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Full Length Research

Evaluation and selection of pawpaw accessions for production and breeding programmes in Southeast Nigeria Using Rank Summation Index (RSI) Approach

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ABSTRACT: Pawpaw (*Carica papaya*) is a tropical crop with significant economic, nutritional, and medicinal importance. However, its production in Nigeria is largely casual and subsistence-based, with many farmers relying on naturally growing plants due to a lack of knowledge of suitable cultivars for improved yield. This study was therefore aimed to evaluate the growth and yield characteristics of twelve pawpaw accessions in Nsukka, Southeast Nigeria, to select the most suitable accession using the Rank Summation Index (RSI) approach for improved production, food security and economic development. The accessions were collected from Kogi State and Enugu State, Nigeria, and evaluated using a randomized complete block design with three replications. Data were collected on some important growth and yield characters and analyzed using Analysis of Variance at a 5 per cent significant level. The results showed significant variations ($p<0.05$) among the accessions in the number of leaves per plant, stem girth, number of harvested fruits per plant, average fruit weight, and fruit yield per plant. The Rank Summation Index (RSI) was used to combine and rank the accessions based on their performance across those traits that showed significant variations. Accession unn10 with the lowest RSI score (12) was identified as the most superior, followed by unn12 with an RSI score of 14 and could therefore be selected for pawpaw production in the study area. The findings provide valuable information for farmers and researchers to improve pawpaw production and breeding programmes in Nigeria.

Keywords: Growth characteristics, multiple-trait selection, pawpaw, Rank Summation Index (RSI), yield characteristics.

INTRODUCTION

Pawpaw (*Carica papaya* L.) is a tropical crop that belongs to the Caricaceae family. It is an herbaceous plant that grows up to 10 meters tall, with a broad, lobed leaf and a solitary stem with rare branching (FAO, 2003). The fruit is a large, juicy berry with a soft, edible flesh and numerous black seeds. Pawpaw is native to Central America and southern Mexico but it is now cultivated in many tropical and subtropical regions of the world (Fuentes and Santamaría, 2014). The importance of pawpaw to agriculture and the world's economy is well understood by its wide distribution and substantial production. It is widely distributed in Africa, Asia, and the Pacific Islands, and is a major crop in many countries, including India, China, Brazil, and Nigeria (Koul *et al*., 2022; Fuentes and Santamaría, 2014). It is the fourth most important tropical fruit crop in the world (Scheldeman *et al*., 2007), with world exports in 2022 at 372,758 tons (FAO, 2023). In Nigeria, pawpaw is a common fruit tree in many backyards, particularly in the southeastern region where it is widely available. It is commonly eaten as a fruit when ripe and as a vegetable when green. The fruit is eaten fresh, used in cooking, and processed into various products, such as juice, jam, and candy (Boshra and Tajul, 2013). It is an excellent source of nutrition, rich in vitamins A and C, potassium, and fibre, making it a valuable fruit for human and livestock consumption (Alara *et al*., 2020). The plant contains papain which is a proteolytic enzyme that is used in healing wounds (Khatun *et al*., 2023; Aravind *et al*., 2013). Additionally, it has other medicinal properties, including anti-inflammatory and antioxidant effects (Alara *et al*., 2020; Aravind *et al*., 2013). In addition to providing nutrition security and medicinal importance, pawpaw is valuable in income generation, export market, employment opportunities and stabilizing the environment (Demissie *et al.*, 2009). It has economic importance as a cash crop, providing income for farmers and traders. The nutritive, economic, and medicinal importance of pawpaw cannot be overstated.

Despite its widespread availability, pawpaw production in Nigeria is largely casual and subsistence-based, with many farmers relying on naturally growing plants rather than cultivated ones. This over-reliance on naturally growing pawpaw could be attributed to a lack of information on the production techniques and suitable varieties for profitable production. Many researchers have reported considerable variation for many traits in pawpaw accessions (Ara *et al*., 2016; Ocampo *et al*., 2006). Furthermore, studies have shown that genetic diversity among pawpaw accessions is essential for improving crop yields and adaptation to changing environmental conditions (Scheldeman *et al*., 2007). Evaluating and selecting suitable pawpaw accessions is crucial for improving crop performance, yield and increasing food security.

Rank Summation Index (RSI) proposed by Mulamba and Mock (1978) is a commonly applied multiple-trait selection method that allows superior and adaptive cultivars to be selected by combining several characteristics (Nedeljković *et al*., 2023; Sampaio Filho *et al*., 2023; Coutinho *et al*., 2019). It involves ranking the performance of cultivars in respect to the desired agronomic characters and summing up the ranks of several characters for each cultivar, with a lower score suggesting better performance (Okoli, 2021; Coutinho *et al.*, 2019; Onwubiko *et al.,* 2018; Teixeira *et al*., 2012). There is a dearth of information on the selection of pawpaw accessions in Southeast Nigeria using the Rank Summation Index. This study was therefore aimed to evaluate the growth and yield characteristics of twelve pawpaw accessions in Nsukka Southeast Nigeria to select the most suitable accession using the Rank Summation Index (RSI), for improved food security and economic development in the region. This research would contribute to the development of sustainable pawpaw production in Southeast Nigeria and provide valuable information for farmers, researchers and plant breeders.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Research and Teaching Farm of the Department of Crop Science, University of Nigeria, Nsukka, Southeast, Nigeria, located within latitude 6°52'N and longitude 7°24'E, and altitude of 447.26 m above sea level.

Pawpaw accessions

The pawpaw accessions evaluated in the study were collected from Kogi State and Enugu State, Nigeria. They were labelled as unn1, unn2, unn3, unn4, unn5, unn6, unn7, unn8, unn9, unn10, unn11 and unn12 based on the location they were collected and their characteristics in terms of fruit shape and colour.

Experimental design and treatments

The experiment was carried out in a Randomized Complete Block Design (RCBD) with three replications. The treatments were 12 pawpaw accessions and they were randomly assigned to the experimental unit using the table of random numbers.

Field layout and crop establishment

The land at the experimental site was cleared and ploughed to loosen the soil. The field was laid out using a Randomized Complete Block Design with three replications. Twelve single-line plots were prepared in each of the three blocks used as replicates with 2 m and 3 m alleys separating adjacent plots and blocks, respectively. The seeds from the fruits of the twelve accessions were extracted and dried. The seedlings were raised separately in the nursery using soil nursery mixture prepared with topsoil, well-cured poultry droppings and sharp sand in a ratio of 3:2:1, respectively. Healthy seedlings from the accessions were transplanted two months after sowing into dug holes in the experimental field with each plot in each block containing one accession. A total of 5 plants were planted per plot using a spacing of 1.5 m between plants. Poultry manure at the rate of 10 tons per hectare was applied in three splits at two weeks before transplanting, one month after transplanting and four months after transplanting. Normal horticultural practices were observed to manage the crop. Weeding was done manually and with the use of herbicide applied with caution to avoid damaging the pawpaw stands.

Data collection

Data were collected on plant height, number of leaves per plant, stem girth, percentage of plants that fruited, number of harvested fruits/plant, average fruit weight and fruit yield per plant.

Plant height (cm)

Two sample plants were tagged and used to determine plant height. Plant height was determined using measuring tape to measure the tagged sample plants from the base to the top, six months after transplanting.

Number of leaves per plant

Data on the number of leaves per plant was collected through direct counting of the leaves on the two tagged sample plants, six months after transplanting.

Stem girth (cm)

The stem girth was determined from two tagged sample plants. The circumference of the stems of the sample plants 5 cm above the ground level was measured using measuring tape, six months after transplanting.

Percentage of plants that fruited

The percentage of plants that fruited was calculated by dividing the total number of plants that fruited per plot by the total number of plants (5 plants) and multiplying by 100. Thus;

$$Percentage\ of\ plants\ that\ fruited = \frac{\text{TNPF}}{\text{TNPP}}\ x\ 100$$

Where: TNPF = Total number of plants that fruited, and TNPP = Total number of plants per plot

Number of harvested fruits per plant

The number of harvested fruits per plant was determined by counting the total number of fruits harvested at the ripe stage and dividing by the number of plants they were harvested from. Thus;

$$Number\ of\ harvested\ fruit\ per\ plant = \frac{TNHF}{TNP} x\ 100$$

Where: TNHF = Total number of harvested fruits and TNP = Total number of plants.

Average fruit weight (g)

The average fruit weight was determined by weighing the total fruits harvested on a weighing scale and calculating the average as thus:

$$Averagefruit\ weight\ (g) = \frac{\text{TWF}}{\text{TNFW}} x\ 100$$

Where: TWF = Total weigh of fruits, and TNFW = Total number of fruits weighed.

Fruit yield per plant (kg)

Fruit yield per plant was calculated using the values gotten from number of fruit per plant and average fruit weight. The calculation was done by multiplying the average fruit weight (g) by the number of fruit per plant and dividing by 1000 to convert the value to kilogram (kg). Thus;

$$Fruit\ yield\ per\ plant\ (kg) = \frac{\text{AFW}\ (g)\ x\ \text{NFP}}{1000}$$

Where: AFW = Average fruit weight (g), and NFP = Number of fruits per plant.

Data analysis

The data collected from the parameters observed was analyzed using Analysis of Variance (ANOVA) at 5% level of probability using Genstat Release 10.3DE software (GenStat, 2011).

Rank Summation Index application

Rank Summation Index (RSI), a multiple-trait selection method was used to rank the cultivars for their overall performance with respect to characters that showed significant differences (p<0.05) among the accessions. The Rank Summation Index model: $Ij = \sum nij$ was applied, where *Ij* is the index for accession *j* and *nij* is the ranking number of characters *i* for accession *j*. In applying Rank Summation Index, the accessions were firstly ranked for each of the characters they showed significant difference using the mean values and the ranks were summed up to get the Rank Summation Index score for each of the accessions. The lower the rank summation index score, the better the accession.

RESULTS AND DISCUSSION

The harvested fruits from the twelve pawpaw accessions evaluated were presented in Figure 1. The inner parts of the fruits were shown in Figure 2. The fruits from the pawpaw accessions showed varied shapes with varied pulp colouration. Accessions unn3, unn7, unn9 and unn10 showed red colouration while accessions unn1, unn2, unn4, unn6, unn8, and unn12 showed yellow colouration. These findings were in consistence with the findings of Aikpokpodion (2012) who reported variations in fruit shapes and pulp colours among pawpaw accessions in Nigeria. These variations could be attributed to genetic differences among the accessions, as well as environmental

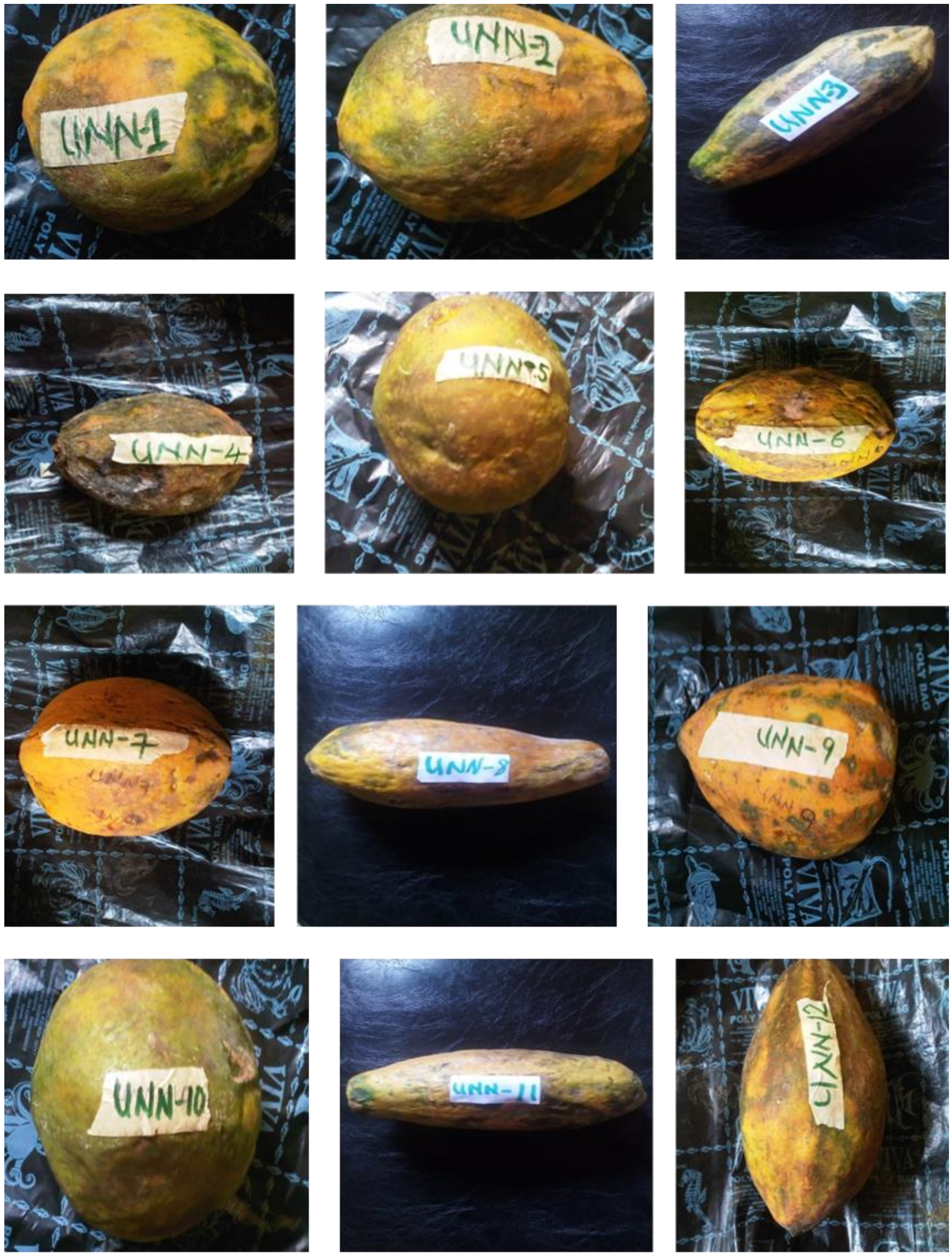

Figure 1. Images showing the fruit of the twelve pawpaw accessions.

factors such as climate, soil, and light exposure. The varied shapes and colours of the fruits could have implications for consumer and industry preferences, with some consumers and industries potentially being attracted to particular shapes and colours (Picha, 2006). Additionally, fruit pulp colour may be related to nutrient content as the level of carotenoid contributes to fruit colouration. Crupi *et al*. (2010) noted that the bright red, orange, and yellow colours in the fruit of higher plants are partly due to carotenoid accumulation in the chromoplasts of the fruits. In papaya fruits, the colour variations depend on the carotenoid content of the genotypes (Chan-León *et*

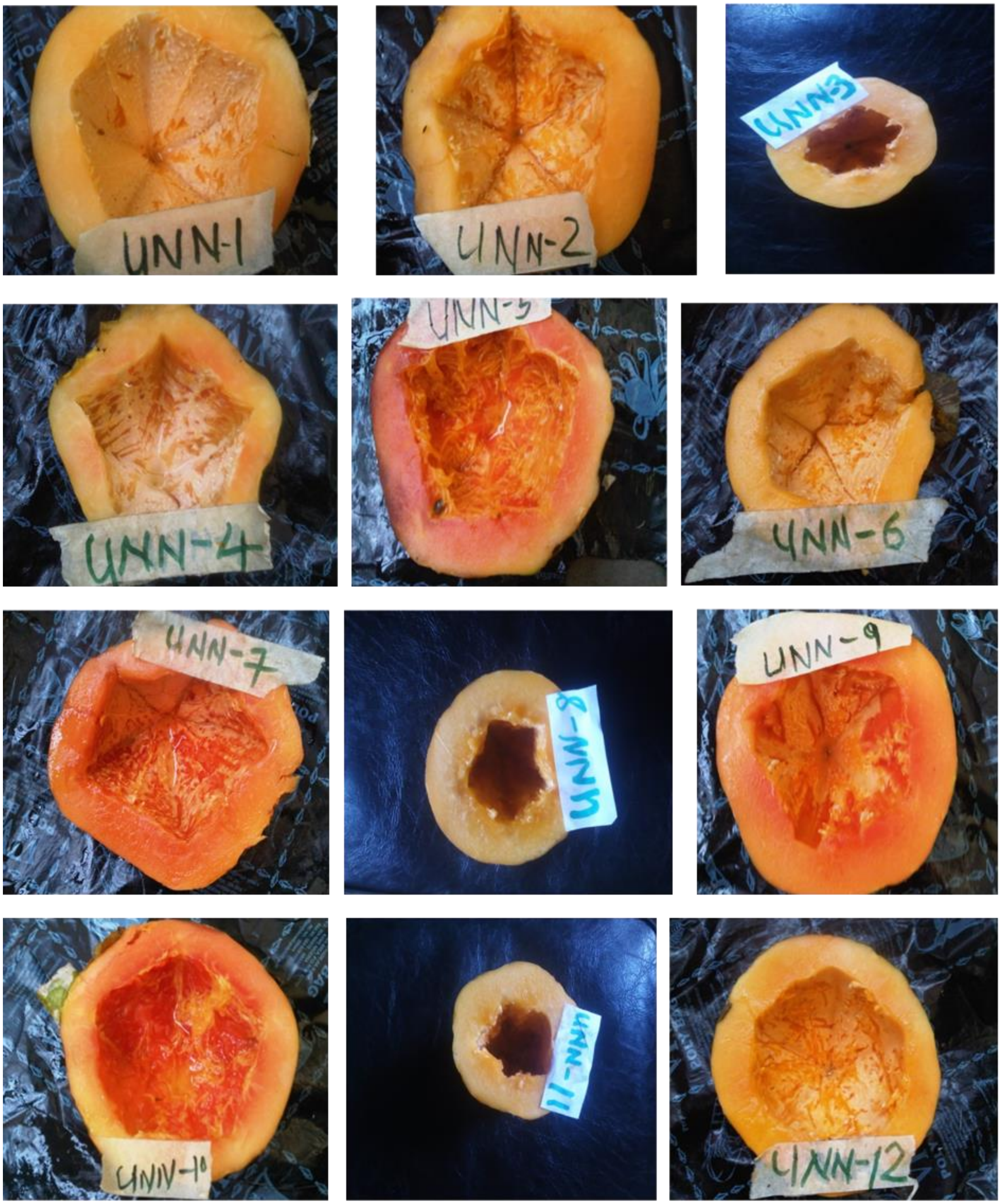

Figure 2. Images of the inner part of the fruit of the twelve pawpaw accessions showing the pulp colour.

al., 2017; Fu *et al*., 2016). The main carotenoid present in the red pulp of pawpaw fruit is lycopene, whereas *β*-carotene and *β*-cryptoxanthin are the main carotenoids in the yellow pulp (Shen *et al.*, 2019; Saengmanee *et al*., 2017; Wall, 2006). Yellow pawpaw fruits are as result of the conversion of carotenoid (lycopene) into β-carotene and finally into xanthophylls, whereas red fruits are a result of large lycopene accumulation due to inactivation of the gene responsible for conversion of lycopene, caused by mutation (Shen *et al.*, 2019; Chan-León *et al.*, 2017; Blas *et al*., 2010). From a breeding and cultivation perspective, these variations present opportunities for selecting

Table 1. Mean values of some agronomic characters of the pawpaw accessions.

Pawpaw Accessions	Plant height (cm)	Number of leaves per plant	Stem Girth (cm)	Percentage of plants that fruited	Number of harvested fruits/plant	Average fruit weight (g)	Fruit yield/ plant (kg)
unn1	134.33	7.17	26.17	86.67	7.33	604.93	4.44
unn2	166.33	6.50	26.17	53.33	11.17	654.33	7.31
unn3	143.83	6.17	23.67	53.33	10.00	1124.83	11.25
unn4	157.83	7.67	28.17	60.00	9.83	657.27	6.46
unn5	137.83	7.67	24.33	60.00	13.00	722.75	9.40
unn6	194.83	5.67	23.53	40.00	4.00	612.43	2.45
unn7	156.00	6.67	24.17	53.33	7.50	963.10	7.22
unn8	154.83	9.33	25.67	46.67	4.17	710.87	2.96
unn9	164.00	8.33	26.50	33.33	8.00	707.50	5.62
unn10	173.50	11.88	31.00	53.33	11.33	990.53	11.22
unn11	178.33	11.17	30.17	53.33	14.00	652.73	9.12
unn12	151.00	9.60	25.50	20.00	15.17	1250.93	18.52
Grand mean	159.39	8.15	26.25	51.11	9.63	804.35	8.00
CV (%)	14.0987	24.24	9.51	38.33	8.54	1.76	10.04
	Ns	p<0.05	p<0.05	ns	p<0.05	p<0.05	p<0.05

P<0.05= probability value is less than 0.05. ns =non-significant. CV = Coefficient of variation.

Table 2. Rank Summation Index (RSI) of the pawpaw accessions.

Pawpaw accessions	Number of leaves per plant	Stem girth (cm)	Number of harvested fruits/plant	Average fruit weight (g)	Fruit yield/ plant (kg)	RSI
unn1	8	5	10	12	10	45
unn2	10	5	5	9	6	35
unn3	11	11	6	2	2	32
unn4	6	3	7	8	8	32
unn5	6	9	3	5	4	27
unn6	12	12	12	11	12	59
unn7	9	10	9	4	7	39
unn8	4	7	11	6	11	39
unn9	5	4	8	7	9	33
unn10	1	1	4	3	3	12
unn11	2	2	2	10	5	21
unn12	3	8	1	1	1	14

desirable traits. Breeders may prioritize accessions with desirable shapes and colours, and understanding the genetic basis of these variations could inform breeding programmes.

The results of the analysis of variance of some agronomic characters of the pawpaw accessions evaluated in the study are presented in Table 1. The results revealed significant differences (p<0.05) among the accessions in the number of leaves per plant, stem girth, number of harvested fruits/plant, average fruit weight and fruit yield per plant. These findings conformed with the findings of Brewer *et al*. (2021) and da Silva *et al.* (2017) who reported diversity in growth and yield performance of some pawpaw accessions and attributed it to the genetic makeup of the genotypes evaluated and environmental influence. Aikpokpodion (2012) also reported variations in some growth and yield characters among pawpaw accessions in Nigeria.

Applying rank summation index (RSI) to evaluate the performance of the pawpaw accessions to determine the superior accessions using agronomic characters that showed significant differences among the accessions namely; the number of leaves per plant, stem girth, number of harvested fruits/plant, average fruit weight and fruit yield per plant; the result showed that accession unn10 had the lowest Rank Summation Index score (12). Next to it was unn12 (14), followed by unn11 (21), unn5 (27), unn3 and unn4 (32), unn9 (33), unn2 (35), unn7 and unn8 (39), unn1 (45) while unn6 (59) had the highest Rank Summation Index score (Table 2). The lower the Rank

Summation Index scores the better the performance. Accession unn10 was therefore the most superior accession among the 12 accessions evaluated closely followed by unn12. This suggests that accession unn10 has superior multiple traits that control productive performance, adaptability and stability for the climatic condition of the study area, closely followed by unn12.

Conclusion

The findings of the study showed that there were varied fruit shapes and colours among the twelve accessions of pawpaw evaluated in the study. Significant variations were observed in some agronomic characters among the pawpaw accessions. Rank Summation Index scores showed that accessions unn 10 and unn12 are the most superior accessions and could be selected for improved cultivation of pawpaw in the study area. The findings also provided veritable and pertinent information for plant breeders to explore in breeding for improved cultivars of pawpaw.

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