fertilizer application (Eze and Onwubiko, 2020).

Vegetative propagation using rhizome segments is the predominant method for ginger cultivation. The size and physiological maturity of the planting material are crucial factors affecting sprouting, establishment and final yield (Adeyemi *et al*., 2018). Studies have shown that larger and well-cured rhizome seeds tend to produce more vigorous sprouts and higher yields compared to smaller or freshly harvested ones (Akinyemi *et al*., 2019). Nitrogen, an essential macronutrient, influences chlorophyll formation, vegetative growth, and rhizome development in ginger. The source and form of nitrogen fertilizers significantly impact nitrogen-use efficiency and plant performance (Okonkwo *et al*., 2022). Organic sources, such as poultry manure and inorganic forms like urea or ammonium sulfate, differ in their availability, uptake and residual effects on soil fertility (Musa *et al*., 2023). Given the growing demand for ginger both locally and internationally, there is a pressing need to optimize agronomic practices for sustainable productivity. This study aimed to assess the combined effects of propagation methods and nitrogen fertilizer sources on the growth and yield of ginger to determine the better propagation method with nitrogen fertilizer source.

MATERIALS AND METHODS

The experiment was conducted at the experimental field of the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso in 2024 and 2025. Ogbomoso lies on latitude 8^{o} 08'N and longitude 4^{o} 14'E in the Southern Guinea Savanna agro-ecological zone of Nigeria. It is characterized by mixed grassland and scattered trees. It supports both crop cultivation and livestock grazing (Owoade, 2021). The climate of the environment of Ogbomoso can be expressed as fairly hot, tropical with marked wet and dry seasons. There is usually a bit of harmattan between these seasons. Mean annual rainfall is about 1400 mm and bimodal in distribution with peaks in June and September and a break in August. Mean annual temperature is about 27^{0}C (Owoade, 2021).

Treatments were: ginger rhizome seeds ranging from 25 - 30 g sizes containing 2 – 3 buds (Ravindran and Babu, 2005); rhizome seedlings raised from rhizome seeds of 25 – 30 g sizes, and nitrogen sources. The rhizome seeds, obtained from National Root Crop Research Institute, Kaduna State, Nigeria) were selected and weighed using Falcon electronic scale BL 3002 and thereafter disinfected by rinsing in 1 L water containing 20 g Mancozeb powder (FAO, 2017), while the rhizome seedlings were raised from the rhizome seeds in the nursery for one month. The nitrogen sources used were 100% NPK 15:15:15 at 933 kg/ha, organic liquid fertilizer known as Supergro at 2.9 mL/L, 100% Tithonia compost at 5.2 tons/ha, and 50% Tithonia compost + 50% NPK at 2.6 tons/ha + 466.5 kg/ha). The nitrogen sources were applied at a rate of 140 kg N/ha each (Asafa and Akanbi, 2018), while the control received no fertilizer treatment. NPK fertilizer contained 15% each of nitrogen, phosphorus and potassium; Super Gro contained

72, 45 and 15 g/L of nitrogen, phosphorus and potassium (equivalent to 7.2%, 4.5% and 1.5% respectively) and Tithonia compost contained 5.2% nitrogen (Table 1).

The yellow variety of ginger (UG1) obtained from the National Root Crop Research Institute Substation, Kaschia, Kaduna, Kaduna State, was used for the study, while the fertilizer materials that served as the nitrogen sources were procured from an Agro-allied store in Ogbomoso. The Tithonia compost was composted from Tithonia plant biomass and poultry manure in the ratio 3:1 dried weight (Akanbi, 2002). The samples were analysed to determine the essential nutrient compositions (Table 1). Total Nitrogen, Phosphorus (P) and Potassium (K) composition was determined using methods described by Juo (1978). Pre-planting soil analysis was done to determine the physical and chemical properties of the soil before planting. Soil samples were collected from a depth of 0–20 cm to analyze soil texture and chemical properties (IITA, 1982). Particle size was assessed using the hydrometer method (Gee and Or, 2002). Soil pH was measured in water at a 1:1 ratio, and available phosphorus was determined using the Bray P-1 method (Bray & Kurtz, 1945). Organic carbon content was evaluated via the dichromate wet oxidation method (Nelson & Sommers, 1982). Exchangeable potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg) were extracted with 1 M ammonium acetate at pH 7 and quantified through atomic absorption spectrophotometry. Effective Cation Exchange Capacity (ECEC) was calculated by summing exchangeable bases and acidity. Cation Exchange Capacity (CEC) was determined using the neutral 1 N ammonium acetate method, and Total Nitrogen was analyzed following the Macro Kjeldahl method as outlined by Bremner & Mulvaney (1982).

The experimental field was manually cleared and laid out into thirty (30) plots, each plot measuring 1.5 × 1.0 m, containing 24 ginger plants spaced at 30 x 30 cm (Tiwari *et al.*, 2019). Experimental plots were separated by 0.5 m space while 1.0 m alleyway gaps separated the replicates. Weeding was manually done to prevent weed interference.

The 2 x 5 factorial experiment was fitted into a randomized complete block design with main plot factor of 2 levels, propagation method and 5 levels of nitrogen sources as sub - plot factor, giving 10 treatment combinations, replicated 3 times to have 30 experimental units.

Three ginger plants at the center of the experimental plot were tagged as samples per treatment for assessment of growth, yield and yield parameters. The parameters were: plant height measured using a measuring tape from the base of the plant to the apex, number of tillers per plant obtained by counting the number of tillers per stand, number of leaves per plant obtained by counting number of fully expanded green leaves and the leaf area.

The leaf area was obtained by using the formula:
$LA = L \times W \times CF$ (Kandiannan *et al.*, 2009).
Where: CF = Correction factor = 0.73, LA = leaf area (cm^2), L = leaf length (cm), W = leaf width (cm)

The leaf length and leaf width were obtained by measuring the length and width of the leaves with a measuring tape. At 7 months after planting, the number of rhizome fingers, fresh rhizome yield, dry rhizome yield, fresh plant weight, dry plant weight and dry matter accumulation data were collected. Data were subjected to Analysis of Variance (ANOVA) using Statistical Analysis System version 9.4 (SAS, 2022) software package. The treatment means were compared using Tukey's Honest Significant Difference (HSD) at a 5% level of probability.

Table 1: Nutrient Composition of the Fertilizer Materials Used

Fertilizer materials	N%	P%	K%
Foliar (Super Gro)	7.2	4.5	1.5
NPK	15	15	15
Tithonia Compost	2.6		

RESULTS

Physical and chemical properties of the experimental field before planting

The soil textural class was sandy loam, with 91.10% sand, 3.40% silt, and 5.50% clay, with slightly alkaline pH (6.58), very low in organic carbon (0.65 g/kg), total nitrogen (0.08 g/kg) and 2.64 mg/kg available phosphorus (Table 2). Exchangeable cations ranged from low K and Ca to medium Mg and Ca (Esu, 1991).

Table 2: Pre-planting physical and chemical properties of the experimental field

Element	Value
pH (H_2O) 1:1	6.58
Organic carbon (g/kg)	0.65
Total nitrogen (g/kg)	0.08
Available P (mg/kg)	2.64
Exchangeable cations (c mol/kg)	
Ca^{2+}	1.26
Mg^{2+}	0.43
K^{+}	0.19
Na^{2+}	0.81
EA	0.15
ECEC	2.84
Micronutrients (mg/kg)	
Zinc	3.45
Copper	0.63
Iron	104.71
Manganese	101.21
Particle size (%)	
Clay (%)	5.50
Silt (%)	3.40
Sand (%)	91.10
Textural class	Sandy loam

Effects of propagation methods and nitrogen sources on growth parameters of ginger

Propagation methods and fertilizer sources produced significant effect on plant height of ginger all through the observation period (Table 3). Plants raised through seedlings were taller than plants raised from rhizome seeds at 1 month after planting. From 2 months (25.73 cm, 12.73 cm) all through to 7 months after planting (63.70 cm, 35.84 cm), plants raised from rhizome seeds were taller than plants raised from rhizome seedlings.

The effect of nitrogen source was significant all through the sampling periods except at 1 month after planting. Tithonia compost + NPK treatment produced taller plants than other treatments. At 2 months after planting, Tithonia compost treatment produced 20.87 cm plant height which increased by 36% to 57.83 cm at 7 months after planting. The control treatment had the shortest plants all through the sampling period. At 7 months after planting, the foliar fertilizer treatment (55.53 cm) had taller plants than plots treated with Tithonia compost (49.43 cm) and NPK (47.91 cm).

With number of leaves per tiller, plants raised from seeds had increased number of leaves per tiller from 9.84 to 24.89 compared to plants raised from seedlings which increased from 6.02 to 16.47 at 2 and 7 months after planting, respectively.

The effects of nitrogen sources were not significant on number of ginger leaves at 1 month after planting. The control, the Foliar fertilizer and the Tithonia compost treatments had similar number of leaves at 2 and 3 months after planting (MAP). At 7 months after planting, the control treatment had similar number of leaves with Tithonia compost treatment, while Tithonia compost + NPK treatment produced the highest number of leaves (24.75), followed by NPK (21.91) and Foliar treatment (20.68) – Table 3.

Plants raised from seeds had higher leaf areas throughout the sampling period except at 1 month after planting (Table 3). At 7 months after planting, plants raised from rhizome seeds had broader leaves (51.59 cm^2) than plants raised through seedling (31.02 cm^2). The control had the lowest leaf area of 33.25 cm^2 which were comparable with leaf area from the plots treated with Compost (35.34 cm^2); Tithonia compost + NPK treatment produced the highest leaf area of 57.93 cm^2.

Plants raised from seeds produced the highest number of tillers from 2 to 7 months after planting compared to plants raised through seedling (Table 3). At 7 months after planting, plants raised through seedlings were lower in number of tillers (6.86) than plants raised from seeds (14.52). There were no significant differences in numbers of tillers amongst NPK, Foliar fertilizer and Control treatments at 1 month after planting; and all the nitrogen sources at 2 months after planting. At 7 months after planting, Foliar fertilizer treatment (11.57) had similar numbers of tillers with Tithonia compost treatment (11.09), while Tithonia compost + NPK treatment produced the highest number of tillers (Table 3). The interactions of propagation methods and nitrogen sources had significant effects on the plant height, number of leaves, leaf area and number of tillers of ginger (Table 3).

Table 3: Effect of propagation methods and fertilizer sources on growth parameters of ginger in Ogbomoso, Oyo State

Treatment	1	2	3	4	5	6	7
				Months after Planting			
Propagation methods (PM)				**Plant height (cm)**			
Rhizome Seed	0.00a	25.73a	39.26a	47.75a	51.82a	56.56a	63.70a
Rhizome Seedling	9.35a	12.73b	18.28b	22.28b	28.52b	31.31b	35.84b
Prob. F (0.05)	*	*	*	*	*	*	*
Nitrogen Sources (NS)							
100% NPK	4.83a	19.95ab	28.63b	34.41b	38.67c	42.64c	47.91c
100% Tithonia Compost	4.90a	19.09ab	27.34bc	34.10bc	39.80bc	43.37bc	49.43bc
50% Tithonia Compost + 50% NPK	5.19a	20.87a	35.22a	42.58a	47.30a	51.72a	57.83a
Foliar fertilizer	4.58a	20.42ab	29.66b	36.38ab	44.46ab	48.55ab	55.53ab
Control	3.87a	15.83b	22.99c	27.62c	30.62d	33.40d	38.14d
Prob. F (0.05)	*	*	*	*	*	*	*
Interaction							
PM x NS	*	*	*	*	*	*	*
				Number of leaves/tiller			
Propagation methods (PM)							
Rhizome Seed	0.00b	9.84a	12.73a	15.10a	18.12a	20.32a	24.89a
Rhizome Seedling	4.95a	6.02b	7.17b	8.85b	11.70b	13.07b	16.47b
Prob. F (0.05)	*	*	*	*	*	*	*
Nitrogen Sources (NS)							
100% NPK	2.48a	8.03ab	10.31ab	12.43ab	15.76ab	17.45b	21.91ab
100% Tithonia Compost	2.26a	7.08b	9.06b	11.84ab	13.31cd	14.78cd	18.18c
50% Tithonia Compost + 50% NPK	2.93a	10.07a	11.87a	13.93a	17.78a	20.64a	24.75a
Foliar fertilizer	2.74a	7.22b	9.46b	11.15b	14.92bc	16.46bc	20.68bc
Control	1.98a	7.28b	9.06b	10.53b	12.79d	14.13d	17.87c
Prob. F (0.05)	*	*	*	*	*	*	*
Interaction							
PM x NS	*	*	*	*	*	*	*
				Leaf area (cm²)			
Propagation methods (PM)							
Rhizome Seed	0.00b	17.83a	34.97a	41.00a	45.30a	48.84a	51.59a
Rhizome Seedling	8.56a	12.19b	15.70b	20.65b	25.50b	28.57b	31.02b
Prob. F (0.05)	*	*	*	*	*	*	*
Nitrogen Sources (NS)							
100% NPK	5.39a	18.23a	28.53a	32.27ab	36.63b	36.84b	37.32bc
100% Tithonia Compost	4.19a	15.33ab	26.07a	28.77bc	32.11bc	35.70b	35.34c
50% Tithonia Compost + 50% NPK	4.48a	15.79ab	27.41a	35.46a	43.36a	50.32a	57.93a
Foliar fertilizer	3.94a	13.85ab	25.31a	31.80ab	31.67c	37.07b	42.68b
Control	3.39a	11.84b	19.37b	25.81c	33.23bc	33.60b	33.25c
Prob. F (0.05)	*	*	*	*	*	*	*
Interaction							
PM x NS	*	*	*	*	*	*	*
				Number of tillers/plant			
Propagation methods (PM)							
Rhizome Seed	0.00b	3.25a	5.07a	6.93a	9.30a	11.88a	14.52a
Rhizome Seedling	1.16a	1.75b	2.08b	2.72b	4.26b	5.35b	6.86b
Prob. F (0.05)	*	*	*	*	*	*	*
Nitrogen Sources (NS)							
100% NPK	0.52ab	2.49a	3.58ab	4.50bc	5.81b	7.31ab	9.05ab
100% Tithonia Compost	0.50b	2.39a	3.71a	4.50bc	6.83ab	9.01ab	11.09ab
50% Tithonia Compost + 50% NPK	0.75a	3.14a	4.25a	6.29a	9.05a	10.82a	13.65a
Foliar fertilizer	0.61ab	2.53a	3.81a	5.29ab	7.33ab	9.51ab	11.57ab
Control	0.53ab	1.95a	2.53b	3.53c	4.89b	6.41b	8.09b
Prob. F (0.05)	*	*	*	*	*	*	*
Interaction							
PM x NS	*	*	*	*	*	*	*

Means with the same letters are not significantly different using Duncan's Multiple Range Test at 5% probability level. * Significant.
100% NPK – NPK 15:15:15 at 933 kg/ha, Foliar fertilizer- Supergro at 2.9 mL/L, 100% Tithonia compost - 5.2 tons/ha, and 50% Tithonia compost + 50% NPK at 2.6 tons/ha + 466.5 kg/ha.

Effects of propagation methods and nitrogen sources on yield and yield parameters of ginger

The effects of propagation methods and nitrogen source were significant on number of rhizome fingers/plant, fresh rhizome yield, dry rhizome yield, fresh plant weight, dry plant weight and dry matter accumulation of ginger at harvest (Table 4). Plants raised from rhizome seeds (6.20) had higher number of rhizomes fingers than plants raised through seedlings (4.90). Plants raised from rhizome seeds had higher fresh rhizome yield of 9.92 tons/ha than 7.77 tons/ha from plants raised through seedlings (Fig. 1). Tithonia Compost + NPK treatment produced the highest fresh rhizome yield (15.91 tons/ha), followed by NPK (10.97 tons/ha), while the control (2.95 tons/ha) produced the lowest fresh rhizome yield (Fig. 2).

Ginger grown from rhizome seeds yielded more dry rhizomes (0.12 tons per hectare) than those grown from rhizome seedlings (0.10 tons per hectare) - Table 4. Among all fertilizer treatments, the combination of Tithonia compost and NPK produced the best results, giving the highest dry rhizome yield (0.20 tons per hectare), exceeding those from the other fertilizer types and the control group (0.04 tons per hectare).

There was no major difference between rhizome seeds and rhizome seedlings in terms of fresh and dry plant weights. Plants treated with complementary Tithonia compost and NPK showed the greatest growth, recording 341.36 g in fresh weight and 108.94 g in dry weight; both were higher from than other nitrogen treatments. The unfertilized control treatment had similar yields (122.57 g fresh, 39.17 g dry) as with Foliar treatment (118.68 g, 37.77 g) and Tithonia compost sole treatment (154.70 g, 49.62 g) – Table 4.

Propagation methods did not have a significant impact on dry matter accumulation. The Tithonia compost + NPK treatment had the highest dry matter accumulation rate of 2.03 $g/m^2/day$, significantly higher than from other nitrogen sources and the control treatment that had 0.91 $g/m^2/day$.

The interaction between propagation method and nitrogen source had a significant effect on several yield parameters, including the number of rhizome fingers, fresh and dry rhizome yield, as well as fresh and dry plant weights (Table 4).

Table 4: Effects of propagation methods and nitrogen sources on yield and yield parameters of ginger at 7 months after planting

Treatment	Number of fingers/ plant	Fresh rhizome yield (tons/ha)	Dry rhizome yield (tons/ha)	Fresh plant weight (g)	Dry plant weight (g)	DMA (g/ m²/day)
Propagation methods (PM)						
Rhizome Seed	6.20a	9.92a	0.12a	212.99a	67.95a	1.17a
Rhizome Seedling	4.90b	7.77b	0.10b	168.25a	53.75a	0.90a
Prob. F (0.05)	*	*	*	*	*	*
Nitrogen Sources (NS)						
100% NPK	4.98b	10.97b	0.13b	215.81ab	68.73ab	0.79ab
100% Tithonia Compost	5.39ab	7.94c	0.10bc	154.70b	49.62b	0.87ab
50% Tithonia Compost + 50% NPK	7.59a	15.91a	0.20a	341.36a	108.94a	2.03a
Foliar fertilizer	5.15ab	6.45c	0.08c	118.68b	37.77b	0.59b
Control	4.66b	2.95d	0.04d	122.57b	39.17b	0.91ab
Prob. F (0.05)	*	*	*	*	*	*
Interactions						
PM x NS	*	*	*	*	*	NS

Means with the same letters are not significantly different using Duncan's Multiple Range Test at 5% probability level. * Significant, NS – Not significant. 100% NPK – NPK 15:15:15 at 933 kg/ha, Foliar fertilizer-Supergro at 2.9 mL/L, 100% Tithonia compost - 5.2 tons/ha, and 50% Tithonia compost + 50% NPK at 2.6 tons/ha + 466.5 kg/ha. DMA – Dry Matter Accumulation

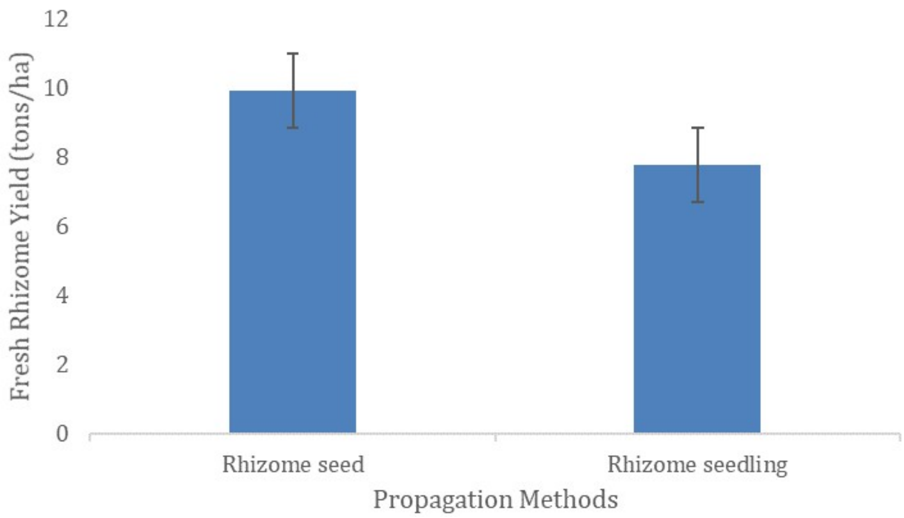

Figure1: Effect of propagation methods on fresh rhizome yield of ginger

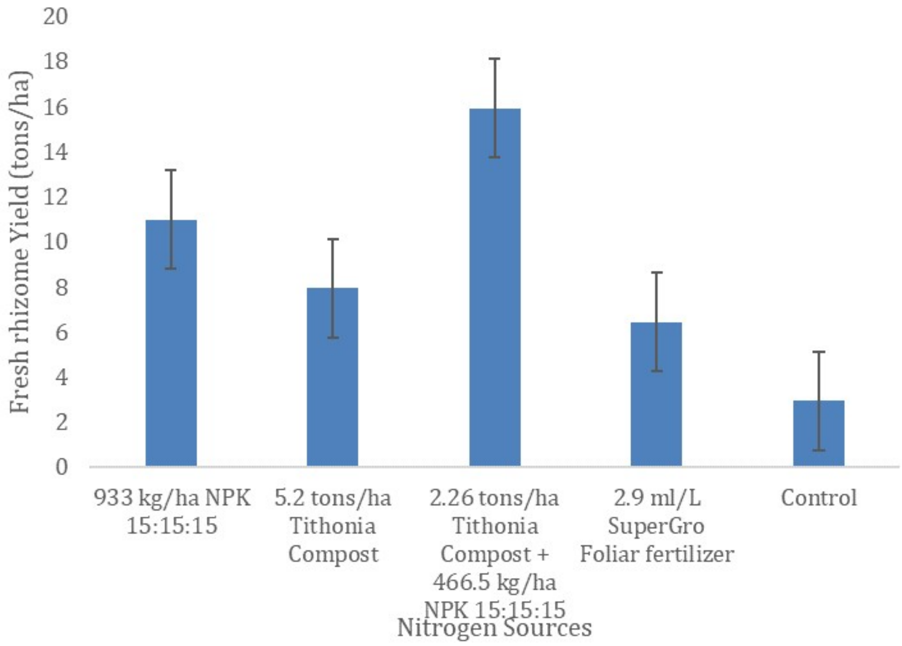

Figure 2: Effect of nitrogen sources on fresh rhizome yield of ginger per ha

DISCUSSION

The observed variations in plant height, number of leaves/tiller, leaf area, and tiller count/plant between plants raised from seeds and from seedlings could be attributed to the inherent physiological differences in the propagation materials. Rhizome seeds, being mature and nutrient-rich, offer a more substantial initial energy reserve, facilitating robust early growth and sustained development. Conversely, rhizome seedlings, while advantageous for rapid establishment, may lack the extensive nutrient reserves necessary for prolonged vigorous growth. This is in line with Kumar *et al.*, (2020) who reported that ginger rhizomes possess pre-formed buds and stored nutrients, allowing for faster growth after germination.

The significant enhancement of plant height, leaf area, and number of tillers with application of Tithonia compost combined with NPK fertilizer underscores the synergistic effect of integrating organic and inorganic nutrient sources. *Tithonia diversifolia*, known for its high nitrogen content, complements the readily available nutrients in NPK fertilizers, leading to improved nutrient uptake and enhanced plant growth. This finding corroborates the report of Asafa and Akanbi (2018) who demonstrated that application of 140 kg N/ha, particularly when sourced from Tithonia compost, significantly increased vegetative growth parameters and rhizome yield of ginger. The study highlighted that the combined nutrient supply from organic and inorganic sources meets the nitrogen demand of ginger, promoting enhanced growth (Srinivasan *et al.*, 2019). The observed superiority of foliar fertilizer application over the control treatment at 7 months after planting may be attributed to the immediate availability of nutrients directly to the leaves, facilitating rapid assimilation and utilization during critical growth stages

(Ekwugha *et al*., 2023). The significant interaction effects between propagation methods and fertilizer sources on growth parameters of ginger suggest that the optimal combination of these factors is crucial for maximizing plant performance. The enhanced growth observed with rhizome seeds combined with Tithonia compost + NPK fertilizer indicates that the substantial nutrient reserves in rhizome seeds, when supplemented with a balanced nutrient supply, create a conducive environment for vigorous growth (Okwuowulu and Eze, 2020).

Rhizome seeds hold higher amounts of stored carbohydrates and nutrients than rhizome seedlings (Suhaimi *et al*., 2018). This nutrient advantage supports more vigorous early growth and stronger establishment, which in turn enhances photosynthetic efficiency. Consequently, more assimilates are directed toward rhizome formation, leading to improved yield traits such as a higher number of fingers, greater fresh rhizome weight, and increased dry rhizome output. *Tithonia diversifolia* compost is rich in nitrogen and other essential nutrients; when combined with NPK fertilizer, it provides both immediate (inorganic) and sustained (organic) nutrients release. This might have enhanced root development, shoot biomass, and rhizome bulking through increased nitrogen-use efficiency and improved soil structure and microbial activity, leading to significantly higher yields. This result corroborates the findings of Adekiya *et al.* (2020) who reported that combining organic manures with inorganic fertilizers resulted in improved nutrient uptake, better ginger yield, and enhanced soil fertility. Otun *et al.* (2021) observed that the combination of Tithonia compost + NPK increased ginger fresh rhizome yield more than individual applications fertilizer, attributing the effect to synergistic nutrient interaction and enhanced photosynthetic efficiency.

The significant interaction between propagation method and nitrogen source suggests that optimal yield depends on matching vigorous planting material with an adequate nutrient supply. Rhizome seeds under Tithonia compost + NPK fertilization exhibited the best performance due to compounded benefits of strong initial growth and a balanced nutrient regime, enhancing biomass accumulation and yield. This conforms to the report of Sharma *et al.* (2019) that propagation method and fertilization interaction significantly influenced growth and yield traits in ginger, where mature rhizomes under integrated nutrient management produced superior outcomes. Islam *et al.* (2022) also reported improved yield indices such as fresh and dry weights when vigorous planting material (rhizome seed) was supplemented with combined organic and inorganic fertilizers. Dry matter accumulation is influenced by nutrient availability, especially nitrogen, which is crucial for protein synthesis, chlorophyll production, and photosynthesis. Tithonia compost + NPK enhanced dry matter accumulation by supporting prolonged nutrient availability and reducing nitrogen leaching losses. The result is in line with the findings of Ngwira and Taylor (2018) who reported that combining green manure like Tithonia with NPK significantly increased dry matter production and nutrient-use efficiency in ginger cropping systems. Mandal *et al.* (2023) also reported that integrated nutrient management (including green manures) improved ginger growth and biomass production under rain-fed conditions.

CONCLUSION AND RECOMMENDATION

Use of rhizome seed as propagating material for ginger significantly increased the growth and yield of the crop. Application of nitrogen fertilizer produced significant growth and yield performance compared to the control. There is a need to apply nitrogen fertilizer to enhance the growth and yield of the crop. However, nitrogen source from an integrated Tithonia compost and NPK 15:15:15 at 2.6 tons/ha and 466.5 kg/ha fertilizer respectively had a significant effect on ginger yield.

This study hereby recommends the use of rhizome seed as an effective propagation method for ginger production and an integrated application of Tithonia compost + NPK 15:15:15 fertilizer for optimum production of the crop in the study area.

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