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Variability in morphological, yield and nutritional attributes of ginger (*Zingiber officinale*) germplasm in Nigeria

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ABSTRACT

Ginger is a spice cum medicinal plant with fluctuating price and consumer demands that depends on the varietal qualities. Ten ginger genotypes were evaluated in 2017 and 2018 at the Department of Crop Science, University of Nigeria for variation in their morphological, yield and nutritional attributes. Data were collected on seedling emergence, number of leaves, leaf length, leaf width, plant height, pseudo-stem diameter and rhizome yield. The harvested rhizomes were analyzed for proximate, minerals and phytochemical compositions. Genotype EN-1 gave the best rhizome yield of 18 t/ha followed by KD-2 (16.5 t/ha), KD-1 (14.5 t/ha) and KD-3 (14 t/ha) while lower yield of 3.3 t/ha was obtained in RT-3 genotype. The results of proximate analysis revealed a high variation in nutritional contents with a range of 1.31 to 3.17% protein, 0.88 to 1.33% ash, 2.22 to 4.97% fiber, 0.25 to 0.60% fats and 8.3 to 12.0% carbohydrate contents in the different genotypes. Significant variation among the mineral and phytochemical attributes of the studied genotypes was also observed. The desirable growth, yield and nutritional attributes identified in different genotypes calls for gene mapping in these genotypes to establish their genetic diversity. The premium price placed on ginger rhizome is dependent on its quality and yield hence, grower should consider quality as well as the rhizome quantity accruable from each genotype in deciding which genotype to grow.

Key words : Genetic diversity, ginger, growth, phytochemicals, rhizome

INTRODUCTION

The importance of a plant depends on its identified benefits. Ginger (*Zingiber officinale* Roscoe) is a spice as well as a medicinal plant. Its global recognition stands more for its spicy properties than its medicinal properties. Studies on ginger's medicinal properties indicated its ability to prevent skin, breast and prostate cancers (Ling *et al.*, 2010; Karna *et al.*, 2012). Ginger derivatives can scavenge reactive oxygen species, free radicals, peroxides, and various other damaging oxidants (Eleazu and Eleazu, 2012; Rajan *et al.*, 2013). Dhanik et al. (2017) described ginger as the storehouse of antioxidant. Most of the bioactive components responsible for spicy quality of ginger also contributes to its medicinal usage.

Therefore, consuming ginger as a spice has the additional benefit of improving the health of the consumer.

The demand for a specific ginger variety depends on its quality. India, the world leading ginger producer has the best ginger quality along with Jamaica while West African gingers ranked second in quality (Dhanik *et al.*, 2017). Sensory qualities of a crop can be influenced by the interaction of its gene with weather, soil type, available nutrients and management practices (Mncwango *et al.*, 2019; Pallavi and Anuja, 2019). This interaction often confers unique advantage to a location in producing crop qualities that meet specific consumer demands. Nigeria enjoys this advantage as her ginger quality is very good in oleoresin and essential oils (SPA, 2017). Nigeria is the leading

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ginger producer in Africa and ranked second globally based on the cultivated land area and the harvested quantity in 2016 (Slominski, 2018). Nigerian ginger contributed US $115.564 M to the US $2,401.756 M world ginger value from 2008 to 2012 representing a share of 4.81% (Ewuziem *et al.*, 2015).

Ginger production is spread across different agroecological zones in Nigeria with Guinea Savannah agroecology being the production hub. Ginger enterprise is profitable in Nigeria (NdaNmadu and Marcus, 2011) but this profitable enterprise is not without challenges. Price fluctuation, access to credit, availability of seed material (NdaNmadu and Marcus, 2011; Folorunso and Adenuga, 2013) and low yield (Asafa and Akanbi, 2018) are some of the challenges faced by ginger growers in Nigeria. Yield improvement and increase in seed availability can be achieved through characterization of available germplasm. Different ginger rhizome sizes, colors and pungency have been identified in Nigeria (Folorunso and Adenuga, 2013), a pointer to the genetic diversity that exist in her ginger germplasm.

To the best of our knowledge, little attempts have been made to deliberately describe the available ginger germplasm in Nigeria with regards to variability in morphological, nutritional and yield attributes. Most ginger studies in Nigeria had focused on socio-economic impacts on farmers (Folorunso and Adenuga, 2013; Ihuoma and Dogara, 2018) and ginger response to nutrient application and soil types (Enujeke and Egbuchua, 2013; Attoe *et al.*, 2016; Asafa and Akanbi, 2018). Eleazu *et al.* (2012) characterized 10 elite accessions of ginger in Nigeria based on their biochemical qualities. These 10 accessions are progenies of one genotype 'UG II'. Being conscious of this research gap in characterizing available ginger germplasm in Nigeria and how it affects ginger growers in selecting high yielding varieties to improve productivity, this study hypothesizes that there are differences in the morphological, yield and nutritional attributes of ginger genotypes in Nigeria. These differences when identified will guide producers and consumers to maximize the benefits of ginger cultivation. The objective of this study is to assess the variability in growth, yield and nutritional attributes of ginger genotypes in Nigeria.

MATERIALS AND METHODS

Description of Study Site

The experiment was conducted at the research farm of University of Nigeria, Nsukka Enugu State Nigeria during 2017 and 2018 planting seasons. The research farm (06° 52´N, 07° 24´E, 447.26 m above sea-level) is located within the derived savannah zone of Nigeria with bimodal rainfall pattern that is obtained during April and October with peaks during the months of July and October. Relative humidity (%), maximum and minimum temperatures (°C), rainfall amount (mm) and rainfall days for 2017 and 2018 were obtained from the Meteorological Unit of University of Nigeria and are presented in Figs. 1a and 1b. The soil at the experimental site, classified as Ultisol according to the soil taxonomy of the USDA (Soil Survey Staff, 2003), is sandy clay loam, contains low organic carbon (≈1.46%), and low contents of nitrogen, phosphorous, basic cations (potassium, magnesium, calcium) and base saturation contents but high exchangeable acidity (Chukwudi and Agbo, 2014). However, the soil is deep, well drained and coarse textured with leaching as a major problem (Igwe, 2004).
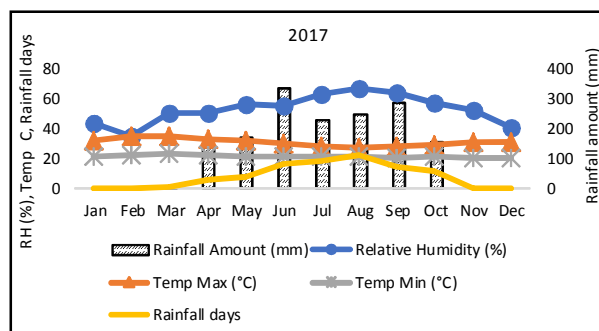

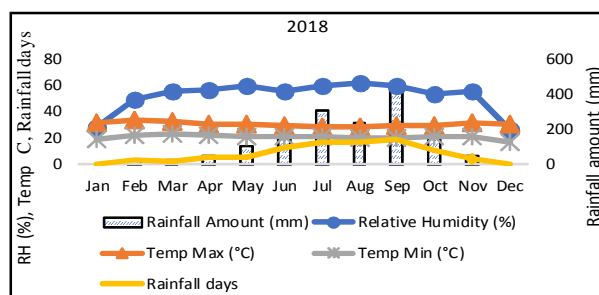Fig. 1a. Weather data at experimental site for 2017.

Fig. 1b. Weather data at experimental site for 2018.

Planting Materials

Ten ginger genotypes utilized in this study were sourced from different parts of Nigeria. Six genotypes namely 'HPL' [RT-1], 'Maran' [RT-2], 'St. Vincent' [RT-3], 'UG I' [RT-4], 'UG II' [RT-5] and 'Wynad' [RT-6] were obtained from the National Root Crops Research Institute Umudike, Abia State. Three others identified by farmers as 'Elephant palm' [KD-1], 'Jumbo or Chinese ginger' [KD-2] and 'Monkey fingers' [KD-3] were sourced from commercial ginger growers in Kaduna State where commercial ginger production and export ranks first (Folorunso and Adenuga, 2013). The remaining genotype [EN-1] was obtained locally from a farmer's field in Enugu State. To increase uniformity and eliminate storage effect on the ginger sett emergence, only healthy matured plants were harvested from the donors' field.

Field Preparation, Treatments, Experimental Design, Layout and Cultural Practices

The land was mechanically cleared, ploughed, and harrowed after which planting beds (75 x 100 cm) were manually raised 15 cm using a handheld hoe. A pathway of 100 cm was maintained between and within blocks. Three blocks (replications) were made, and each contained ten plots for each genotype. The study was fitted into randomized complete block design. Dried pig manure was applied on each raised bed at the rate of 15 t/ha after land preparation while a further 120 kg/ha NPK inorganic fertilizer (15:15:15) was band placed at 12 weeks after planting (WAP) along each planted row. Ginger setts each containing two to three buds were planted at 20 cm by 15 cm inter-and intra-row spacing, respectively on each bed (plot) according to genotypes. A total of 25 setts per genotype were planted per plot representing a plant population of 333,333 plants per hectare. The field was manually weeded without pesticide application.

Trait measurements

The plots were monitored for seedling emergence after planting. Approximately 3 WAP, the first set of emergences were observed. Thereafter, the plots were monitored to determine the number of days to attain half (50%) and complete setts emergence in each plot. These attributes were recorded as days to 50% emergence (D50E) and final emergence (FE). The FE description was used as most of the genotypes did not attain complete or 100% emergence. Hence, FE represents the percentage of emerged seedlings over planted setts per treatment. The emergence characteristic of the seedlings across the different genotypes was erratic.

By the sixth WAP, data collection on the morphological attributes started and three middle plants in each plot were randomly selected and tagged for this purpose. The number of leaves per tiller was counted. Leaf length and width of the second fully opened leaf was measured with a meter rule from one end to other end in a straight line and recorded in centimeter (cm). The plant height was measured with a flexible meter rule from soil level to the tip of the plant while the pseudo-stem diameter was measured with a micrometer screw gauge (Outside© Micrometer, Nigeria) 2 cm above the soil level. Data collection on morphological attributes was performed at bi-weekly intervals and ended 12 WAP.

At 30 WAP, most of the plants' leaves had turned yellow and withered; suggesting that the rhizomes are ready for harvest. During harvesting, holes were carefully and manually dug round the root zone and the rhizomes were carefully lifted with the aid of hand fork to reduce rhizome damages. Harvested rhizomes per plot were placed in paper bags with proper labels before been moved to the laboratory. All adhering soil particles to the rhizomes were gently removed prior to weighing. To obtain yield on dry basis, 500 g of rhizomes from each replicate was air-died to constant weight before fresh and dry weights per plot were converted into yield per hectare.

Laboratory Analyses

The protein, fat, fiber, ash, and moisture percentages of the proximate composition of the ginger genotypes were analyzed using the methods described in AOAC (2005). The carbohydrate content was obtained by subtracting the sum values of protein, fat, fiber, ash, and moisture from 100. Magnesium, calcium, sodium, potassium, phosphorous and iron contents were determined using atomic-absorption spectrophotometry (Shimadzu

Model AA-7000). The alkaloid, flavonoid and tannin contents were also analyzed as described by AOAC (2005).

Data Analysis

One-way analysis of variance for randomized complete block design was done on the collected data using GenStat Software (VSN Int. Ltd., Rothamsted Experimental Station, UK). When the F-value in the ANOVA Table is significant, Fisher's protected least significant difference (F-LSD) was used in means separation at p = 0.05. Line graphs and bar charts were plotted using Microsoft Excel spreadsheet. The two years data were pooled together for data analysis.

RESULTS AND DISCUSSION

The observed significant variation in seedling emergence and morphological characteristics among the ginger genotypes is an indication of their genetic differences. These differences may have also contributed to the variation observed in the yield. The number of days to first seedling emergence ranged from 24 to 30 days after planting (DAP). EN-1 attained 50% seedling emergence at 24 DAP (Fig. 2) while RT-1 attained at 31 DAP. The result of final percentage emergence showed that only EN-1 and KD-2 attained 100% emergence at 12 and 7 days after emergence, respectively. The ginger genotypes studied had good emergence capacities. Only two genotypes had emergence lower than 80%. The reported average number of days for the first seedling emergence in this study is higher than 15 days reported in Ethiopia (Wolde *et al.*, 2016) but lower than the 59 days reported in Manipur (Jyotsna *et al.*, 2012).
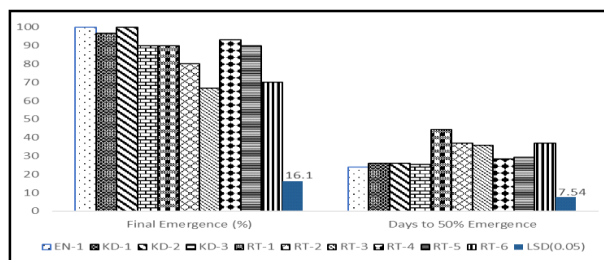

Fig. 2. Impact of genotype on final emergence and days to 50% emergence in ginger.

Results revealed that KD-1 produced the longest leaf length at 6 (18 cm), 8 (21 cm)

and 10 (22 cm) WAP while RT-1 produced it (22.3 cm) at 12 WAP (Fig. 3). RT-3 and RT-6 produced the shortest leaf lengths at 6 and 8 WAP; 10 and 12 WAP, respectively. There was no statistical difference among the measured leaf lengths in KD-1, KD-2, KD-3 and EN-1 at 6, 8, 10 and 12 WAP. KD-2 and EN-1 gave the broadest leaf widths that were significantly higher than the other genotypes at 6 (6.2, 7.4 cm), 8 (6.6, 6.3 cm), 10 (5.7, 5.7 cm) and 12 (5.2, 4.8 cm) WAP (Fig. 4) while RT-3 and RT-6 had the least leaf widths at 6 (1.9 cm) and 10 (1.9 cm) WAP. The leaf traits measured showed morphological differences in the ginger germplasm. Leaf width was more distinct in differentiating the genotypes than leaf length. Leaf width distinguished KD-2 and EN-1 from other genotypes while leaf length categorized them as similar with KD-1 and KD-3. Chukwudi *et al.* (2017) identified leaf broadness as the most representative trait in leaf study of Fluted pumpkins (*Telfairia occidentalis*). Broad leaves tend to intercept more light energy needed for photosynthesis. The photosynthetic capacity of plants is determined by both its number and the spread of the leaves. Average number of leaves per tiller and number of tillers per plant contributes to the final number of leaves per plant. The genotypes RT-6, RT-2 and RT-3 that had low number of leaves per tiller and low number of tillers per plant produced the least number of leaves per plant and also had short heights. All these growth attributes
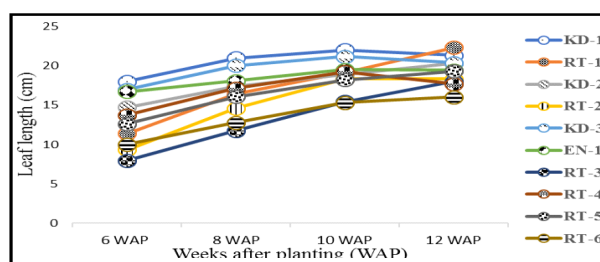

Fig. 3. Leaf length (cm) trend from 6 to 12 weeks after planting of ginger genotypes.
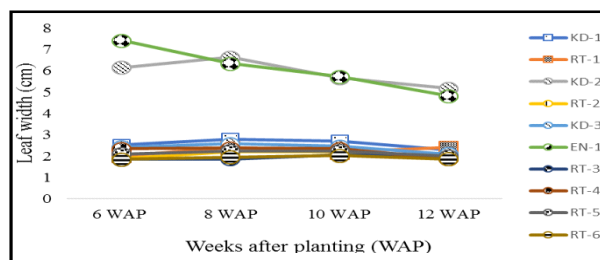

Fig. 4. Leaf width (cm) trend from 6 to 12 weeks after planting of ginger genotypes.

may have resulted in reduced photosynthetic capacity that possibly contributed to the low rhizome yield obtained from them. The genotypes that produced more tillers and higher number of leaves per plant gave the best rhizome yields.

The highest number of leaves/tiller was observed in EN-1 (7) at 6 WAP however, at 10 and 12 WAP KD-1 (15 and 20) gave the highest number of leaves per tiller (Fig. 5). Significant differences were observed among the ginger plant heights with KD-1 and KD-3 producing the tallest plants at 6 (31.3 cm) and 12 (56.3 cm) WAP; 8 (38.7 cm) and 10 (48.8 cm) WAP, respectively (Fig. 6). KD-3 was significantly higher than the other genotypes at 10 WAP except KD-1 and EN-1 genotypes. The plant height results revealed that RT-3 genotype produced the shortest plants at 6 and 8 WAP while RT-6 genotype gave shortest plants as 10 and 12 WAP.
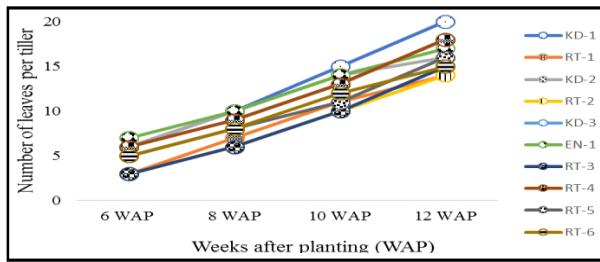

Fig. 5. Number of leaves per tiller in ginger genotypes from 6 to 12 weeks after planting.
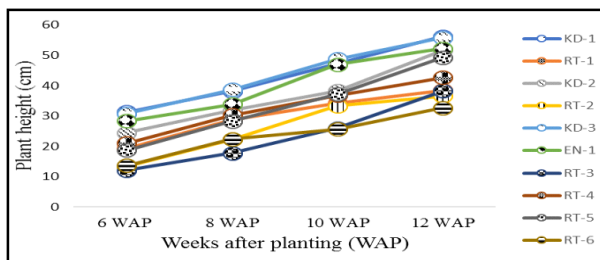

Fig. 6. Plant height (cm) in ginger genotypes from 6 to 12 weeks after planting.

The pseudo-stem diameter of the ginger genotypes showed significant variations. KD-2 had significantly higher pseudo-stem diameter (6.9 mm, 7.8 mm) than RT-1, RT-2, KD-3, RT-3, RT-4, RT-5 and RT-6 genotypes at 6 and 8 WAP while EN-1 produced the widest diameter at 10 (8.2 mm) and 12 (9.0 mm) WAP (Fig. 7). KD-2 produced significantly higher number of leaves per plant (31 and 64) than RT-1, RT-2, RT-3 and RT-6 at 10 and 12 WAP while the lowest number of leaves per plant was recorded in RT-2 genotype (11 and 24) during both

periods (Fig. 8). RT-3 produced the least pseudo-stem diameter at 6 and 8 WAP and RT-2 at 10 and 12 WAP. The number of tillers per plant differed significantly among the genotypes with the highest observed in KD-3 (6 and 9) and the least (2 and 4) in RT-2 and RT-3 at 10 and 12 WAP (Fig. 9).
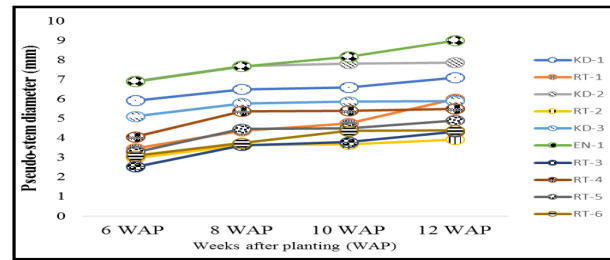

Fig. 7. Pseudo-stem diameter (mm) in ginger genotypes from 6 to 12 weeks after planting.

Fig. 8. Number of leaves per plant at 10 and 12 weeks after planting of ginger genotypes. Error bars = F-LSD (p=0.05).

The rhizome yield of the ten ginger genotypes differed significantly (Fig. 10) with the highest fresh yield of 98.7 t/ha and dry yield of 18 t/ha produced by EN-1. This was followed by KD-2, KD-1 and KD-3 genotypes. The yield of EN-1 was statistically different from those of RT-4, RT-6, RT-5, RT-1, RT-2 and RT-3 genotypes with the least yield of 18.8 t/ha (fresh) and 3.3 t/ha (dry) obtained from RT-3 genotype. The observed morphological variabilities alone did not explain the differences observed in the yield. The genetic make-up and the interaction of the genetic make-up with the environment may have played some roles in the difference in yield. The genotypes RT-4 and RT-5 that shared similar growth features with the KD series, and EN-1 genotype had huge yield variations with the later. When different crop varieties are grown under identical conditions it is genetic factor that explains the morphological differences (Goudar *et al.*, 2017). Understanding the dry matter partitioning in these ginger genotypes can help explain the observed differences in
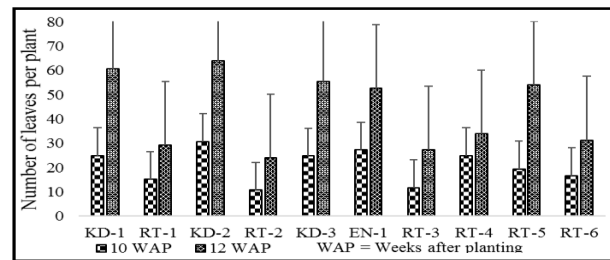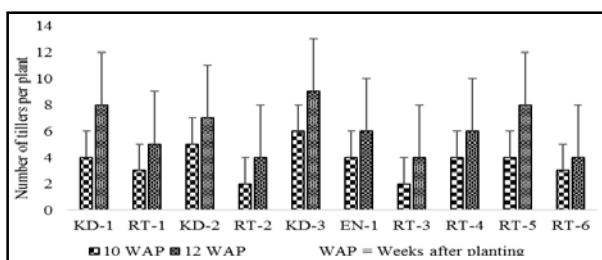
Fig. 9. Number of tillers per plant at 10 and 12 weeks after planting of ginger genotypes. Error bars = F-LSD (p=0.05).
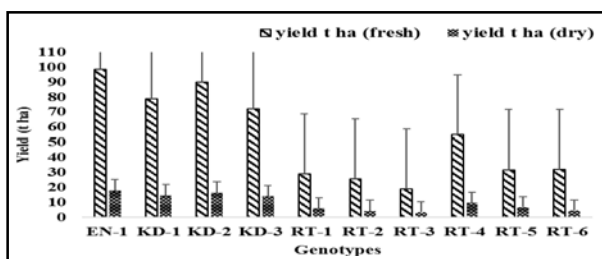

Fig. 10. Impact of genotypes on fresh and dry rhizome yield (t/ha) of ginger. Error bars = F-LSD (p=0.05).

yield. Yield in plant is a complex trait affected by genotype and genotype-by-environment interaction.

The proximate analysis revealed significant differences in the nutritional quality of the ten ginger genotypes except for their carbohydrate content (Table 1). The RT-1 genotype had the highest protein (3.17%) while RT-3 genotype had the highest ash content (1.33%). Moisture content was highest in RT-6 genotype (86%) while KD-2 (4.97%) and EN-1 (0.6%) contained significantly highest fiber and fat content, respectively. However, the fat content of EN-1 genotype was significantly comparable to those of RT-1 and RT-5 genotypes. The ash (0.88%) and carbohydrate (8.27%) percentages of RT-6 genotype was the

least among the ten ginger genotypes while genotype KD-2 gave the lowest fat (0.25%) and protein (1.31%) contents. The least fiber and moisture contents were obtained from RT-3 and RT-4 genotypes, respectively.

The mineral and phytochemical composition of the ten ginger genotypes showed significant differences in magnesium, calcium, phosphorus, iron, potassium, sodium, alkaloid, tannin and flavonoid contents of the ginger genotypes (Tables 2 and 3). The RT-6 genotype had the highest phosphorus (0.543), calcium (0.009), potassium (24.45) and flavonoid (1.6) concentrations while genotype RT-1 gave the highest values for iron (0.986), sodium (1.433), flavonoid (1.6) and tannin (0.924) contents. The highest amount of alkaloid and lowest sodium content were observed in KD-1 genotype. The highest amount of magnesium and the lowest amount of tannin were extracted from EN-1 genotype. The KD-2 genotype contained least phosphorus, iron, potassium, alkaloid and flavonoid while RT-4 genotype similarly had the lowest calcium and magnesium content. RT-3 genotype had the lowest iron concentration among all ten genotypes.

The variabilities witnessed in the growth and yield attributes of the ginger genotypes manifested in the nutritional composition of the ginger germplasm. Variation in the nutritional composition of ginger genotypes had been reported (Eleazu *et al.*, 2012; Ravindran and Babu, 2016). In this present study, the variation in the proximate analysis results ranged from 1.31 to 3.17% for protein, 0.88 to 1.33% for ash, 79.4 to 86.0% for moisture, 2.22 to 4.97% for fiber, 0.25 to 0.60% for fats and 8.3 to 12.0% for carbohydrate. These values are in line with ginger rhizome proximate analysis on wet basis reported by El-Ghorab *et*

Table 1. Proximate composition (%) of fresh ginger genotypes

Genotypes	Protein	Ash	Moisture	Crude Fiber	Fat	Carbohydrate
EN-1	1.970 ± 0.51	1.05 ± 0.00	82.2 ± 4.19	4.30 ± 0.46	0.60 ± 0.40	9.9 ± 4.63
KD-1	2.299 ± 0.38	1.20 ± 0.12	81.1 ± 4.79	3.75 ± 0.12	0.33 ± 0.03	11.3 ± 4.61
KD-2	1.313 ± 0.25	1.18 ± 0.14	80.3 ± 3.81	4.97 ± 0.61	0.25 ± 0.06	12.0 ± 3.15
KD-3	3.065 ± 0.25	1.18 ± 0.09	80.7 ± 2.17	3.23 ± 0.49	0.35 ± 0.00	11.5 ± 1.84
RT-1	3.174 ± 1.14	1.23 ± 0.38	80.1 ± 4.85	3.32 ± 1.01	0.40 ± 0.06	11.8 ± 4.54
RT-2	2.408 ± 1.01	0.98 ± 0.09	82.0 ± 6.21	2.60 ± 0.52	0.35 ± 0.06	11.7 ± 6.55
RT-3	1.970 ± 0.51	1.33 ± 0.26	82.7 ± 1.76	2.22 ± 0.03	0.35 ± 0.06	11.4 ± 1.98
RT-4	2.408 ± 0.25	1.20 ± 0.12	82.8 ± 2.25	2.83 ± 0.49	0.30 ± 0.17	10.5 ± 2.30
RT-5	2.846 ± 1.01	1.10 ± 0.17	79.4 ± 2.86	3.80 ± 1.33	0.48 ± 0.32	12.4 ± 2.05
RT-6	1.532 ± 0.76	0.88 ± 0.03	86.0 ± 0.87	3.00 ± 0.35	0.33 ± 0.03	8.3 ± 0.51
F-LSD (p=0.05)	0.79	0.22	5.7	0.94	0.24	NS

NS : Not Significant; Mean ± Standard deviation.

Table 2. Mineral contents (ppm) of fresh ginger genotypes

Genotypes	Magnesium	Calcium	Phosphorus	Iron	Potassium	Sodium
EN-1	0.0138 ± 0.006	0.006 ± 0.002	0.296 ± 0.04	0.197 ± 0.23	18.29 ± 1.17	1.274 ± 0.07
KD-1	0.0096 ± 0.001	0.004 ± 0.002	0.309 ± 0.08	0.394 ± 0.46	17.18 ± 1.64	0.926 ± 0.13
KD-2	0.0108 ± 0.001	0.007 ± 0.003	0.209 ± 0.01	0.099 ± 0.11	13.52 ± 0.88	1.013 ± 0.00
KD-3	0.0102 ± 0.002	0.004 ± 0.002	0.330 ± 0.01	0.197 ± 0.00	15.79 ± 0.91	1.086 ± 0.02
RT-1	0.0126 ± 0.001	0.007 ± 0.001	0.465 ± 0.08	0.986 ± 0.00	17.48 ± 1.62	1.433 ± 0.08
RT-2	0.0096 ± 0.001	0.007 ± 0.001	0.374 ± 0.05	0.197 ± 0.23	19.90 ± 2.26	1.361 ± 0.13
RT-3	0.0066 ± 0.001	0.008 ± 0.000	0.330 ± 0.10	0.099 ± 0.11	17.39 ± 2.46	1.086 ± 0.35
RT-4	0.0054 ± 0.002	0.002 ± 0.000	0.317 ± 0.01	0.197 ± 0.00	19.22 ± 2.46	1.245 ± 0.23
RT-5	0.0090 ± 0.001	0.007 ± 0.001	0.383 ± 0.06	0.493 ± 0.11	16.90 ± 0.62	1.129 ± 0.03
RT-6	0.0096 ± 0.003	0.009 ± 0.003	0.543 ± 0.15	0.887 ± 0.57	24.45 ± 0.62	1.201 ± 0.05
F-LSD (p=0.05)	0.0038	0.003	0.102	0.372	3.77	0.23

Mean ± Standard deviation.

Table 3. Phytochemical contents (%) of fresh ginger Genotypes

Genotype	Alkaloid	Tannin	Flavonoid
EN-1	1.78 ± 0.49	0.257 ± 0.08	1.25 ± 0.29
KD-1	2.05 ± 0.06	0.563 ± 0.14	1.45 ± 0.17
KD-2	1.33 ± 0.38	0.379 ± 0.01	0.45 ± 0.17
KD-3	1.73 ± 0.32	0.508 ± 0.01	1.00 ± 0.23
RT-1	1.75 ± 0.52	0.924 ± 0.02	1.60 ± 0.35
RT-2	1.60 ± 0.12	0.410 ± 0.16	1.30 ± 0.00
RT-3	1.85 ± 0.23	0.483 ± 0.23	1.45 ± 0.06
RT-4	1.73 ± 0.49	0.441 ± 0.16	1.05 ± 0.29
RT-5	1.80 ± 0.35	0.618 ± 0.09	1.55 ± 0.29
RT-6	1.50 ± 0.00	0.845 ± 0.23	1.60 ± 0.81
F-LSD (p=0.05)	0.405	0.121	0.44

Mean ± Standard deviation.

al. (2010) but differed from the values reported by Okolo *et al.* (2012) on ginger proximate analysis on wet basis. Moisture content of the ginger rhizome can influence the concentrations of other proximate contents (El-Ghorab *et al.*, 2010; Okolo *et al.*, 2012). Reduced moisture content will result in increased concentrates of flavonoid, phosphorus and protein contents in ginger rhizomes. Shirin and Jamuna (2010) had reported many health benefits of tannins and flavonoids extracted from ginger rhizome. Eze and Orjioke (2010) associated the antimicrobial activities of ginger to its tannins. Flavonoids have been implicated in the antioxidant properties of ginger (Eleazu and Eleazu, 2012; Dhanik *et al.*, 2017). In addition, the sedative and analgesic effects produced by ginger alkaloid may be useful for the pharmaceutical sector. Eze and Orjioke (2010) recommended that alkaloids can be used in the production of pain-relieving drugs.

The correlation coefficients among selected mineral, nutritional and phytochemical contents of the ginger genotypes revealed that alkaloid had positive significant relationship with ash (r = 0.37) and fat (r = 0.39) (Table 4). Tannin had positive significant relationship with flavonoid, phosphorus, iron

Table 4. Correlation coefficients of proximate, mineral and phytochemical composition of fresh ginger genotypes

	Alk	Tannin	Fla	Mg	Ca	P	Fe	K	Na	Protein	Ash	MC	Fiber	Fat	CHO
Alk	1														
Tannin	-0.17	1													
Fla	0.11	0.58**	1												
Mg	-0.29	0.05	-0.06	1											
Ca	-0.22	0.13	0.06	0.42*	1										
P	-0.03	0.76**	0.70**	-0.10	0.18	1									
Fe	0.08	0.83**	0.59**	0.05	0.03	0.79**	1								
K	0.13	0.34	0.55**	-0.27	0.09	0.73**	0.45*	1							
Na	-0.05	0.17	0.24	0.09	0.16	0.45*	0.17	0.43*	1						
Protein	0.05	0.41*	0.40*	-0.06	-0.45*	0.27	0.32	-0.10	0.23	1					
Ash	0.37*	-0.20	-0.27	-0.12	-0.05	-0.46*	-0.24	-0.44*	-0.38*	-0.19	1				
MC	-0.28	0.12	0.09	-0.09	0.15	0.18	0.02	0.31	0.12	0.08	-0.39*	1			
Fiber	0.06	-0.28	-0.46*	0.43*	0.04	-0.38*	-0.10	-0.34	-0.20	-0.45*	0.15	-0.52**	1		
Fat	0.39*	-0.18	-0.03	0.05	0.03	0.12	0.14	0.04	0.04	0.10	0.01	0.14	0.001	0.17	1
CHO	0.24	-0.13	-0.04	-0.02	-0.06	-0.13	-0.07	-0.19	-0.12	-0.20	0.37*	-0.96**	0.37*	-0.13	1

Alk : Alkaloid, Fla : Flavonoid, Mg : Magnesium, Ca : Calcium, P : Phosphorus, Fe : Iron, K : Potassium, Na : Sodium, MC : Moisture content, CHO : Carbohydrate, **and * : Correlation significant at p=0.01 and p=0.05 levels (2-tailed), respectively.

and protein (r = 0.41-0.83; p<0.05) with the highest correlation obtained in iron. Similarly, the content of flavonoid had positive significant relationship with phosphorus, iron, potassium and protein (r = 0.40-0.70; p<0.05). Fiber content showed negative correlation with flavonoid (r = -0.46), protein (r = -0.45), and moisture content (r = -0.52) but had positive correlation with the content of carbohydrate (r = 0.37) and magnesium (r = 0.43). There was a negative significant relationship between calcium and protein (r = -0.45). Ash showed negative significant correlation with phosphorus, potassium, sodium and moisture content (r = -0.38 to -0.46) but had positive correlation with carbohydrate (r = 0.37). Moisture content showed highly significant and negative correlation with carbohydrate (r = -0.96).

CONCLUSION

This study unveils the differences in the morphological, yield and nutritional attributes of ginger genotypes in Nigeria. Significant variations were observed in seedling emergence, plant height, pseudo-stem diameter, leaf length, width, number of tillers per plant, rhizome yield and nutritional compositions in the ginger germplasm evaluated. There is need for gene mapping in these genotypes to establish their actual genetic diversity. Since the premium price placed on ginger rhizome depend on its quality, growers should consider quality as well as the rhizome quantity accruable from each genotype in deciding which genotype(s) to grow.

REFERENCES

AOAC - Association of Official Analytical Chemists (2005). Official Methods of Analysis of the Association of Official Analytical Chemists. 18th Edn., Gaithersburg.

Asafa, R. F. and Akanbi, W. B. (2018). Growth and rhizome yield of ginger (*Zingiber officinale* L.) as influenced by propagule size and nitrogen levels in Ogbomoso, Southwestern Nigeria. *Int. Lett. Nat. Sci.* **67** : 35-45.

Attoe, E. E., Ojikpong, T. O. and Kekong, M. A. (2016). Evaluation of growth and yield parameters of two ginger varieties in different soils of Cross River State, Nigeria. *Eur. J. Acad. Essays* **3** : 109-20.

Chukwudi, U. P. and Agbo, C. U. (2014). Effect of trellis height and cutting frequency on leaf and fruit yield of fluted pumpkin (*Telfairia occidentalis* Hook F.). *J. Animal Plant Sci.* **24** : 1190-97.

Chukwudi, U. P., Agbo, C. U., Ene, C. O., Uba, C. U. and Enyi, J. I. (2017). Analysis of leaf yield components in fluted pumpkin (*Telfairia occidentalis* Hook F.) grown in derived savannah agro-ecology. *Not. Sci. Bio.* **9** : 386-91.

Dhanik, J., Arya, N. and Nand, V. (2017). A review on *Zingiber officinale. J. Pharmacogn. Phytochem.* **6** : 174-84.

Eleazu, C. and Eleazu, K. (2012). Physico-chemical properties and antioxidant potentials of 6 new varieties of ginger (*Zingiber officinale*). *Am. J. Food Technol.* **7** : 214-21.

Eleazu, C., Amadi, C. and Iwo, G. (2012). Biochemical qualities of 10 elite accessions of ginger (*Zingiber officinale* Roscoe). *Afr. J. Food Sci. Technol.* **3** : 187-92.

El-Ghorab, A. H., Nauman, M., Anjum, F. M., Hussain, S. and Nadeem, M. (2010). A comparative study on chemical composition and antioxidant activity of ginger (*Zingiber officinale*) and cumin (*Cuminum cyminum*). *J. Agric. Food Chem.* **58** : 8231-37.

Enujeke, E. and Egbuchua, C. (2013). Growth and yield responses of ginger (*Zingiber officinale*) to three sources of organic manures in a typical rainforest zone. *Nigeria J. Hort. Forst.* **5** : 109-14.

Ewuziem, J., Onyenobi, V., Ironkwe, A. and Tokula, M. (2015). Nigeria in world ginger trade: An analysis of performance from 2008-2012. *J. Agric. Food Sci.* **13** : 26-42.

Eze, E. I. and Orjioke, C. (2010). Phytochemical and antimicrobial activities of *Physcia grisea* on clinical isolate of *Salmonella typhi. J. Med. Appl. Biosci.* **2** : 93-98.

Folorunso, S. T. and Adenuga, K. M. (2013). An analysis of technical efficiency of ginger crop production in Jaba local government area, Kaduna State, Nigeria. *Adv. Appl. Sci. Res.* **4** : 85-90.

Goudar, S. A., Gangadharappa, P., Dodamani, S. M., Lokesh, C. and Dharamatti, V. U. (2017). Evaluation of ginger (*Zingiber officinale* Rosc.) genotypes for growth and yield attributes. *Int. J. Pure Appl. Biosci.* **5** : 994-99.

Igwe, C. (2004). Soil properties influencing stability of structure of B-horizons of Ultisols in semiarid Nsukka, Eastern Nigeria. *Arid Land Res. Manage.* **18** : 185-95.

Ihuoma, A. A. and Dogara, M. (2018). Impact of ginger production on poverty alleviation in Kaduna State, Nigeria. *J. Econ. Finance* **9** : 37-44.

Jyotsna, N., Ghosh, D. and Meitei, W. (2012). Study of growth, yield and quality of organically grown ginger varieties under rainfed condition of Manipur. *J. Crop Weed* **8** : 17-21.

Karna, P., Chagani, S., Gundala, S. R., Rida, P. C. G., Asif, G., Sharma, V., Gupta, M. V. and Aneja, R. (2012). Benefits of whole ginger extract in prostate cancer. *British J. Nutr.* **107** : 473-84.

Ling, H., Yang, H., Tan, S. H., Chui, W. K. and Chew, E. H. (2010). 6-Shogaol, an active constituent of ginger, inhibits breast cancer cell invasion by reducing matrix metalloproteinase-9 expression via blockade of nuclear factor-κB activation. *British J. Pharm.* **161** : 1763-77.

Mncwango, N. C., Mavengahama, S., Ntuli, N. R. and Jaarsveld, C. M. V. (2019). Variability in leaf mineral content of colchicine-treated Chorchorus olitorius. *Res. Crops* **20** : 569-75.

NdaNmadu, J. and Marcus, P. L. (2011). Efficiency of Ginger production in selected local government areas of Kaduna State, Nigeria. *Int. J. Food Agric. Econ.* **1** : 39-52.

Okolo, S., Olajide, O., Idowu, D., Adebiyi, A., Ikokoh, P. and Orishadipe, A. (2012). Comparative proximate studies on some Nigerian food supplements. *Ann. Biol. Res.* **3** : 773-79.

Pallavi, N. and Anuja, S. (2019). Effect of organic nutrients on leaf yield and quality of moringa (*Moringa oleifera* Lam.) cv.PKM-1.

Res. Crops **20** : 563-68.

Rajan, I., Narayanan, N., Rabindran, R., Jayasree, P. and Kumar, P. M. (2013). Zingerone protects against stannous chloride-induced and hydrogen peroxide-induced oxidative DNA damage in vitro. *Biol. Trace Elem. Res.* **155** : 455-59.

Ravindran, P. and Babu, K. N. (2016). Ginger: the genus Zingiber. CRC press, Boca Raton https://doi.org/10.1201/9781420023367.

Shirin, A. P. R. and Jamuna, P. (2010). Chemical composition and antioxidant properties of ginger root (*Zingiber officinale*). *J. Med. Plants Res.* **4** : 2674-79.

Slominski, B. (2018). Nigeria: Ginger, production quantity (tons) Factfish. http://www.factfish. com/statistic-country/nigeria/ginger%2C% 20production% 20quantity. Accessed 26-10-2019.

Soil Survey Staff (2003). Keys to soil taxonomy 9th Edn., United States Department of Agriculture, U.S.A.

SPA - State Partnership for Agricutlure (2017). Identification and mapping of ginger production clusters and markets in Kaduna state Nigeria. State partnership for agricutlure, Federal Ministry of Agriculture and Rural Development. Pp. 1-98.

Wolde, M. W., Bizuayehu, T. and Andargachew, G. (2016). Effects of sett size and spacing on the growth and yield of ginger (*Zingiber officinale* Rosc.) at Areka, Wolaita, Southern Ethiopia. *J. Nat. Sci. Res.* **6** : 1-23.