RESEARCH ARTICLE

The growth, yield and nutritional value of ginger (*Zingiber officinale* Roscoe) as influenced by application of organic phosphorus fertilizer and plant denseness

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A field experiment was carried out at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, to determine the effect of Organic Phosphorus fertilizer (Aleshinloye) and plant spacing on the growth, yield and nutritional value of ginger. The treatments consisted of five levels of organic fertilizer 0, 50, 75, 100, and 125 kg P_2O_5/ha applied in form of Organic Phosphorus fertilizer (Aleshinloye) and three plant spacings namely 25 × 20, 25 × 25 and 25 × 30 cm^2. The 3 × 5 factorial experiments were laid out in a randomoized complete block design, replicated three times. The data collected were plant height, number of leaves, and fresh rhizome weight. The mineral nutrients and quality of ginger were also assessed.

The result showed that application of the organic fertilizer influenced the growth, yield, nutrient contents and the quality of ginger. The growth parameters increased as the applied fertilizer rate increased up to 100 kg P2O5/ha, then a declined thereafter. Likewise, the growth, yield, nutrient contents and quality of ginger increased as the organic fertilizer rate increased up to 100 kg P_2O_5/ha. In conclusion, the sole and or combined 100 kg P_2O_5/ha Organic Phosphorus fertilizer rate and spacing of 25 × 30 cm^2 can be recommended for better performance of *Zingiber officinale Roscoe* in Ogbomoso, south west Nigeria.

Key Words: *Mineral nutrients; Edible plants; Dry climate; Fertilizer*

INTRODUCTION

Ginger (*Zingiber officinale Roscoe)*, a spice crop, is a member of the family Zingiberaceae and sub-family Zingeradaea. It is a monocotyledonous crop which produces rhizomes that serves as the ginger of commerce. It grows to a height of 2 to 3 feet with robust heavily branched rhizomes called "hands". The food, perfumery and pharmacy industries are the main outlets which it is used. Globally, it is used for medicinal purposes Ajami and Vazirijavid, and can also be ground and blended with other local species for use in soups and porridge [1]. Ginger possesses warm pungent taste and pleasant odour which makes it acceptable as a flavoring in numerous food preparation and beverages. In the early days in Nigeria fresh ginger was mostly chewed for it hot peppery taste, and FAO, reported that the country is a major producer of ginger in Africa.

Crop yield is a function of three major factors: the soil upon which the crop is grown, climatic conditions and management practices. Ginger has a high demand for nutrients just like other roots and tuber crops. It does well in farmlands newly opened from long fallow, making use of nutrients reserves accumulated during the fallow period. The yield of ginger is adversely affected by climate change. As a result, it is paramount for researchers to find ways to ameliorate this effect [2].

Fertilizers are chemical compounds given to plants to promote growth. Fertilizers are derived from either organic or inorganic source and are available in many different formulations. Organic manure in form of compost also contains phosphorus and other nutrients needed for seed production [3]. Composting is a natural biological process carried out under controlled aerobic conditions. In the process, micro-organisms including bacteria and fungi breakdown organic matter into simpler substances. Finished compost can be classified as 100 per cent organic fertilizer containing primary nutrients, trace minerals, humus and humic acid in a slow released form. Fertilizer burn can occur when too much fertilizer is applied resulting in drying out of the root and damage or even death of the plant. For this reason, it is recommended that knowledge of the nutrient content of the soil and nutrient requirement of the crop are carefully balanced with application of nutrient. The recommended dose of fertilizer for ginger is 75 kg N, 50 kg P_2O_5 and 50 kg K_2O/ha. The fertilizers are to be applied in split doses at 40 days and 90 days after planting. The beds are to be earthed up, after each top dressing with the fertilizers. In zinc deficient soils basal application of zinc fertilizer up to 6 kg zinc/ha (30 kg of zinc sulphate/ha) gives good yield (Spices Board, India Ministry of Commerce and Industry.

Spacing is the distance between-row and within-row of planted crops [4]. Tiwari and Stoffela, reported that within-row spacing affected total plant growth to a greater extent than between-row spacing in edible plants, for instance, cucumbers. Plant height increased with higher plant populations, while stem diameter, root and shoot mass generally decreased as plant populations increased. Wider spacing is recommended for planting in usually dry climate, because plant roots need to search further for water. Plant spacing has been shown to have a significant impact on ginger growth and yield [5]. If soil is not very fertile, heavy feeders will also benefit from wider spacing. Overcrowded conditions result in competition for moisture and nutrients, which leads to weak and unhealthy plants [6]. At various locations around the world, different spacing's have been recommended. In Bangladesh, Islam recommended a spacing of 20 × 25 cm; Mahender proposed, in India, 25 cm × 15 cm spacing; in Trinidad and Tobago, Wilson and Ovid, (1993), favoured 45 × 40 cm spacing. The aim of this work is to determine the optimum rate of Organic Phosphorus fertilizer (Aleshinloye) and spacing required for the cultivation of ginger *(Zingiber officinale Roscoe)*.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out at the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso. Ogbomoso lies on latitude 8°07' 60.00" N and longitude 4°14' 60.00" E. The climate of

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Ogbomoso is mostly influenced by the North - East trade wind. Temperature ranges from 28°C to 300°C and the humidity of this area is high (74%) all year round except in January when the dry wind blow from the North. Annual rainfall for this area is 1200 mm.

Land preparation

The experimental area was divided into three blocks. Each block was further sub-divided into 15 plots with each plot measuring 1 m by 1 m with 0.5 m gap within the block and 1 m between blocks for easy cultural activities. These were arranged in a factorial experiment and fitted into a randomised complete block design with three replications. The experimental site's soil was sampled using a soil Auger. The soil samples were air dried and sieved using a 0.02 mm wire mesh sieve. The particle size estimate was determined utilising hydrometer method proposed by Bouyoucos [7].

Soil properties

The following are the soil properties: Soil pH-6.0; Available phosphorus-5.77 ppm; Texture class-sandy loam; Sand-86.7 percent; Silt-9.2 percent; Clay-4.10 percent; Ca^{2}2.25 c mol kg^{-1}; Mg2 -1.12 c mol kg^{-1}; Na-0.4 c mol kg^{-1}.

Treatment and experimental design

The treatments consisted of five levels of Organic Phosphorus fertilizer (Aleshinloye) at the rate 0, 50, 75, 100, and 125 kg P_2O_5/ha and three planting distances (25 × 20, 25 × 25, and 25 × 30 cm^2) with ginger as a test crop. And the experiment design as described below (Figure 1).

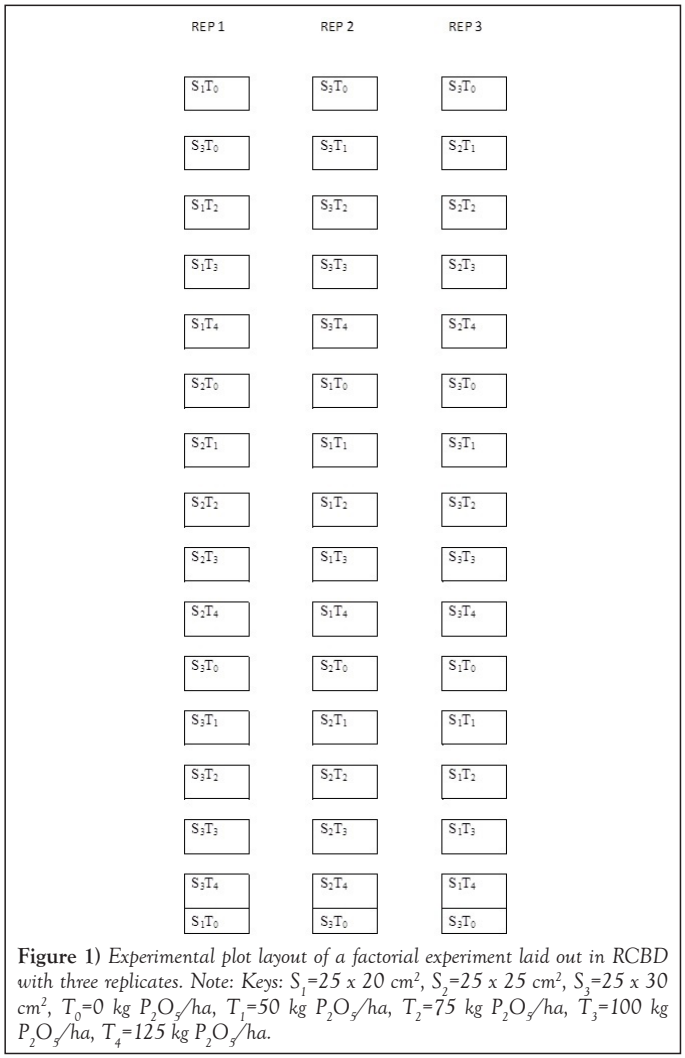

Figure 1) *Experimental plot layout of a factorial experiment laid out in RCBD with three replicates. Note: Keys: S_1=25 x 20 cm^2, S_2=25 x 25 cm^2, S_3=25 x 30 cm^2, T_0=0 kg P_2O_5/ha, T_1=50 kg P_2O_5/ha, T_2=75 kg P_2O_5/ha, T_3=100 kg P_2O_5/ha, T_4=125 kg P_2O_5/ha.*

Planting

The recommended cultural practices, proposed by Kerala Agricultural University, were consistently used for all treatments.

Harvesting

It was carried out when the green leaves started changing colour from green to yellow by hand pulling. The rhizomes were separated from the ginger plant with the use of sharp knife.

Data collection

Data collection commenced immediately after sprouting occurred and continued at 2 weeks interval. Parameters assessed included: germination date, height of germinated plants, and the number of leaves. The plant height was measured using a measuring rule, and the numbers of leaves were determined by counting, rhizome yield was determine using a sensitive digital weighing balance and nutritional values were determined after harvest.

Nutritional value analysis

The macrokjeldahl technique, as specified by Baur and Ensminger, was used to estimate crude protein concentration [8]. The vanadomolybdate yellow colorimetry technique was used to measure the phosphorus concentration as proposed by Jackson, 1964. Dilute hydrochloric acid was used to treat samples for starch analysis (PENTA, Chrudim). Polarimetry was used to determine the optical rotation of the solution after clarifying and filtration. Routine concentration was measured in all samples using a modified approach described by Deineka, Grigor'ev and Staroverov, and Gokarn [9]. Other proximate analyses of ginger were performed chemically in accordance with the AOAC's standard techniques of analysis (1990, 1998, 1984).

Data analysis

Data collected were subjected to analysis of variance (ANOVA) and significant means were separated by using the least significant difference at 5% level of probability [10].

RESULTS

Plant height

The mean plant height of ginger is represented in Table 1. The plant height improved by the application of Organic Phosphorus fertilizer (Aleshinloye) with the highest value obtained from plant treated with 100 kg P_2O_5/ha, irrespective of the planting distance. The plant height increased as the fertilizer rates increased from 0 kg to 100 kg P_2O_5/ha, then a decline thereafter. The mean plant height of ginger was improved by the plant spacing at different sampling occasions. The highest plant height was obtained from the plant spaced at 25 × 30 cm^2 while 25 × 20 cm^2 spacing gave the least value (Table 1). The combined effect of plant spacing and the applied Organic Phosphorus fertilizer (Aleshinloye) influenced the plant height. The highest mean of 29.47 was recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations [11].

Number of leaves

The mean number of leaves of ginger is represented in Table 2. The mean number of leaves increased as the plant aged. The applied P fertilizer increased the number of leaves of ginger plant with the highest value obtained at 100 kg P_2O_5/ha. As the applied fertilizer rates increased from 0 kg up to 100 kg P_2O_5/ha, the mean number of leaves increased, then a decline thereafter. The mean numbers of leaves of ginger were also improved by plant spacing at different sampling occasions. The highest plant height was obtained from the plant spaced at 25 × 30 cm^2 with those spaced at 25 × 20 cm^2 recorded the least value (Table 2). The combined effect of plant spacing and the applied Organic Phosphorus fertilizer (Aleshinloye) influenced the mean number of leaves. The highest mean number of leaves at 20.92 was recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations [12].

Rhizome yield

The ginger rhizome yield improved by the applied of P fertilizer with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The ginger rhizome yields also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied P fertilizer influenced the ginger rhizome yield with the highest value (14.8 t/ha) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations (Figure 2) [13].

TABLE 1

The mean plant height of ginger plant as affected by organic phosphorus fertilizer and plant spacing at different sampling period

		Plant height (cm)					
		Weeks after planning					
Plant spacing (cm)	Fertilizer rate(kg/ ha)	8	10	12	14	16	18
25 × 20 21.39	0		18.59	17.44	19.35	20.26	20.88
23.14	50		17.23	19.46	21.38	22.89	22.65
24.07	75		16.79	20.53	22.80	22.79	23.35
25.27	100		20.12	22.07	20.28	24.23	24.56
24.89	125		17.88	21.50	23.25	24.23	24.61
23.75	Mean		18.18	20.02	21.61	**22.68**	**23.21**
25 × 25 21.24	0		16.28	17.54	18.80	19.61	21.94
22.19	50		15.86	19.35	21.39	21.97	20.08
23.39	75		17.76	19.96	20.88	21.40	22.42
26.61	100		20.15	22.09	23.95	24.47	25.09
22.29	125		16.38	18.89	19.96	20.05	21.53
23.14	Mean		17.29	19.57	21.00	21.5	22.21
25 × 30 23.81	0		15.67	19.43	21.20	22.50	22.21
26.46	50		14.67	19.04	22.10	24.29	26.09
26.65	75		17.37	20.37	24.26	25.61	26.20
29.47	100		18.33	20.31	24.46	28.46	28.90
24.85	125		18.02	19.74	22.96	23.86	24.42
26.25	Mean		16.81	19.78	23.00	24.95	25.73
LSD(0.05)							
Spacing (NS)			NS	NS	NS	NS	NS
Fertilizer rate (NS)			3.27	NS	NS	NS	NS
spacing × FR (NS)			NS	NS	NS	NS	NS
CV 27.00			19.46	23.15	23.71	26.75	26.38

Note: NS: No significant difference

TABLE 2

The mean number of leaves of ginger as affected by organic phosphorus fertilizer and spacing at different sampling period

		Number of leaves					
		Weeks after planning					
Plant Spacing (cm)	Fertilizer Rate(kg/ ha)	8	10	12	14	16	18
25 × 20 17.50	0		9.90	13.08	16.42	15.97	16.28
19.47	50		11.00	14.08	15.75	17.66	18.33
18.52	75		11.33	14.75	15.25	17.33	19.83
20.51	100		13.00	15.75	14.89	19.17	17.83
17.67	125		10.00	12.92	18.00	16.50	17.08
18.73	Mean		11.05	14.12	16.06	17.33	17.87
25 × 25 18.34	0		10.22	13.47	16.03	16.75	17.67
18.67	50		10.92	13.50	16.00	17.25	17.53
19.30	75		10.75	13.58	15.83	17.42	18.08
19.68	100		12.33	15.25	16.83	17.67	18.83
17.50	125		11.83	14.00	16.42	16.42	17.17
18.70	Mean		11.21	13.96	16.22	17.10	17.86
25 × 30 18.72	0		8.00	14.92	13.25	15.06	19.08
19.63	50		10.92	13.25	16.83	18.58	18.00
16.39	75		10.00	15.25	16.17	17.92	15.75
20.92	100		11.17	15.92	17.00	18.33	19.67
18.93	125		10.33	13.33	15.67	17.50	18.17

18.92	Mean	10.08	14.53	15.78	17.48	18.13
LSD(0.05)						
Spacing		NS	NS	NS	NS	NS
Fertilizer rate		2.1	NS	NS	NS	NS
spacing × FR		NS	NS	NS	NS	NS
CV 17.21		20.41	17.89	18.39	18.71	18.72

Note: NS: No significant difference

Table 3

Nutritional value of fresh ginger rhizomes as affected by Phosphorus fertilizer and plant spacing

Plant Spacing (cm)	Fertilizer Rate(kg/ha)	CP	P	K	Ca	CF	EE	TA	TS
25 × 20	0	7.64	22.70	316.50	15.20	1.98	2.25	2.74	3.45
19.47	50	7.68	23.80	333.60	16.30	2.10	2.31	2.82	3.65
18.52	75	7.73	24.55	340.10	16.75	2.13	2.84	2.35	3.76
20.51	100	7.80	25.46	354.10	17.65	2.20	2.40	NS	NS
17.67	125	7.72	24.70	346.80	16.85	2.12	2.34	2.93	3.75
	Mean	7.71	24.24	338.22	16.56	2.11	2.33	2.90	3.72
25 × 25	0	8.80	25.84	350.30	17.64	2.14	2.36	3.09	3.83
18.67	50	8.83	25.86	350.35	17.75	2.20	2.38	3.11	3.83
19.30	75	8.86	25.96	352.03	17.82	2.20	2.39	3.16	3.84
19.68	100	8.94	26.08	354.65	17.98	2.35	2.48	3.21	3.92
17.50	125	8.89	26.05	354.10	17.88	2.30	2.46	3.20	3.90
	Mean	8.86	25.96	352.29	17.81	2.24	2.41	3.15	3.86
25 × 30	0	8.84	26.30	361.50	17.80	2.16	2.39	3.15	3.15
19.63	50	8.85	26.70	376.50	18.17	2.19	2.48	3.26	3.35
16.39	75	8.90	26.75	376.55	18.35	2.21	2.50	3.30	4.40
20.92	100	9.13	26.85	378.17	18.53	3.40	2.58	3.40	4.50
18.93	125	9.05	26.80	378.05	18.46	2.50	2.56	3.35	4.47
	Mean	8.95	26.68	374.15	18.26	2.49	2.50	3.29	3.97
LSD(0.05)									
Spacing		0.53	1.19	28.20	1.47	NS	NS	NS	NS
Fertilizer rate		NS	2.1	NS	NS	NS	NS	NS	0.61
spacing × FR		NS	NS	NS	NS	NS	NS	NS	NS
CV 17.21		8.3	20.41	17.89	18.39	18.71	18.72	26.70	16.40

Note: NS: No significant difference

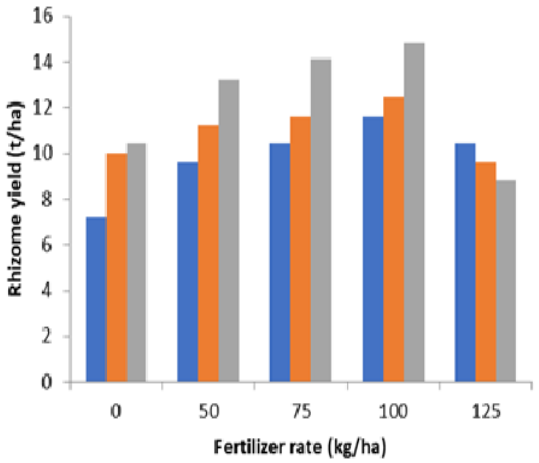

FIGURE 2) *GINGER RHIZOME YIELD AS INFLUENCED BY PHOSPHORUS FERTILIZER AND PLANT SPACING.*
NOTE: ■ *25 × 20 CM,* ■ *25 × 25 CM,* ■ *25 × 30 CM*

DISCUSSION

Nutritional value

The result of the nutritional value of *Zingiber officinale Roscoe* as affected by Organic Phosphorus fertilizer (Aleshinloye) and plant spacing is represented in Table 3.

Percentage of crude protein (CP)

The percentage of Crude protein improved by the application of Phosphorus fertilizer (Aleshinloye) with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The

percentage of Crude protein also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of Crude protein with the highest value (9.13) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations [14].

Percentage of phosphorus (P)

The percentage of Phosphorus improved by the applied of P fertilizer with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The percentage of Phosphorus also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of Phosphorus with the highest value (26.85) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations.

Percentage of potassium (K)

The percentage of Potassium improved by the applied of P fertilizer with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The percentage of Potassium also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of Potassium with the highest value (378.17) recorded at the rate of 100 kg P_2O_5/ha and 25 x 30 cm^2 spacing treatment combinations.

Percentage of calcium (Ca)

The percentage of Calcium improved by the applied of Phosphorus fertilizer (Aleshinloye) with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The percentage of Calcium also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of Calcium with the highest value (18.53) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations.

Percentage of crude fiber (CF)

The percentage of Crude fiber improved by the applied of Phosphorus fertilizer (Aleshinloye) with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The percentage of Crude fibre also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of Crude fibre with the highest value (3.40) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations.

Percentage of ether extracts (EE)

The percentage of Ether extract improved by the applied of Phosphorus fertilizer (Aleshinloye) with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The percentage of Ether extract also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of ether extract with the highest value (2.58) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations.

Percentage of total ash (TA)

The percentage of Total ash improved by the applied of Phosphorus fertilizer (Aleshinloye) with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The percentage of Total ash also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of Total ash with the highest value (3.40) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations.

Percentage of total starch (TS)

The percentage of Total starch improved by the applied of Phosphorus fertilizer (Aleshinloye) with the highest value obtained from plants treated with 100 kg P_2O_5/ha while plants treated with 0 kg P_2O_5/ha gave the least value. The percentage of Total starch also improved by plant spacing at different sampling occasions with the highest value obtained from plants spaced at 25 × 30 cm^2 while those spaced at 25 × 20 cm^2 recorded the least. The combined effect of plant spacing and the applied Phosphorus fertilizer (Aleshinloye) influenced the percentage of total starch with the highest value (4.50) recorded at the rate of 100 kg P_2O_5/ha and 25 × 30 cm^2 spacing treatment combinations.

CONCLUSION

The required amount of the fertilizer varies due to type of plant, soil, plant spacing and other cultural practices. Fertilizer application is highly essential for enhancing soil nutrient status and increasing crop yield as well as quality. Phosphorus fertilizer (Aleshinloye) contained nutrients that are very essential for plant growth and yield.

In this research work, various levels of Phosphorus fertilizer (Aleshinloye) and different spacings suitable for increasing the yield and nutrient content of ginger have been investigated. There were increased in yield, quality, and nutrient composition of ginger with the application of various rates of the fertilizer at each of the spacing when compared with the control treatment. It was noticed that the combination of spacing at 25 × 30 cm^2 and fertilizer rate at 100 kg P_2O_5/ha recorded the best growth and yield performance. The fertilizer as well as the various spacings used influenced the height and number of leaves of the ginger plant. In conclusion, the use of sole and or combined 100 kg P_2O_5/ha Phosphorus fertilizer (Aleshinloye) and spacing of 25 × 30 cm^2 gave better performance of *Zingiber officinale Roscoe*.

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