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Growth and Rhizome Yield of Ginger (*Zingiber officinale* L.) as Influenced by Propagule Size and Nitrogen Levels in Ogbomoso, Southwestern Nigeria

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Abstract. The study was conducted to determine the effect of propagule size and nitrogen levels on the growth and rhizome yield of ginger. The nitrogen source was from Tithonia compost (TC). Three propagule sizes were tested (20, 30 and 40 g) and seven nitrogen levels (0, 40, 60, 80, 100, 120 and 140g kg N/ha). The experimental pots were laid out in a randomized complete block design with three replicates. Data were collected on growth parameters (plant height, number of leaves, leaf length and leaf width); rhizome yield components (number of tillers and rhizomes, and rhizome weight and length); and proximate composition (crude protein (CP), crude fibre (CF), total lipid (TL); Total Ash (TA), Starch and water soluble extract). Data collected were subjected to analysis of variance (ANOVA) and significant means were compared using Duncan Multiple Range Test (DMRT) ($P\leq0.05$). Propagule size, N levels and their interactions significantly ($P\leq0.05$) influenced most of the parameters assessed. In most cases, the use of 30 and 40 g planting material gave similar results. Plants nourished with 140 kg N/ha significantly and consistently outperformed other nitrogen levels. Crude protein obtained from 40 g propagule size was significantly ($P\leq0.05$) higher than other tested propagule sizes. The rhizome yields of fertilized plants were significantly higher than the control plants. Rhizome yields ranged from 1.67 t/ha in 80 kg N/ha to 3.71 t/ha in 140 kg N/ha. The establishment of ginger with 40 g planting materials and its nourishment with 140 kg N/ha enhanced growth, rhizome yield and proximate composition of the plant.

1. Introduction

Ginger (*Zingiber officinale*) belongs to the family Zingiberaceae. It is an economically important plant largely cropped for its variety of uses, especially for its medicinal and flavouring potentials [1]. The spice is of indigenous to warm tropical climates particularly Southeastern Asia and is propagated through rhizome [2]. The valuable ginger is a herbaceous, perennial reed-like herb, the leaves are erect, slender, usually grown as an annual, with one or more aerial leafy stems, up to 1.2 m tall, rhizome robust flesh, up to 2 cm thick. A mature ginger rhizome is fibrous and has a striated texture. The outer skin of the rhizome is brownish in colour while the flesh depending on the variety which may be red, yellow or white [3].

Ginger is well known in human communities around the world. Among all spices, ginger is the main cash crop supporting the livelihood and improving the economic level of many people [4]. It is the underground rhizome of a perennial tropical crop called Ginger plant (*Zingiber officinale*). Originally, the plant is a native of South Eastern Asia but over centuries has been introduced to various parts of the world like Caribbean, the Americas and Africa. Presently, the top grower of the crop includes India, China, Japan, Jamaica, Indonesia, Fiji and so on [5].

The production of ginger in recent years especially in rainforest zone of Nigeria is increasing due to the high demand of the rhizomes both for dietary spice and in control of various diseases that include; high blood cholesterol level, high blood pressure, nausea and insomnia. Results of the study indicated that increasing levels of nitrogen and rhizome sizes significantly affected growth, yield and proximate composition of ginger rhizome [6].

Nigeria is one of the top producers of ginger in the world. In Nigeria market, ginger is well known and on high demand even though it is quite expensive. Kaduna State stands as the highest producers of the crop while states like Gombe, Bauchi, Benue, and Nassarawa among others are major producers of the crop. In the market, ginger is available in various forms; fresh ginger rhizome, powder ginger and dry ginger rhizome [7]. Ginger yields in Nigeria are extremely low on farmers' fields. Reported yield ranging from 7 to 14 ton/ha in the southern Kaduna State [8]. Low yielding varieties, poor agronomic practices and vagaries of the weather were some of the factors reported to result in low ginger yields (8).The emergence and early growth of ginger is inherently slow and the crop competes very poorly with weeds [9, 10].

Among the agronomic practices that affect crop growth and yield are size of planting materials and nutrient sources. Set or corm sizes have been reported to have influence on the sprouting rate, early growth and development of crops like yam, pineapple and plantain [11]. Positive correlation was also observed between set size and sucker proliferation rates in plantain [11]. From various reports, the quantity and quality of food reserve in materials for crop establishment are important factors. The food reserves provide nutrients and energy required for crops seeds/propagule germination/sprouting and means of sustenance to the plantlets and seedling. The higher and more readily available this growth factors, the better the early crop growth and development.

As a result of the increasing consumption of ginger in medicines and in food ingredients, it was considered important to assess some of the factors that could boost its production. Therefore, the objective of this work was to examine the contribution of N-fertilizer and set sizes on the growth and rhizome yield of ginger plants.

2. Material and Methods

Description of the Experimental Site

The experiments were conducted at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeria in 2010 and 2011, Ogbomoso. The city lies on latitude $8^{o}10'$N, longitude $4^{o}16'$E and about sea level. It is located in the Guinea savanna Zone of southwest Nigeria. The temperature of the area ranges from 28 ^{o}C - 33^{o}C with relative humidity of about 75% all year except in January when the dry wind blows from the north. Rainfall distribution is bimodal and extends for eight to nine months of the year. On the average, the total annual rainfall is about 128 mm. The soil of the site belongs to the USDA classification of Alfisol, which is moderately drain, ferruginous tropical soil with a sandy loamy texture. The vegetation cover of site area characterized by scattered trees and shrubs and by cynodon species.

Treatments and Experimental Design

Potting media were perforated at the base to improve drainage and aeration. Each pot was filled with 12 kg top soil. The treatments were arranged as factorial experiment laid out in a randomized complete block with three replicates. The treatments consisted of three rhizomes sizes (S1= small (20 g), S2= medium (30 g) and S3= Big (40 g) and nitrogen level viz: 0, 40, 60, 80, 100, 120 and140 kg N/ha. The rhizome (yellowish variety also known as Tafin giwa or elephant foot) was planted in each pot according to the treatment size and plant that received no fertilizer (0 kg N/ha) constituted the control. Each treatment has six pots making a total of 84 pots in all. For each trial, gross experimental pots were 126. Watering of the soil in the pots were done before planting and mulched with dry grass. Two weeks after planting (WAP), N fertilizer treatment was applied to the pots while weeding was manually done by roughing out the weeds from the pot whenever necessary.

Data Collection

In each trial, data collection commenced from 4 weeks after planting (WAP). At each sampling time, data were collected on growth and rhizome parameters and proximate contents. The growth parameters assessed were number of leaves, plant height, leaf length, leaf width while yield parameters include: number of tillers/treatment, number of rhizome/plant treatment, rhizome weight/treatment and length of rhizome per treatment. The rhizome proximate compositions were also determined using AOAC method. Percentage crude protein contents were calculated from Kjeldahl nitrogen using the conversion factor 6.25. Total lipid was estimated by exhaustively extracting a known weight of sample with petroleum ether (BP 60 ^{o}C) using a Tecator Soxhlet apparatus. Total Ash content was determined by ignition in a muffle furnace for 4 hours at 525 ^{o}C. The crude fibre content was estimated from the loss in weight of the crucible and its content on ignition.

Data Analysis

Data collected from trials 1 and 2 were pooled and average before analysis. Statistical analysis of data collected was carried out using standard analysis of variance for randomized complete block design. The significance of the treatment effect was determined using the F-test and mean separation was done with Duncan Multiple Range Test at 5% probability level .

3. Results

Effect of Nitrogen Level on Growth Parameters of Ginger Rhizomes

Response of ginger to different levels of nitrogen is presented in Table 1. Nitrogen levels had significant ($P \leq 0.05$) effects on number of ginger plant leaves and height at different growth stages. The number of leaves per plant ranged from 2.33 at 4WAP to 20.61 at 16WAP. At 16WAP, application of 100 kgN/ha through compost had the highest value while non-fertilized plants produced the least. Effect of N levels on ginger plant height was significant ($P \leq 0.05$) only at 8 and 12WAP. At this stages, the use of 60 kg N/ha gave the tallest plants height. This was closely followed by plant that received 140kg N/ha while plant treated with 0 kg N/ha had the least (38.12cm) at 12WAP. The interactive effect of N level and rhizome sizes was significant on ginger number of leaves at 12 and 16WAP. Among the treatment combinations and at 12WAP, the highest number of leaves was obtained from plants established with 40g material and fertilized with 60kg N/ha, followed by 40g + 140kg N/ha while the least was obtained from 20g + 80 kg N/ha. However, at 16WAP, the interactive effect influence of rhizome size and nutrient level had great effect on number of leaves from treatment combination of 40g + 60 kg /ha TC, followed by 40 g + 100 kg /ha TC while the least was 20g + 80 kg /ha TC at 16WAP. The interactive effect of N level and rhizome size on plant height was significant only at 12WAP. At this stage, the treatment combination that gave tallest plant was 30g + 120 kg N/ha while the least was obtained with 20g + 80 kg N/ ha.

In respect to leaf length, applied treatment had significant effects at 12WAP. At 12WAP, application of 100 kg/ ha had the longest leaf (19.83 cm) while control plants had the least (16.94 cm). At 4, 8 and 16WAP, there was no significant difference in the leaf length of ginger in response to applied N levels. Significant ($P \leq 0.05$) was observed in leaf wide with response to N level at 4, 8, and 12WAP. At 4WAP, application of 100 and 120 kg N/ha were significantly ($P \leq 0.05$) better than other treatments on leaf width. Application of 100 N kg / ha produced highest leaf width, these rates had the widest leaf (3.69 cm) while 0 kg N/ha treatment had the least value (1.42 cm).

Table 1. Effect of Nitrogen level on growth parameters of ginger at different growth stages

Nitrogen level (kg/ha)	Weeks after planting (WAP) 4	8	12	16	Mean
		Number of leaves			
0	2.83ab	9.56ab	16.89a	17.81b	11.72
40	2.61ab	9.78ab	16.58a	18.50ab	11.87
60	2.33ab	10.67a	17.28a	20.28ab	12.72
80	2.06ab	8.39b	13.67b	17.44b	10.39
100	2.22ab	9.67ab	16.61a	20.61a	12.2
120	1.83b	11.22a	16.33a	19.44ab	12.2
140	2.33ab	9.50ab	17.00a	19.17ab	12
Mean	2.33	9.83	16.34	133.05	
Plant height (cm)					
0	17.88a	32.11ab	38.39b	38.12a	31.63
40	15.73a	31.61ab	38.83b	39.12a	31.32
60	17.95a	32.72ab	48.28a	43.72a	35.67
80	15.17a	24.22b	35.33b	39.56a	28.57
100	16.08a	32.22ab	36.06b	42.83a	31.8
120	15.67a	36.05a	42.88ab	41.61a	34.05
140	16.01a	34.93a	41.89ab	38.94a	32.94
Mean	16.36	31.98	40.24	40.54	
Leaf length (cm)					
0	8.49a	19.39a	16.94c	17.33a	15.59
40	8.11a	20.56a	18.39abc	17.11a	16.04
60	8.28a	23.22a	19.61ab	18.56a	17.42
80	6.99a	20.17a	17.28bc	17.67a	15.52
100	10.14a	21.29a	19.83a	19.61a	17.71
120	7.06a	20.94a	18.94abc	18.94a	16.47
140	7.78a	19.44a	18.11abc	18.44	15.94
Mean	8.12	20.72	18.44	18.24	
Leaf width (cm)					
0	1.42ab	2.22ab	2.34b	1.89a	2
40	2.12ab	2.63a	2.42ab	1.92a	2.27
60	1.71ab	2.42ab	2.49ab	2.09a	2.18
80	1.6ab	2.00b	2.44ab	2.14a	2.05
100	3.69a	2.58a	2.46ab	2.26a	2.74
120	2.42b	2.67a	2.68a	2.38a	2.29
140	1.68ab	2.34ab	2.40ab	2.14a	2.14

Mean along the column with the same letter are not significant ($P \leq 0.05$)
Data are average of 1st and 2nd trial

Effect of Rhizome Size on the Growth Parameters of Ginger

The influence of rhizome sizes on number of leave (Table: 2) were significant at ($P \leq 0.05$) only at 12 WAP. At this stage, 40 g propagule size produced plants with highest number of leaves (17.4), this is closely followed by 16.5 leaves produced by 30 g sizes while 20 g had the least (15.1). In case of plant height, effect of size of planting materials was not significant ($P \leq 0.05$) throughout the growth period. Despite this, at 16 WAP, 30 g planting size had the tallest plants (42.74 cm) while 40g had the least (38.53 cm) at 16 WAP.

Leaf length was significantly influenced by various propagule size at 4 and 8WAP but not significant at 12 and 16WAP. The longest leaf, 9.41 cm, was observed in pot treated with 30 g; this was followed by that of 20 g (7.7 cm) while 40 g treatment had the least (7.2 cm). At 8WAP, leaf length of 30 and 40 g propagule sizes were significant ($P \leq 0.05$) similar at 12 and 16 WAP. The observation on leaf width with different propagule sizes show no significantly different throughout their vegetative growth stage.

Table 2. Effect of Rhizome size on Growth Parameters of ginger plant

Rhizome Size (g)	Weeks after planting (WAP) 4	8	12	16	Mean
Number of leaves/plant					
20	2.36a	9.64a	15.05b	18.55a	11.4
30	2.45a	10.00a	16.55a	19.02a	12.01
40	2.14a	9.83a	17.41a	19.45a	12.21
Mean	2.32	9.82	16.39	19.01	
Plant height (cm)					
20	16.24a	33.00a	36.62a	40.41a	32.1
30	16.39a	32.38a	43.69a	42.74a	33.55
40	16.44a	30.56a	38.40a	38.53a	31
Mean	16.39	31.98	40.24	40.56	
Leaf length (cm)					
20	7.26b	16.95b	17.74a	17.74a	14.92
30	9.41a	22.69a	18.71a	18.48a	17.32
40	7.70ab	22.50a	18.88a	18.50a	17
Mean	8.12	20.71	18.44	18.24	
Leaf width (cm)					
20	1.54a	2.33a	2.37a	2.18a	2.11
30	1.96a	2.35a	2.50a	2.16a	2.24
40	2.39a	2.59a	2.51a	2.01a	2.38

Mean along the column with the same letter are not significant ($P \leq 0.05$)
Data are average of 1st and 2nd trials

Effect of Nitrogen Level and Propagule Size on Yield Parameters of Ginger

Response of ginger yield parameters to the applied N levels is shown in Table 3. Nitrogen level had significant ($P \leq 0.05$) effect on numbers of tillers, rhizome, rhizome weight and length. The highest (2.67) number of tillers/plant was observed from the pot treated with 140 kg N/ha while the least (1.67) was reported in non-fertilized plants. Number of tillers were significantly ($P \leq 0.05$) similar in 40, 60, 80 and 140 kg N/ha treated plants. Number of rhizomes/ plant varies from 0 kg N/ha to 140 Kg N/ha. In reference to rhizome length, the best result was observed with 100 kg N/ ha. The result obtained with this rate was similar to that of 60 Kg N/ha treatment but significantly higher than what was obtained with other nitrogen levels. Rhizome weight was significantly influenced by the applied nitrogen level. The values of this parameter ranges from 34.92 g/plant in 0 kg N/ha to 67.59g/plant in 140kg N/ha. The value obtained in the pot treated with 140Kg N/ha was 67.59 and 18% higher than what was obtained in the plant treated with 60, 40 and 100 kg N/ha respectively. Plant treated with 140 kg N/ha gave highest rhizome yield (11.27 t/ha) followed by 60 kg N/ha (10.32 t/ha) while the least (5.82 t/ha) was recorded with 0kg N/ha plant.

Propagule size significantly influenced the ginger yield parameters (Table 4). For the entire yield parameters (numbers of tillers and rhizome/plant, rhizome length and weight) considered in this study, the used of 40g materials consistently had the best results. Number of tillers varied from 2.95/plant in 40 g materials to 1.38 in 20 g materials. The number of tiller produced by plants established with 30 and 40 g materials were statistically similar. Number of rhizomes /plant varied with the use of different planting materials. There was increased in the value of this parameter with increase in propagule size and order of increase of the parameter with different propagule size were 40 g > 30 g > 20 g. Rhizome length varied significantly with different size of planting material. The longest length was obtained with the use of 40 g propagule size, and this was 10.58 and 22.6% significantly longer than the length of rhizome of plants established with 20 and 30 g material respectively. Again, rhizome weight was significantly influenced by size of planting materials. The use of 20 g planting material gave the least (39.03 g / plant) weight while that of 40 g produced plants with rhizome weight of 64.83 g/plant and 10.81 t/ha.

Table 3. Effect of Nitrogen level on Yield Parameters of ginger

Nitrogen level (kg/ha)	Number of tillers / plant	Number of rhizomes / plant	Mean rhizomes length (cm)	Mean rhizomes weight (g)	Rhizome yield t/ha
0	1.67f	2.57d	7.13e	34.92g	5.82g
40	2.11d	2.83c	10.07c	53.01c	8.84c
60	2.33c	2.83c	13.00b	61.90b	10.32b
80	2.56b	1.67f	6.77f	43.13f	7.19f
100	1.78e	2.97b	13.59a	55.31d	9.22d
120	1.78e	2.47e	7.49d	51.69e	8.61e
140	2.67a	3.17a	6.46g	67.59a	11.27a

Mean along the column with the same letter are not significant ($P \leq 0.05$)
Data are average of 1st and 2nd trials

Table 4. Effect of propagule size on Yield Parameters of ginger

Rhizome size (g)	Number of tillers / plant	Number of rhizomes / plant	Mean rhizomes length (cm)	Mean rhizomes Weight (g)	Rhizome yield t/ha
20	1.38b	2.26c	9.00b	39.03c	6.51c
30	2.05ab	2.73b	8.06c	45.09b	7.52b
40	2.95a	2.94b	10.58a	64.83a	10.81a

Mean along the column with the same letter are not significant ($P \leq 0.05$)
Data are average of 1st and 2nd trials

Effect of Nitrogen Level and Propagule Size on Proximate Composition of Ginger Rhizome

The ginger rhizome proximate compositions were affected by applied Nitrogen level (Table 5). Ginger rhizome crude protein was significantly affected by N level. Generally, there was an increase in the level of applied nitrogen. This increment continued till the highest applied N level. The highest crude protein of 6.64% was obtained with 120 kg N/ha treatment, while the least 5.75% was obtained with 0 kg N/ha treatment. Variation in the level of total lipid, crude fibre and total ash in response to the followed the same trend to applied N level. For these parameters, application of 120 and 140 kg N/ha gave the highest proximate composition while non fertilized plants recorded the least. The rhizome starch content obtained from the plant treated with of 120 and 140 kg N/ha was statistically similar but significantly higher than what were obtained with other treatments. The acid and water soluble ash varied significantly with applied N levels. The acid and water soluble ash was highest (3.72 and 3.48 %) respectively was obtained in 140 kg N/ha and least in 0 kg N/ha. Plants treated with 120 kg N / ha had highest alcohol soluble extracts (1.85) compared with other treated plants and untreated plants which had the least alcohol soluble extracts.

Rhizome size had significant effect on all the proximate composition assessed in this study (Table 5). The rhizome crude protein ranges from 6.52% in 40 g propagule size to 6.12% in 20 g size treatment. Total lipid, crude fibre and ash content gave similar response to propagule size. In these three parameters, the use of 40g material gave the best result while the least were observed with non-fertilized plants. In the case of rhizome starch, the use of 30 g material gave the highest value, and the value obtained with this treatment was 21.7 which is 16% higher than those of 20 and 40 g material respectively. The rhizome acid and water soluble ash varied significantly with increase in planting material size. The highest acid soluble ash of 3.56% was obtained with the highest propagule while the least was obtained with the smallest ones. The water soluble ash increased with increase in the weight of planting material reaching peak with the use of 40 g material treatment.

The water soluble extract varied significantly with increase in propagule size. The use of 40 g material gave the highest value while the least was obtained with 20 g treatment. Plant established with 30 g planting material had the highest (1.61%) alcohol soluble extract. This value was similar to 1.58% obtained with 40g material but significantly higher than 1.52% obtained with the use of 20 g material.

Analysis of variance showed significant differences among the treatments combination on ginger rhizome proximate composition. The rhizome proximate compositions were highest in most cases with 40 g + 140 kg N /ha.

Table 5. Effect of Nitrogen level on Proximate composition of ginger rhizome

Nitrogen level (kg/ha)	Crude Protein	Total Lipid	Crude Fibre	Total Ash	Starch %	Acid soluble ash	Water Soluble Ash	Water Soluble Extract	Alcohol Soluble Extracts
0	5.75g	0.14g	0.64g	2.37f	2.72f	2.33g	2.07f	2.44g	1.12g
40	5.82f	0.16f	0.72f	1.90g	2.89e	2.82f	2.05g	2.55f	1.34f
60	6.00e	0.19e	0.78e	2.90e	3.54d	2.84e	2.69e	3.20e	1.51e
80	6.13d	0.22d	0.83d	3.19d	3.66c	3.19d	2.94d	3.33d	1.63d
100	6.45c	0.26c	0.87c	3.62c	3.85b	3.50c	3.33c	3.46c	1.76b
120	6.64a	0.29b	0.96b	3.83b	4.45a	3.68b	3.45b	3.75b	1.85a
140	6.22b	0.37a	1.01a	3.89a	4.36a	3.72a	3.48a	3.92a	1.64c

Mean along the column with the same letter are not significant ($P \leq 0.05$)
Data are average of 1st and 2nd trials.

Table 6. Effect of Rhizome size on Proximate composition of ginger rhizome

Rhizome size (g)	Crude Protein	Total Lipid	Crude Fibre	Total Ash	Starch %	Acid soluble ash	Water Soluble Ash	Water Soluble Extract	Alcohol Soluble Extracts
20	6.12c	0.20c	0.81b	2.81c	3.45c	2.88c	2.44c	2.93c	1.52c
30	6.23b	0.22b	0.77c	3.10b	3.75a	3.02b	2.78b	3.34b	1.61a
40	6.52a	0.26a	0.91a	3.39a	3.71b	3.56a	3.45a	3.43a	1.58b

Mean along the column with the same letter are not significant ($P \leq 0.05$)
Data are average of 1st and 2nd trials

Table 7. Interactive effect of nitrogen level and propagule size on proximate composition (%) of ginger rhizome

Nitrogen level (kg/ha)	Propagule size (g)			Propagule size (g)		
	20	30	40	20	30	40
	Crude protein			Total lipid		
0	5.70	5.72	5.84	0.14	0.13	0.14
40	5.75	5.78	5.94	0.16	0.15	0.18
60	5.79	5.83	6.02	0.21	0.18	0.24
80	5.91	5.90	6.57	0.21	0.20	0.26
100	6.24	6.37	6.74	0.23	0.24	0.31
120	6.28	6.74	6.90	0.23	0.30	0.34
140	7.10	7.24	7.32	0.27	0.36	0.38
	Crude fibre			Total ash		
0	0.64	0.63	0.66	2.27	2.33	2.50
40	0.75	0.68	0.74	2.37	2.49	3.84
60	0.79	0.72	0.83	2.43	2.63	3.64
80	0.82	0.76	0.91	2.47	3.27	3.84
100	0.86	0.82	0.98	3.17	3.58	4.12
120	0.89	0.88	0.12	3.48	3.66	4.36
140	0.94	0.93	0.16	3.51	3.74	4.42
	Starch content			Acid soluble ash		
0	3.20	2.48	2.49	2.23	2.30	2.45
40	3.27	2.69	2.70	3.32	2.44	2.76
60	3.40	3.74	3.48	2.37	2.57	2.53
80	3.48	3.85	3.64	2.39	3.90	3.98
100	3.52	4.24	3.78	3.08	3.48	3.94
120	3.57	4.57	4.90	3.38	3.54	4.11
140	3.74	4.69	4.96	3.38	3.60	4.18
	Water soluble ash			Water soluble extract		
0	2.15	3.73	2.32	2.40	2.38	2.55
40	1.23	2.30	2.62	2.53	2.44	2.67
60	2.26	2.42	3.40	2.60	3.51	3.48
80	2.23	3.03	3.56	2.74	3.64	3.62
100	2.89	3.31	3.80	3.09	3.60	3.68
120	3.18	3.34	3.84	3.50	3.74	4.00
140	3.17	3.36	3.90	3.66	4.07	4.03

Data are average of 1st and 2nd trials.

4. Discussion

Ginger Growth Parameters in Response to Applied Nitrogen Level and Propagule Size.

Application of different nitrogen levels had marked effect on the growth and yield parameters of ginger. Increasing levels of nitrogen application gave a corresponding increase in plant height, leaf numbers and size over non fertilized plants. This observation is in agreement with previous studies on tomato [12] and on Turmeric, a similar spice [13]. Olojede et al. [13] opined that nitrogen is a major nutrient element requirement by plant as it plays significant role in cell division, multiplication and growth which lead to growth in plant. In addition, the observed significant increase in growth parameters clearly indicated the optimum requirement level of nitrogen fertilizer for a reasonable growth of ginger plant as 140 kg N/ha. It has been reported that ginger is a heavy feeder crop and it responds well to fertilizer application [14].

Size of planting materials was found to have significant influence on the growth parameters of ginger plant and this was at best for most parameters with the use of 40 g materials. However, the use of 30 and 40 g materials gave similar results in most cases. This corroborated the results of previous study [13] where the use of 30 g planting material gave the best plant growth and the smallest size material result in poorest plant growth. The results obtained could be attributed to small amount of food reserve in it compared to what could be present in 30 and 40 g materials. Size of propagule was reported by [11] to affect the growth and early development of plantain suckers. Linear relationship was found to exist between growth 'parameters and size of planting sizes. The higher the food reserves in the propagule the more the materials the seedling or plantlets would have to make use of before commencement of photosynthesis. Hence, plant established with bigger propagule may have better advantage in the establishment of ginger plant. The dependence of yam (*Dioscorea sp*.) seedling on the parent sets, pointing out that the mother sets serve as food reserves for the young seedling in their early growth stage [15].

Ginger Rhizome Yield and Yield Parameters in Response to Applied Nitrogen Level and Propagule Size

Significant increase in ginger rhizome yield and yield parameters was observed with applied nitrogen level and propagule size. All the yield parameters - numbers of tillers and rhizome, length and weight of rhizome were affected by the applied treatments. The use of 60 kg N /ha fertilizer gave the best yield. This could be because this same treatment gave the best vegetative development especially number and size of the leaves. When number and size of leaves of a typical crop is at optimum development, dry matter production and partitioning into the economic part of the plant will be enhanced. Similar observation was reported by [16] on ginger and [17] on turmeric. In most of these reports, it was reported that nutrient availability at appropriate growth stages is imperative for the development of yield parameters in root crops. In the present study, the use of 140 kg N/ha resulted in optimum yield. This implied that 40 g contained sufficient amount of nitrogen which the crop required for post flowering or reproductive growth stages activities. Low yield obtained from unfertilized plants when compared with fertilized plants is a pointer to the fact that application of nitrogen enhanced the growth and development of ginger rhizome. [15] discussed the dependence of Yam (*Dioscorea sp*) seedling on the parent sets, pointing out that the mother sets serve as food reserves for the young seedling in their early growth stage. In another study, [18, 19] reported that the food reserve varies with sett sizes. The sizes of the sett determine the level of emergence and subsequent growth since the process is energy dependent. Inoti et al. [20] reported that large seeds were found to contain large cotyledon size and the larger the cotyledons the more the food reserve which provide energy for the young seedling to emerge and early vigorous growth. Recent study has shown that the greater the seed rhizome size/weight, the larger is the fresh rhizome yield [21]. It was posited that the yield of ginger depends on size of ginger rhizomes use as planting material, larger rhizome size emerged earlier and showed vigorous and rapid growth using the initial food reserve materials and producing maximum yield [22]. This suggests that large sett sizes are desirable for ginger production.

Ginger Rhizome Proximate Compositions in Response to Applied Nitrogen Level and Propagule Size

Rhizome sizes and nutrient levels also had positive effect on rhizome proximate composition. As the nutrient levels and the rhizome sizes increases, the proximate composition also increased. This shows that nitrogen improved the chemical composition of this crop except in alcoholic soluble extract where the highest value (1.85%) was obtained with application of 120 kgN/ha TC. The alcohol soluble extract (1.61%) and starch (3.75%) were also obtained with the use of 30 g rhizome.

5. Conclusions

This study was conducted to determine the effects of propagule size and nitrogen levels on the growth and rhizome yield of ginger using factorial experimental design. The findings from the study suggested that the production of ginger requires adequate fertilizer application and appropriate sett sizes. Rhizome sizes and nutrient levels were found to have positive effect on rhizome proximate composition. The use of 140 kg N/ha and 40 g propagule size produced ginger plants with the highest rhizome yield and nutritional qualities. The use of 140 kg N / ha fertilizer and 40 g propagule size was recommended for optimum production of ginger when considering the nutritional quality of the rhizome in the study area.

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Conflict of Interest

Authors declare no conflict of interest

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