Morphological Variation in Fruits and Seeds of African Pear (*Dacryodes Edulis*) Across Five States in South-South AND South-East Nigeria

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Received 18 October 2025, Accepted 20 November 2025, Published 30 December 2025

Direct Research Journal of Agriculture and Food Science

Direct RESEARCH JOURNALS

Vol. 13(3), Pp. 305-318, December 2025
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https://journals.directresearchpublisher.org/index.php/drjafs; https://www.ajol.info/index.php/drjafs

Research Article
ISSN: 2354-4147

ABSTRACT

*African pear (Dacryodes edulis (G. Don) H.J. Lam) is an important indigenous tropical fruit tree, useful for its nutritional, economic and industrial benefits. Limited information is available on morphological variations of its fruits and seeds. Based on this, five States, three locations in each State were selected and ten matured African pear trees were marked and tagged given a total of 150 trees per year. Each selected tree were divided into four section for data collection. Randomized Complete Block design was used to investigate morphological variations in African pear fruits and seeds. Field surveys on morphological variation were conducted from 2013 to 2015. Pomological data were collected including fruit shape and fruit colour at maturity. Data were analyzed using descriptive statistics, randomized complete block design, regression and correlation analyses, with mean separation by Duncan's New Multiple Range Test in Statgraphic Centurion XVI software package. Results revealed considerable morphological variation within and among study locations. Four fruit shapes—globular, oval, conical and elliptical—were identified, with 33%, 28%, 24% and 15%, respectively. Four unripe fruit colours and ten ripe fruit colours were also observed. Variations occurred in fruit and seed characteristics. At Abia state in 2014, Pulp Thickness were significantly ($P < 0.05$) different at Oboro, Alayi and Ngwa with mean of 12.40 (mm), 8.53 (mm) and 15.69 (mm), respectively. In 2015 at Rivers State, fruit weight was significantly ($P < 0.05$) different at Etche, Elele and Obiebe with mean of 39.99 (g), 17.23 (g) and 17.43 (g), respectively. At Imo State, the fitted model for fruit weight was FW = 3.92339 + 4.62739*PW - 7.14384*SW + 1.26313*PT - 50.0564*FD + 1.32192*FLC - 1.55914*FL + 14.6021*NS. Positive relationships were observed among several pomological traits, but strength of association varied across locations. Findings indicate substantial morphological diversity, offering opportunities for selecting desirable traits and developing improved cultivars with better fruit size, pulp characteristics and other horticultural attributes. Further research is recommended to investigate the genetic and environmental factors responsible for observed variations and to support the development of African pear improvement programmes.*



Keywords: *African pear, morphological variation, fruit characteristics, pomological traits, indigenous fruit tree*

Citation: Njoku, T. C. (2025). Morphological Variation in Fruits and Seeds of African Pear (*Dacryodes Edulis*) Across Five States in South-South AND South-East Nigeria. *Direct Research Journal of Agriculture and Food Science*. Vol. 13(3), Pp. 305-318. https://doi.org/10.4314/drjafs.v13i3.31

INTRODUCTION

The African pear (AP) (*Dacryodes edulis* (G. Don) HJ Lam) is one of the most important indigenous African tropical fruit trees species (TFTS). It is a multipurpose fruit tree. The fruit is a source of high quality nutritious, non-greasy natural vegetable oil (44 - 67 %) with possibly numerous industrial uses (Waruhiu *et al.,* 2004; Okorie *et al.*, 2006 and Mboujda et al., 2022). In recent years, there has been a growing awareness of the potentials of African pear fruit and seed as a major source of plant oil; mainly amino acids and triglycerides (Okorie *et al.*, 2006 and Mboujda et al., 2022). Despite all these benefits, limited research has been carried out on Domestication of African pear (Okorie, 2000), Genetic variability and inter-relationship among morphological traits accessions (Alaje and Alake, 2020), Characterization of selected tropical trees in Markudi (Okpara and Zegenyo, 2024) and Evaluation of intraspecific variation in African pear fruits in Imo State Nigeria(Njoku, 2019). However, much research has not been carried out on the morphological variations in the fruits and seeds of AP which contains these oil.

In Nigeria, exotic fruit trees such as citrus (*Citrus sinensis*) and mango (*Magnifera indica* (L) have received more research attention. The few indigenous fruit trees that had been studied include oil palm (*Elaeis guineensis Jacq.)* and the kola (C*ola acuminata* (P. Beauv.) Schott and Endl *and Cola nitida (*Vent) A. Chev.) (Okorie *et al.,* 2000 and Okpara and Zegenyo, 2024). Research work like Morphological traits of fruits and seeds of Ziziphus tree species growing in different land uses in Ethiopia, *Heliyon, (Alle et al., 2024).* Such work is lacking in AP. This lack of sufficient research in TFTS mainly, the African pear (AP) has given rise to a conspicuous lack of information in the morphological variation of AP pomological attributes including colour and the shape of the fruit. This has greatly hampered efforts in their fruit and seed development. This may be achieved through the study on morphological variation of African pear including variations in colour and shape. Njoku, (2021) in a research carried out in southeast Nigeria discovered that variations exist in the time of flowering of AP, floral nature and inflorescence length. Furthermore, another research was carried out on the evaluation of intraspecific variations of African pear fruits in Imo state. The researcher discovered some variation in the fruit attributes such as fw, pw, pt, fc, sw etc. (Njoku, 2019).

Knowledge of the AP morphological variation especially as it relates to fruits and seeds in south south and southeast is particularly important for the development and improvement of the species. According to Paulo *et al., (*2016), the morphological identification of seed and fruit allows for the characterization of plants into families, genera, and even species.The researchers further stated that the description of the fruit within an ecological context is a new way to understand the biology of reproduction (Paulo *et al.,* 2016). Biometrics of fruits and seeds, as well as the knowledge of morphology and seed development is critical to support studies of germination and seed production for plant restoration (Paulo *et al.,* 2016). Fruit and seed morphology in agriculture is the scientific study of the external form, physical structure, and developmental characteristics of crop fruits and seeds. Such research works are not much in African indigenous tropical fruit trees species, especially the African pear. In line with the above, Njoku, (2023) suggested that a planned morphological and phenological program for selection and improvement of AP for optimal fruit yield is necessary. Therefore, there is the need to study the morphological variations in the African pear fruit and seeds in South-East and South-South States in Nigeria. The specific objectives of the research were to assess the variations in African pear fruits, fruit colour, shape and seeds in the various locations of the States. The overall objective is not only to provide basic information required for the improvement of the species in terms of fruit and seeds yields within the species,but also to discover the morphological variations in colour and shape of AP fruit and seed.

MATERIALS AND METHODS

Location and Experimental Conditions

Field morphological evaluation and characterization study survey were conducted between 2013-2015. The study covered three South – East and two South – South states of Nigeria. These study areas were located between latitude 4° 75′ and 6° 45¢ N and longitude 06° 20′ and 07° 52′ E and at altitude between 20 m – 440 m above the mean sea level (NIMET, 2014): Abia (latitude 05° 42′ N; longitude 07° 52′ E, altitude: 120 m), Delta (latitude 05° 70′ N; longitude 06° 20′ E, altitude: 50 m) , Imo (latitude 05° 57′ N; longitude 07° 05′ E, altitude 150 m) , Rivers (latitude 04° 75′ N; longitude 06° 83′ E, altitude 20 m) and Enugu (latitude 06° 45′ N; longitude 07° 50′ E, altitude 220 m). The soil type at the research site was mostly sandy loam. South- east and South- south are in the humid tropics and are characterized by a warm wet season (mid – March to October), and a hot dry season (November to mid – March). Most of the annual precipitation of 1810 – 2260mm falls during the wet season, which is broken by a short duration drought of about 10 – 14 days in August. For much of the day time during the wet season, the relative humidity is near saturation point with maximum and minimum temperature of 30° C and 21° C, respectively (NIMET, 2014).

Materials and Characterization Studies for Field Survey

Materials employed include: A telescope, a sensitive digital electronic weighing balance (Sartorius weighing balance model: FEM-100g/0.01g), a sharp knife, a

measuring tape, a microscope, 40 big brown envelops, a camera and 18,000 fruits from 450 *D. edulis* trees sampled for the three years. Different types (cultigens) AP growing in the forests, homesteads, distant and nearby farms were used for the field study. In each location, ten trees were selected and marked. Some individuals were assigned to observe the marked sampled trees for the period of the survey study and to collect morphological data as required. Sampled or monitored individual trees were selected based on evidence of reproductive maturity. A plan visit was also made to the various locations during fruit ripening time to examine the colour and shape of fruits, and collection of ten (10) fruits from each tree. Measurement of all samples collected were carried out within twenty four (24) hours of collection. Critical information obtained includes the following: Fruit weight, pulp weight, seed weight, number of seeds, fruit length, fruit diameter, fruit longitudinal circumference and pulp thickness,

Pomological characteristics and materials

The data on important pomological and yield attributes were collected as follows: 5States × 3 locations × 10 trees/location × 4 branches/tree × 10 fruits/branch (i.e. 6000 fruits/per year). Pomological attributes such as fruit pulp thickness (PT); fruit longitudinal Circumference (FLC) and fruit diameter (FD) were determined using a measuring tape. The fruit weight (FW) and pulp weight (PW) were obtained immediately after harvest using a Satorius electronic (digital) balance (model: FEM-100g/0.01g). Others include, mature ripe AP fruits, digital weighing balance, tape, sharp knife,colour chart and visual observation.

The following parameters were evaluated in the experiment.

Fruit weight: This was obtained by using a Satories electronic balance (pocket scale mini digital scale) model FEM 100g/0.01g (g). Ten fresh fruits each were collected from four different branches of the tree immediately after harvest. The fruits were weighed immediately after harvest individually, and average of the ten fruits weight taken.

Pulp weight: This was determined by using a scale 100g/0.01 capacity (g). The fruits were cut longitudinally, all seeds were removed, and then pulp were weighed on the scale, average of each ten fruits pulp recorded.

Seed number: This was determined by counting the number of small seeds in each fruit. The average of each ten was recorded as their mean.

Seed weight: This was obtained using a pocket scale mini scale (g). Forty fruits were collected from four branches of a tree. Ten fruits from each branch were cut, seeds were carefully removed and weighed on the scale and mean of the ten seeds recorded.

Pulp thickness: This was obtained by using a measuring tape (mm). The forty pulps weighed were also measured using a tape. Their pulp were measured individually by placing the tape across the pulp, average of each group of ten recorded.

Fruit longitudinal Circumference: This was determined by using a measuring tape (cm). The fruit was cut longitudinally. Circumference of the sampled fruits were measured by placing the tape at one end of the cut fruit, then follow the entire outer edge of the fruit to the starting point.

Fruit Length (FL): The FL was also determined by using measuring tape (cm) by placing the tape lengthwise.

Fruit diameter: This was obtained by measuring the diameter of the cut fruit using measuring tape (cm). The forty sampled fruit collected from four different branches of each sampled tree were measured to obtain the fruit diameter and mean of each ten were recorded.

Overall fruit shape: By visual observation and description. Globular-round or sphere - like, Oval - rounded and elongated, Elliptical - follows an ellipse - like outline and Conical - broad base tapering towards a point.

Fruit colour before and after darkening: This was achieved using a colour chart to examine the same ten fruits harvested both from the same tree and from other trees. In each study location, African pear trees chosen for evaluation were appropriately tagged. Parameter evaluation at the plant community level was based on a mean of twenty (20) plants but a mean of ten (10) at the individual plant attribute level. Relevant measurements, line drawings and photographs were also taken.

Experimental Design and Data Analyses

In addition to descriptive statistics and charts, the collected data were analyzed using Randomized Complete Block Design (RCBD) and regression and correlation in Statgraphics Centurion XVI (16.0) software package. Significant means were separated using Duncan's New Multiple Range Test (DNMRT). Correlation coefficients and coefficients of variation (CV) were also used (Gupta, 2011).

RESULTS

Percentage Ripe and Unripe Fruit Colour

Among the 40 fruits sampled per tree, 400 fruits in each location, 1, 200 fruits per state, and 6,000 fruits for the five States per year, there were variations in their fruit colour



Plate 1: Colour Chart (http://www.vinylstickers.com.au/images/colourchart.jpg)

(Figure 1 to 6). The fruit colour when unripe was totally different from the ripe ones both within and between the locations. Some colours observed for unripe fruits at fruit maturity include Magenta, Pink, Almond and Cream while ripe fruits exhibited the following; Marina, Mid blue, Ultra marine, Bright blue, Viking, Navy, Mid night, Violet, Mauve and Lilac (Plate 1-colour chart). At Imo state, all colours were observed except lilac (Figure 1). At Rivers State, lowest score 3.3% was lilac and highest score 16.7% was navy (Figure 2).

At Abia, the highest score was 16.7% while the least was 6.7%t (Figure 3). At Delta, the highest percentage ripe

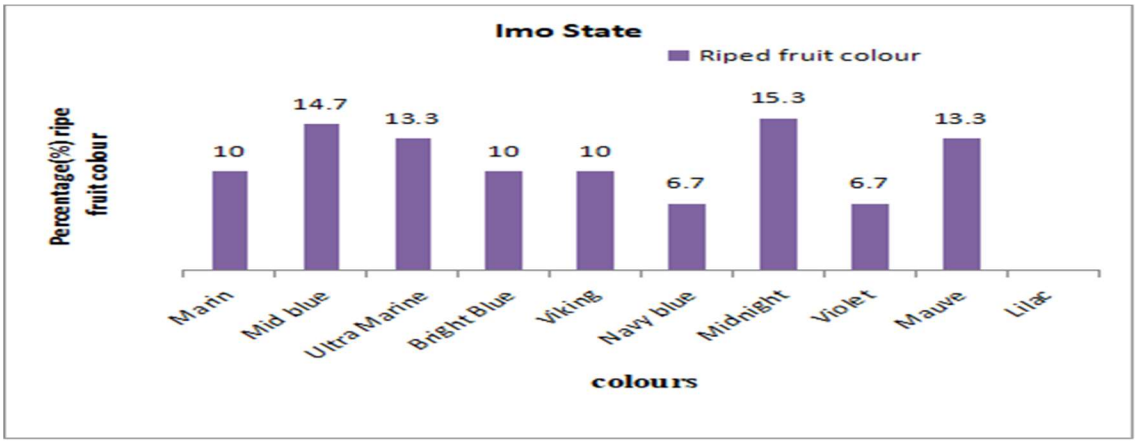


Figure 1: Percentage (%) ripe fruit colour for Imo State in 2013 - 2015.

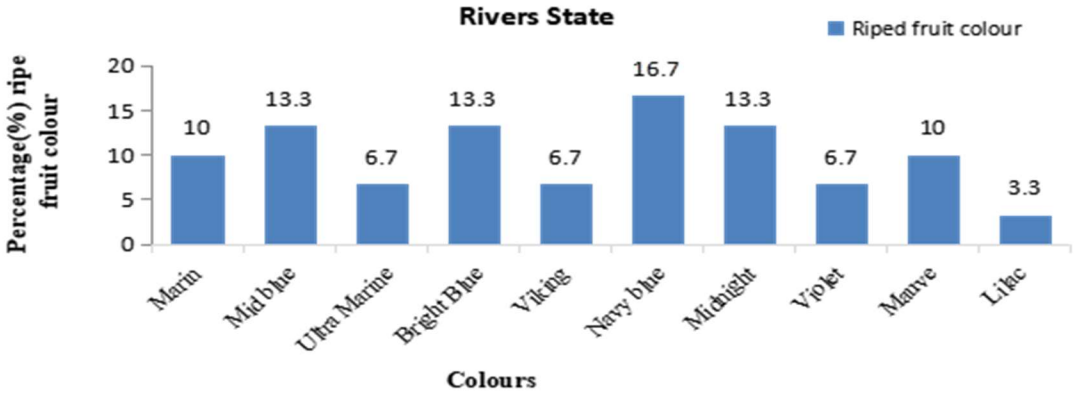


Figure 2: Percentage (%) ripe fruit colour for Rivers State in 2013 - 2015.

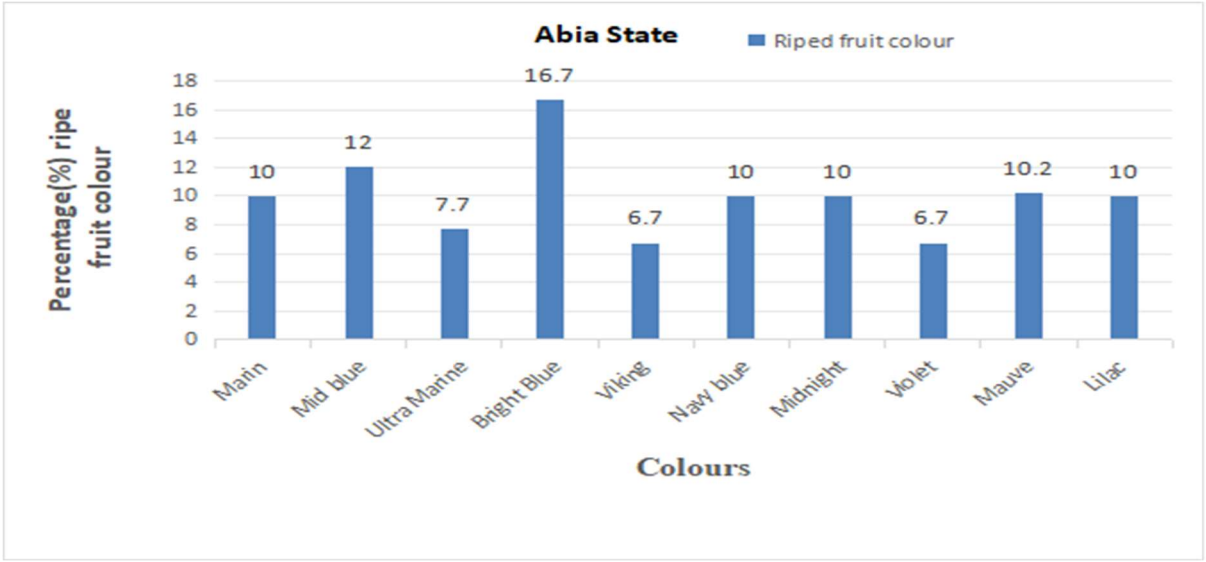


Figure 3: Percentage (%) ripe fruit colour for Abia State in 2013 - 2015.

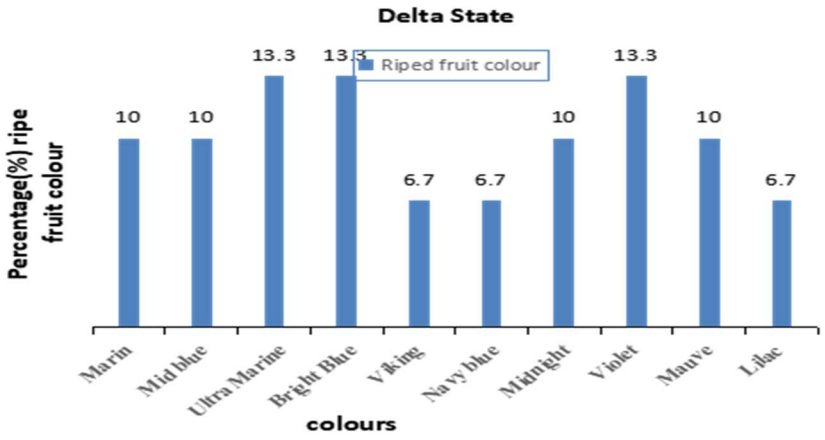


Figure 4: Percentage (%) ripe fruit colours for Delta State in 2013 - 2015.

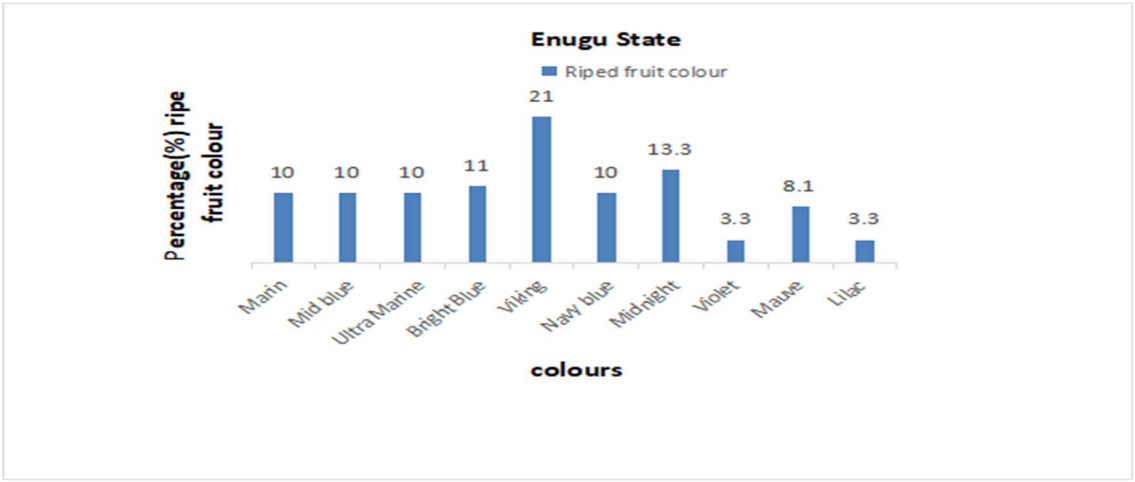


Figure 5: Percentage (%) ripe fruit colours for Enugu State in 2013 - 2015.

fruit colour score was 13.3%y (Figure 4). Enugu state recorded the following percentage ripe fruit colours; 21%, 13.3% and 3.3% respectively (Figure 5). The unripe fruit colours for Enugu were Magenta; Pink and cream. Delta had pink, magenta, almond and cream. Rivers state had pink, almond, cream and magenta. At Abia, the highest was pink while the least was cream. Imo had pink, cream, magenta and almond, respectively (Figure 6). The survey results showed that morphological variation for horticultural interest exist in ripe and unripe AP fruits colour within and between different locations. (Figures 1 to 6).

Fruit Shape

The fruits of AP collected from the study locations showed some differences and similarities in shape (Figures 7 to 11). The shapes observed include; conical, oval, globular and elliptical. Imo state location recorded 20% elliptical, 17% conical, 23% globular and 40% oval (Figure 7). Rivers State had 17% elliptical, 26% conical, 30% globular and 27% oval (Figure 8). Abia State recorded the highest means of 37% for globular and the lowest mean 6% elliptical (Figure 9).

Furthermore, 37% and 20% were the highest and lowest mean fruit shape obtained at Delta State (Figure 10). Finally, Enugu State had highest fruit shape mean of 37% by globular (Figure 11).Many fruit trees exhibit a particular fruit shape,but this is different in African pear. The variation in fruit shape showed its potential for further improvement. Majority of the fruits were globular with 33%, this was followed by oval 28% and the least was elliptical 15% (Figure 11).

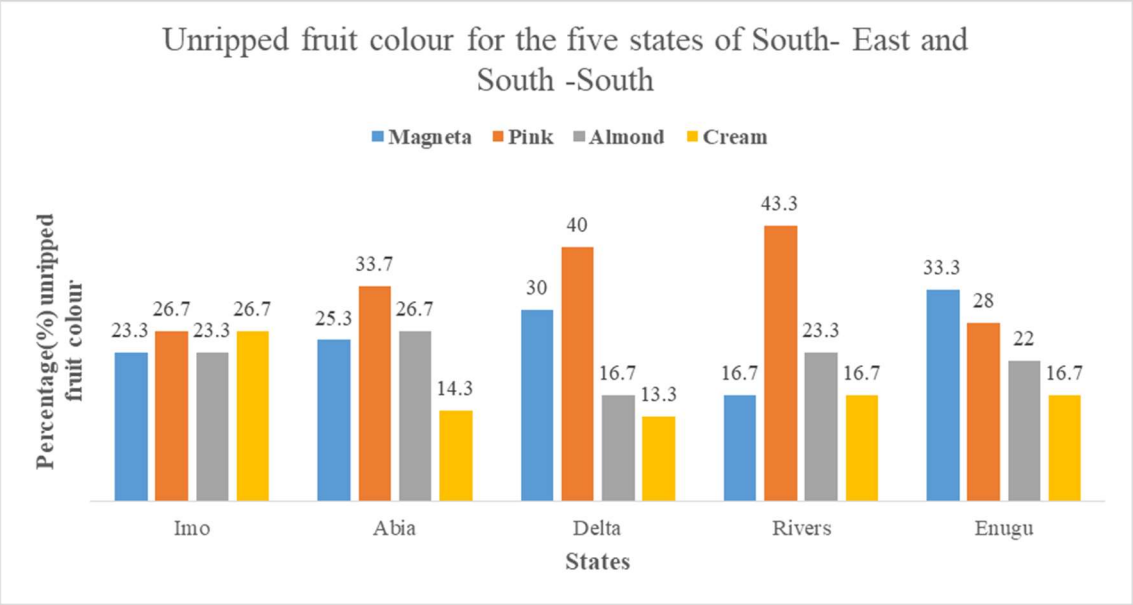
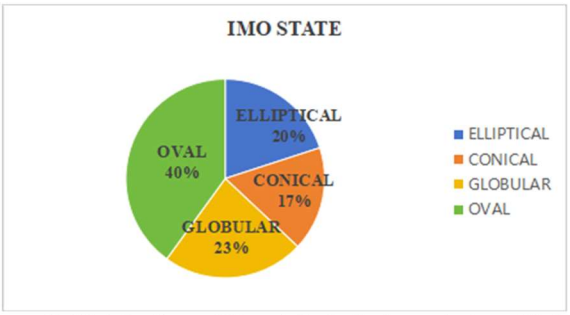


Figure 6: Percentage (%) unripe fruit colour for the five State in 2013 - 2015.



igure 7: Distribution of *D. edulis* fruit shape in Imo State ocation

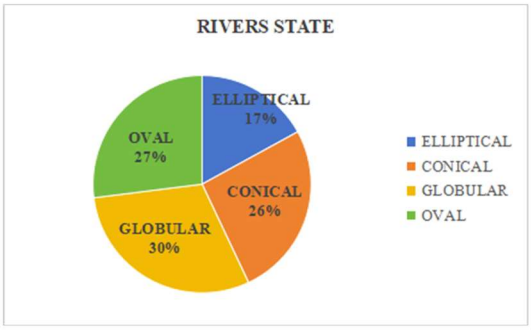


Figure 8: Distribution of *D. edulis* fruit shape in Rivers Sta location

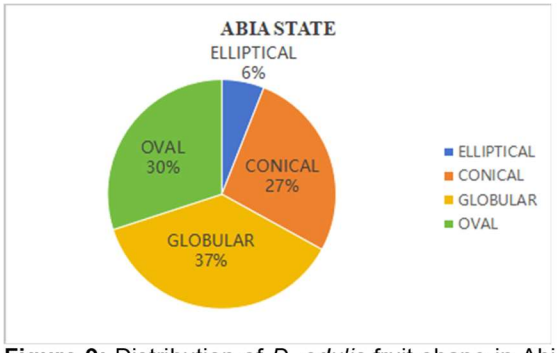


Figure 9: Distribution of *D. edulis* fruit shape in Abia State location

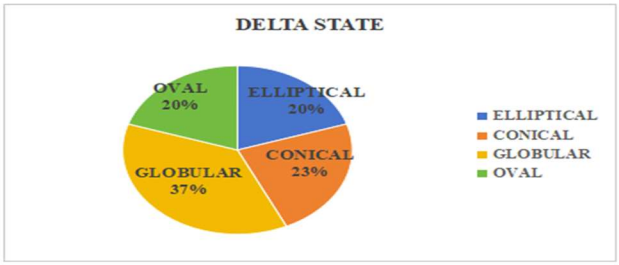


Figure 10: Distribution of *D. edulis* fruit shape in Delta S location

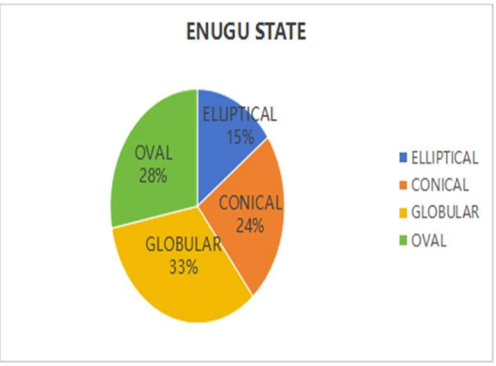


Figure 11: Distribution of *D. edulis* fruit shape in Enugu State location

Pomological Characterization Studies

From the field characterization studies, out of the one hundred and fifty African pear trees examined per year, differences were observed among the pomological attributes. Tables 1–5 present the morphological and pomological attributes of Dacryodes edulis (African pear) across the sampled locations in Imo, Abia, Delta, Enugu and Rivers States over the three-year period (2013–2015), while Tables 6–10 present the correlation analyses of the pomological characteristics for the respective states.

Imo State

The results revealed considerable variation ($P < 0.05$) in fruit characteristics among the three locations (IMSU, Logara and Umuduru). In 2013, Umuduru recorded the highest mean fruit weight (25.31 g) and pulp weight (18.34 g), while IMSU recorded the highest pulp thickness (4.10 mm), fruit length (4.97 cm), fruit diameter (2.70 cm) and seed weight (8.09 g) respectively. In 2014, Umuduru recorded the highest fruit weight (33.59 g), pulp weight (23.16 g), pulp thickness (4.60 mm), fruit circumference (15.13 cm), fruit length (5.90 cm), fruit diameter (3.23 cm) and seed weight (10.28 g). In 2015, Logara recorded the highest fruit weight (32.83 g), pulp weight (23.84 g), fruit circumference (16.23 cm) and fruit length (6.28 cm), while Umuduru recorded the highest seed weight (12.58 g). Overall, the results showed that Umuduru and Logara demonstrated superior performance in several fruit characteristics during the study period (Table 1). The PT in the three locations for 2013 ranged from 1.4mm to 4.1mm respectively. These were statistically ($P < 0.05$) different (Table 1). The correlation results examined showed that fruit weight had significant ($P < 0.05$) relationships with pulp weight, pulp thickness, fruit diameter, fruit circumference and fruit length. However, its relationship with seed weight ($r = 0.2465$) and number of seeds ($r = 0.1052$) was not statistically ($P < 0.05$) significant. Pulp weight also showed significant ($P < 0.05$) relationships with the other measured characteristics. This suggests that fruit weight in Imo State was more closely associated with fruit size and pulp characteristics than with seed weight and number of seeds (Table 6).

Abia State

The results showed differences in pomological characteristics among Oboro, Alayi and Ngwa. In 2013, Oboro recorded the highest fruit weight (25.73 g), pulp weight (14.90 g), pulp thickness (4.04 mm), fruit circumference (13.63 cm), fruit length (5.61 cm), fruit diameter (2.73 cm) and seed weight (10.85 g). In 2014, Ngwa recorded the highest fruit weight (34.94 g), pulp weight (23.64 g), fruit circumference (15.69 cm), fruit length (6.88 cm), fruit diameter (2.96 cm) and seed weight (11.68) respectively. In 2015, Oboro recorded the highest pulp weight (19.38 g), pulp thickness (4.36 mm), fruit diameter (3.08 cm) and number of seeds (12.49), while Ngwa recorded the highest fruit weight (23.00 g). Generally, Oboro and Ngwa showed better pomological performance than Alayi across several of the measured characteristics (Table 2). The mean FLC of AP evaluated for 2013 ranged from 8.18cm to 13.63cm. The mean value obtained for the three locations in 2013 and 2015 for FLC were statistically ($P < 0.05$) similar. In Abia State, all the pomological characteristics showed statistically significant($P < 0.05$) relationships with one another Fruit weight was significantly($P < 0.05$) associated with pulp weight, seed weight, pulp thickness, fruit diameter, fruit circumference, fruit length and number of seeds. The correlation results suggest strong interrelationships among the measured fruit characteristics, indicating that variation in one characteristic was associated with variation in others (Table 7).

Delta State

The results indicated that Anwai generally exhibited superior pomological characteristics compared with Ogbolu and Ogwashi. In 2013, Anwai recorded the highest fruit weight (34.78 g), pulp weight (25.08 g), pulp thickness

Table 1. Pomological characteristics of African pear in Imo State (2013–2015)

Year	Sampling location	Fruit weight (g)	CV (%)	Pulp weight (g)	CV (%)	Pulp thickness (mm)	CV (%)	Fruit longitudinal circumference (cm)	CV (%)	Fruit length (cm)	CV (%)	Fruit diameter (cm)	CV (%)	Seed weight (g)	CV (%)	Number of seeds	CV (%)
2013	IMSU	24.30a	2.89	16.13 a	3.07	4.10a	3.09	12.57 a	17.65	4.97 a	2.08	2.70 a	1.55	8.09a	2.71	5.68ab	11.16
2013	LOGARA	19.19 a	2.89	17.92 a	16.05	1.40b	15.50	15.16 a	15.68	2.21 a	15.88	2.06 a	5.53	1.62b	20.42	2.46b	8.9
2013	UMUDURU	25.31a	9.06	18.34 a	9.34	2.90ab	8.35	11.00 a	8.07	4.63 a	8.30	2.24 a	7.85	6.85b	8.54	9.14a	1.20
2014	IMSU	27.91 a	3.75	19.85 a	4.92	4.40 a	0.29	12.85 a	9.78	5.15 a	1.83	3.00 a	1.94	8.00ab	2.23	11.00a	1.71
2014	LOGARA	23.73 a	6.78	16.79 a	7.62	3.40 a	6.18	13.14 a	5.69	4.42 a	5.96	3.42 a	6.18	7.18b	5.55	7.81b	5.38
2014	UMUDURU	33.59a	2.90	23.16 a	3.21	4.60 a	2.13	15.13 a	1.32	5.90 a	1.46	3.23 a	0.82	10.28a	2.94	9.54ab	0.67
2015	IMSU	25.84 a	3.55	17.65 a	4.88	4.00 a	2.55	13.17 a	15.37	4.66 a	2.24	2.94 a	1.81	8.18b	2.06	11.48a	1.62
2015	LOGARA	32.83 a	3.55	23.84 a	4.61	3.90 a	3.23	16.23 a	1.46	6.28 a	1.87	3.29 a	1.68	9.35ab	0.87	9.89ab	0.40
2015	UMUDURU	32.30a	5.43	23.52 a	5.71	4.30 a	4.73	14.46 a	4.32	5.85 a	4.36	2.92 a	4.28	12.58a	5.47	8.49b	4.10

Note. Values are means; different superscript letters within a column indicate significant differences (p < 0.05). CV = coefficient of variation.

Abbreviations: CV, coefficient of variation; FW, fruit weight; PW, pulp weight; PT, pulp thickness; FLC, fruit longitudinal circumference; FL, fruit length; FD, fruit diameter; SW, seed weight; NS, number of seeds

Table 2. Pomological characteristics of African pear in Abia State (2013–2015)

Year	Sampling location	Fruit weight (g)	CV (%)	Pulp weight (g)	CV (%)	Pulp thickness (mm)	CV (%)	Fruit longitudinal circumference (cm)	CV (%)	Fruit length (cm)	CV (%)	Fruit diameter (cm)	CV (%)	Seed weight (g)	CV (%)	Number of seeds	CV (%)
2013	OBORO	25.73a	1.92	14.90a	2.49	4.04 a	0.75	13.63 a	2.86	5.61 a	0.48	2.73 a	1.01	10.85a	1.20	10.20 a	0.44
2013	ALAYI	19.78 a	9.39	13.64 a	10.03	2.49 a	9.17	8.84 a	9.21	4.00 a	7.58	1.75 a	9.13	6.13a	9.59	5.43 a	9.38
2013	NGWA	14.62a	9.33	8.70 a	9.47	2.45 a	9.18	8.18 a	9.14	3.39 a	9.16	1.67 a	6.32	6.24a	9.15	6.00 a	9.13
2014	OBORO	28.45a	3.94	18.66a	6.06	4.32a	3.78	12.40ab	1.76	5.30ab	1.37	2.30 a	1.88	9.89 a	1.83	11.25 a	1.73
2014	ALAYI	23.50 a	7.38	14.78 a	8.06	2.67a	7.72	8.53b	7.11	4.23 b	6.99	2.19 a	6.90	8.71 a	6.92	7.48 b	6.97
2014	NGWA	34.94a	4.26	23.64 a	5.58	4.17 a	1.28	15.69 a	1.82	6.88 a	2.38	2.96 a	1.06	11.68 a	1.41	9.84 ab	0.72
2015	OBORO	28.22a	4.24	19.38a	6.22	4.36 a	4.09	10.81 a	2.04	5.07 a	1.38	3.08 a	1.89	8.93 a	1.11	12.49 a	2.46
2015	ALAYI	15.77 a	12.42	10.34 a	13.45	1.78 a	12.50	4.82 a	11.31	3.14 a	11.05	1.44 a	11.25	5.43 a	11.16	5.38 b	11.25
2015	NGWA	23.00a	9.44	15.76 a	10.58	2.90 a	7.87	10.42 a	8.07	4.45 a	8.24	2.07 a	7.81	7.4 0a	7.87	6.45 b	7.77

Note. Values are means; different superscript letters within a column indicate significant differences (p < 0.05). CV = coefficient of variation.

Abbreviations: CV, coefficient of variation; FW, fruit weight; PW, pulp weight; PT, pulp thickness; FLC, fruit longitudinal circumference; FL, fruit length; FD, fruit diameter; SW, seed weight; NS, number of seeds.

Table 3. Pomological characteristics of African pear in Delta State (2013–2015)

Year	Sampling location	Fruit weight (g)	CV (%)	Pulp weight (g)	CV (%)	Pulp thickness (mm)	CV (%)	Fruit longitudinal circumference (cm)	CV (%)	Fruit length (cm)	CV (%)	Fruit diameter (cm)	CV (%)	Seed weight (g)	CV (%)	Number of seeds	CV (%)
2013	ANWAI	34.78a	0.43	25.08 a	5.09	3.80 a	2.85	15.52 a	1.81	6.78 a	2.05	2.94a	1.12	9.91ab	2.26	8.85 a	0.97
2013	OGBOLU	25.92 a	2.34	17.77 a	2.15	3.71 a	1.98	14.45 a	1.24	5.80 a	1.53	2.70 a	1.05	7.60 b	2.98	9.17 a	2.60
2013	OGWASHI	24.77 a	0.60	17.38 a	6.13	3.20 a	6.02	12.39 a	5.77	5.20 a	5.83	2.28 a	5.78	17.38 a	6.13	7.00 a	5.65
2014	ANWAI	32.20 a	0.39	22.95 a	4.57	3.80 a	2.15	15.52 a	1.48	6.72 a	1.64	2.92 a	0.95	9.00 a	2.81	8.88 a	0.82
2014	OGBOLU	27.94 a	3.28	20.56 a	3.71	3.70 a	2.53	15.54 a	1.00	6.50 a	1.13	2.87 a	1.76	7.07 a	3.91	9.20 a	0.48
2014	OGWASHI	24.40 a	0.50	18.45 a	4.72	3.20 a	4.44	14.22 a	4.22	6.01 a	4.31	2.47 a	4.22	5.71 a	7.27	5.99 b	5.62
2015	ANWAI	38.38 a	0.40	27.90 a	4.73	4.00 a	2.68	16.25 a	1.76	7.19 a	2.13	2.30 a	0.94	10.24 a	2.58	9.06 a	0.88
2015	OGBOLU	22.96 a	0.85	16.66 a	8.83	3.20 a	7.48	11.94 a	7.06	4.81 a	7.12	2.01 a	7.01	5.98 a	8.06	5.87 a	6.98
2015	OGWASHI	28.64 a	0.63	21.00 a	6.28	3.80 a	5.07	14.49 a	4.62	5.96 a	4.81	2.48 a	4.66	7.41 a	7.29	6.80 a	5.45

Note. Values are means; different superscript letters within a column indicate significant differences (p < 0.05). CV = coefficient of variation.

Abbreviations: CV, coefficient of variation; FW, fruit weight; PW, pulp weight; PT, pulp thickness; FLC, fruit longitudinal circumference; FL, fruit length; FD, fruit diameter; SW, seed weight; NS, number of seeds.

(3.80 mm), fruit circumference (15.52 cm), fruit length (6.78 cm) and fruit diameter (2.94 cm). In 2014, Anwai maintained high values for most characteristics, while Ogbolu recorded the highest fruit circumference (15.54 cm). In 2015, Anwai recorded the highest fruit weight (38.38 g), pulp weight (27.90 g), pulp thickness (4.00 mm), fruit circumference (16.25 cm), fruit length (7.19 cm) and seed weight (10.24 g). These results suggest that Anwai was generally the most outstanding location in Delta State in terms of fruit size and pulp characteristics (Table 3). 2015 PT ranged from 3.20mm to 4.00mm. There were no significant ($P < 0.05$) difference in PT (Table 3) for the three location.The correlation indicated that fruit weight showed significant($P < 0.05$) relationships with pulp weight, pulp thickness, fruit diameter, fruit circumference and fruit length, but its relationships with seed weight and number of seeds were not statistically($P < 0.05$) significant. The remaining characteristics generally exhibited significant ($P < 0.05$ relationships with one another (Table 8).

Enugu State

The results revealed differences among Nsukka, Oba and Amachala. In 2013, Nsukka recorded the highest fruit weight (25.25 g), pulp weight (16.83 g), pulp thickness (3.30 mm), fruit circumference (14.47 cm), fruit length (6.26 cm), fruit diameter (2.64 cm) and seed weight (8.64 g). In 2014, Nsukka recorded the highest fruit weight (28.46 g), pulp weight (19.69 g), fruit circumference (13.79 cm), fruit length (7.12 cm) and fruit diameter (2.82 cm). In 2015, Nsukka recorded the highest fruit weight (38.99 g), fruit circumference (13.74 cm) and fruit length (7.43 cm), while Amachala recorded the highest pulp weight (17.90 g), fruit diameter (2.88 cm), seed weight (10.65 g) and number of seeds (9.87). Overall, Nsukka demonstrated relatively superior performance in fruit weight and several other characteristics (Table 4). Mean PW for the three locations in 2015 ranged from 11.71g to 20.75g. There was no significant ($P < 0.05$) difference between the highest PW mean from lowest mean (Table 4). The results showed that fruit weight was significantly ($P < 0.05$) associated with pulp weight, pulp thickness, fruit diameter, fruit longitudinal circumference and fruit length. However, its relationships with seed weight and number of seeds were not statistically ($P < 0.05$) significant. Most relationships among the other pomological characteristics were statistically ($P < 0.05$) significant (Table 9).

Rivers State

The results showed that Etche generally recorded the highest pomological values compared with Elele and Obiebe. In 2013, Etche recorded the highest fruit weight (39.04 g), pulp weight (28.72 g), pulp thickness (4.90 mm), fruit circumference (16.58 cm), fruit length (6.27 cm), fruit diameter (3.25 cm), seed weight (9.96 g) and number of seeds (9.27). This pattern was maintained in 2014 and 2015. In 2015, Etche recorded 38.99 g fruit weight, 28.40 g pulp weight, 5.00 mm pulp thickness, 16.59 cm fruit circumference and 6.24 cm fruit length. These findings indicate that Etche consistently demonstrated superior fruit characteristics throughout the study period (Table 5). The mean PW of AP in 2013 ranged from 13.05g to 28.72g for the three locations.

These were statistically ($P < 0.05$) similar the correlation results examined the relationships among eight pomological characteristics. Rivers State exhibited significant ($P < 0.05$) relationships among all eight pomological characteristics. Fruit weight was significantly ($P < 0.05$) associated with pulp weight, seed weight, pulp thickness, fruit diameter, fruit circumference, fruit length and number of seeds respectively. The results indicate strong associations among the measured characteristics, suggesting that fruit development and size-related attributes were closely interconnected in the sampled Rivers State populations (Table 10).

DISCUSSION

Morphological Variation on Mean Pomological Characteristic

The results of this study revealed considerable variations in the pomological characteristics of Dacryodes edulis across the sampled locations in Imo, Abia, Delta, Enugu and Rivers States during the 2013–2015 period (Tables 1–5). There were substantial variation in the pomological characteristics of Dacryodes edulis across the five states and sampled locations. Etche in Rivers State, Anwai in Delta State, Nsukka in Enugu State, Umuduru and Logara in Imo State, and Oboro and Ngwa in Abia State recorded comparatively high values for several fruit characteristics. Etche in Rivers State consistently recorded high fruit and pulp weights, with maximum values of 39.16 g and 28.90 g, respectively, in 2014. Abia and Rivers States exhibited statistically ($P < 0.05$) significant correlations among all the measured pomological characteristics. In contrast, Imo, Delta and Enugu States showed non-significant relationships between fruit weight and seed weight, as well as between fruit weight and number of seeds (Tables 6–10).

The variations in morphology of pomological (Pml) attributes could be attributed to the fact that the species were highly out-crossed. This was in agreement with Okorie et al., (2000) cited by Njoku, (2021). Most may have arisen as a result of several generations of natural crossing within the species, and subsequent genetic segregation and recombination during fertilization and gametogenesis (Okorie, 2001). This also is an advantage, hence the higher the variability within the species the greater the potential for further improvement through the development of cultivars using horticultural techniques (Okorie, 2001). There were a lot of variations in ripe fruits colour which include marina, mid blue, ultra marine, bright blue, viking, navy, mid-night, violet, marine, and lilac (Plate 1). Unripe fruit colours ranged from magenta, pink, almond and cream.The shapes observed include conical, oval, globular and extended. The variation observed in terms of fruit shape and colour of AP fruit before and after ripening were inherent in a particular tree for the period of the survey study. Two or more trees cannot have the same shape and colour. Therefore, shape of each AP fruit and colour was in built in them. This means that, they are genetically controlled. A particular tree has its own fruit shape and colour which distinguish one AP from another. It was not influenced by environmental factors rather mostly genetic.Figs.1 to 6 showed variations observed in AP colours before ripening and after ripen in the various location. Four colour before ripening while ten after ripening were identified. In some locations the different colours were observed. Some colours were more in some location while in others few. At Rivers State, pink colours were highest in all the locations while cream colour and magneta were lowest. Also for riped fruit colours navy blue

Table 4. Pomological characteristics of African pear in Enugu State (2013–2015)

Year	Sampling location	Fruit weight (g)	CV (%)	Pulp weight (g)	CV (%)	Pulp thickness (mm)	CV (%)	Fruit longitudinal circumference (cm)	CV (%)	Fruit length (cm)	CV (%)	Fruit diameter (cm)	CV (%)	Seed weight (g)	CV (%)	Number of seeds	CV (%)
2013	**NSUKKA**	25.25a	2.47	16.83 a	2.39	3.30 a	3.36	14.47 a	1.59	6.26 a	1.84	2.64a	0.82	8.64 a	2.75	8.43 a	1.08
2013	**OBA**	10.24 a	12.75	6.63 a	12.69	1.10 b	12.78	5.99 b	12.51	2.57 b	12.55	1.06b	12.63	3.55 b	12.95	3.39 b	12.6
2013	**AMACHALA**	24.35 a	7.81	16.47 a	7.98	2.9ab	8.32	9.83ab	7.38	4.88ab	7.21	2.07ab	7.18	7.85 ab	7.31	6.53ab	6.86
2014	**NSUKKA**	28.46 a	3.20	19.69 a	3.77	3.70 a	3.86	13.79 a	1.81	7.12 a	3.69	2.82 a	1.48	8.97 a	2.44	8.64 a	1.08
2014	**OBA**	27.35 a	3.20	18.66 a	4.72	3.90 a	6.68	11.45ab	4.54	5.61 a	3.69	2.59 a	4.15	8.61 a	4.32	7.99 a	3.96
2014	**AMACHALA**	22.52 a	4.38	14.34 a	7.38	2.90 a	6.36	9.04 b	6.7	4.66 a	4.11	2.31 a	6.05	8.29 a	6.44	8.00 a	5.85
2015	**NSUKKA**	38.99 a	5.45	20.75 a	3.95	4.00 a	3.72	13.74 a	2.10	7.43 a	3.96	2.86 a	1.65	7.72 ab	5.03	8.66 a	1.21
2015	**OBA**	25.03 a	5.19	11.71 a	9.93	2.70 a	12.21	8.41a	9.91	3.95 b	9.61	1.53 b	9.43	5.82 b	8.83	5.23 b	9.39
2015	**AMACHALA**	20.33 a	7.69	17.90 a	3.90	3.80 a	3.78	12.21a	3.11	5.91ab	2.37	2.88 a	1.79	10.65 a	2.57	9.87 a	0.99

Note. Values are means; different superscript letters within a column indicate significant differences (p < 0.05). CV = coefficient of variation.
Abbreviations: CV, coefficient of variation; FW, fruit weight; PW, pulp weight; PT, pulp thickness; FLC, fruit longitudinal circumference; FL, fruit length; FD, fruit diameter; SW, seed weight; NS, number of seeds.

Table 5. Pomological characteristics of African pear in Rivers State (2013–2015)

Year	Sampling location	Fruit weight (g)	CV (%)	Pulp weight (g)	CV (%)	Pulp thickness (mm)	CV (%)	Fruit longitudinal circumference (cm)	CV (%)	Fruit length (cm)	CV (%)	Fruit diameter (cm)	CV (%)	Seed weight (g)	CV (%)	Number of seeds	CV (%)
2013	**ETCHE**	39.04a	5.11	28.72 a	6.17	4.90a	3.20	16.58a	2.22	6.27 a	2.38	3.25a	2.51	9.96a	2.50	9.27a	0.87
2013	**ELELE**	25.44 a	9.69	19.11 a	9.80	2.80ab	8.58	10.39ab	8.62	4.43 a	8.71	1.92ab	8.32	6.17ab	9.39	5.42ab	8.39
2013	**OBIEBE**	17.66 b	10.79	13.05 a	11.02	2.10b	10.69	8.24 b	10.72	3.45 a	10.72	1.46b	10.71	4.67b	10.89	4.24b	10.82
2014	**ETCHE**	39.16 a	5.12	28.90 a	6.22	4.90 a	3.22	16.51 a	2.21	6.27 a	2.39	3.25 a	2.53	10.12 a	2.57	8.83 a	1.03
2014	**ELELE**	34.62 a	5.61	24.91 a	6.09	3.50 a	4.63	12.59 a	5.19	5.72 a	4.77	2.69 a	4.14	9.53 a	5.27	8.00 a	4.35
2014	**OBIEBE**	29.44 a	8.23	19.92 a	9.50	3.60 a	6.82	11.89 a	6.93	4.91 a	6.72	2.59 a	6.57	7.14 a	7.66	6.87 a	6.18
2015	**ETCHE**	38.99 a	5.45	28.40 a	6.70	5.00 a	3.48	16.59 a	2.39	6.24 a	2.55	3.30a	2.64	10.32a	2.43	9.40a	0.57
2015	**ELELE**	17.23 b	13.84	19.78ab	8.55	1.80 b	12.85	7.05 b	12.80	3.04 a	12.84	1.39 b	12.48	4.29 b	13.43	4.47b	10.72
2015	**OBIEBE**	17.43 b	9.69	9.53b	9.71	2.30 b	9.45	6.65 b	9.95	3.46 a	9.72	1.68 b	9.36	5.72 ab	9.56	4.73b	10.71

Note. Values are means; different superscript letters within a column indicate significant differences (p < 0.05). CV = coefficient of variation.
Abbreviations: CV, coefficient of variation; FW, fruit weight; PW, pulp weight; PT, pulp thickness; FLC, fruit longitudinal circumference; FL, fruit length; FD, fruit diameter; SW, seed weight; NS, number of seeds.

Table 6. Correlation coefficients of pomological characters of D. edulis in Imo State

Character	FW (g)	PW (g)	SW (g)	PT (mm)	FD (cm)	FLC (cm)	FL (cm)	NS
FW (g)	1							
PW (g)	0.0074** (81.52%) #							
SW (g)	0.2465ns							
PT (mm)	0.0088** (80.52%)							
FD (cm)	0.0479 * (67.10%)							
FLC (cm)	0.0317 * (71.11%)							
FL (cm)	0.0069** (81.90%)							
NS	0.1052ns							

*Note. * $p \leq 0.05$; ** $p \leq 0.01$; ns, not significant. Parenthetical percentages are reproduced as reported in the source.*

Table 7. Correlation coefficients of pomological characters of D. edulis in Abia State

Character	FW (g)	PW (g)	SW (g)	PT (mm)	FD (cm)	FLC (cm)	FL (cm)	NS
FW (g)								
PW (g)	0.0000** (97.97%) #							
SW (g)	0.0006 ** (91.12%)	0.0080 ** (81.11%)						
PT (mm)	0.0021 ** (87.33%)	0.0071 ** (81.77%)	0.0021** (87.36%)					
FD (cm)	0.0005** (91.54%)	0.0026** (86.46%)	0.0011** (89.66%)	0.0000** (98.38%)				
FLC (cm)	0.0017** (88.19%)	0.0075** (81.42%)	0.0005** (91.89%)	0.002** (87.34%)	0.0045** (84.14%)			
FL (cm)	0.0000** (95.90%)	0.0007** (90.70%)	0.0001** (94.79%)	0.0022** (87.14%)	0.0019** (87.63%)	0.0000 ** (96.41%)		
NS	0.0107 * (79.33%)	0.0235 * (73.69%)	0.0100** (79.79%)	0.0001** (95.15%)	0.0000** (96.40%)	0.0352 * (70.15%)	0.0216 * (74.38%)	

*Note. * $p \leq 0.05$; ** $p \leq 0.01$; ns, not significant. Parenthetical percentages are reproduced as reported in the source.*

Table 8. Correlation coefficients of pomological characters of D. edulis in Delta State

Character	FW (g)	PW (g)	SW (g)	PT (mm)	FD (cm)	FLC (cm)	FL (cm)	NS
FW (g)	1							
PW (g)	0.0074** (81.52%) #							
SW (g)	0.2465ns (43.12%)							
PT (mm)	0.0088** (80.52%)							
FD (cm)	0.0479 * (67.10%)							
FLC (cm)	0.0317 * (71.11%)							
FL (cm)	0.0069**							
NS	0.1052ns							

*Note. * $p \leq 0.05$; ** $p \leq 0.01$; ns, not significant. Parenthetical percentages are reproduced as reported in the source.*

Table 9. Correlation coefficients of pomological characters of D. edulis in Enugu State

Character	FW (g)	PW (g)	SW (g)	PT (mm)	FD (cm)	FLC (cm)	FL (cm)	NS
FW (g)	1							
PW (g)	0.0074** (81.52%) #	1						
SW (g)	0.2465ns (43.12%)	0.0057** (82.97)%	1					
FD (cm)	0.0479 * (67.10%)	0.0001** (94.77%)	0.0006** (91.15%)	0.0003** (92.76%)	1			
FLC (cm)	0.0317 * (71.11%)	0.0013** (88.93%)	0.0195 * (75.18%)	0.0036** (85.18%)	0.0006** (91.08%)	1		
FL (cm)	0.0069** (81.90%)	0.0001** (95.10%)	0.0215 * (74.42%)	0.0009** (90.12%)	0.0002** (93.54%)	0.0000** (95.99%)	1	
NS	0.1052ns							

*Note. * $p \leq 0.05$; ** $p \leq 0.01$; ns, not significant. Parenthetical percentages are reproduced as reported in the source.*

Table 10. Correlation coefficients of pomological characters of D. edulis in Rivers State

Character	FW (g)	PW (g)	SW (g)	PT (mm)	FD (cm)	FLC (cm)	FL (cm)	NS
FW (g)	1							
PW (g)	0.0005** (91.92%)#	1						
SW (g)	0.0000** (97.77%)	0.003** (85.81%)	1					
PT (mm)	0.0000** (96.90%)	0.0031** (85.83%)	0.0001** (95.08%)	1				
FD (cm)	0.0000** (98.51%)	0.0021** (87.33%)	0.0000** (97.43%)	0.0000** (99.03%)	1			
FLC (cm)	0.0000** (98.20%)	0.0005** (91.48%)	0.0001** (94.42%)	0.0000** (98.40%)	0.0000** (97.57%)	1		
FL (cm)	0.0000** (99.64%)	0.0014** (88.66%)	0.0000** (98.47%)	0.0000** (96.88%)	0.0000** (98.40%)	0.0000** (97.67%)	1	
NS	0.0000** (98.76%)	0.0008** (90.59%)	0.0000** (98.38%)	0.0000** (97.32%)	0.0000** (99.04%)	0.0000** (97.06%)	0.0000**	

*Note. * $p \leq 0.05$; ** $p \leq 0.01$; ns, not significant. Parenthetical percentages are reproduced as reported in the source.*

were highest for Rivers State while lilac was lowest. These trees were found growing in the same site with same environmental conditions but differences exists in their fruit colours, suggesting strongly that the differences observed were as a result of morphological variation influenced by genetic makeup. Variations also occurred in fruit shape between trees which included conical, oval, globular and eliptical. (Figures 7 to 11). These shapes were observed within and between locations. Combined distribution of D. edulis fruit shape shown on Figure 12 reveals that 33% of the fruits had Globular shape, 28% Oval while extended and conical had 24% and 15%, respectively. These testify to the variations observed in AP fruits. These were found growing in the same place and under the same climatic condition, but still differences exist. The observed variations in fruit weight, pulp weight, pulp thickness, fruit longitudinal circumference, fruit length, fruit diameter, seed weight and number of seeds confirms the result reported by Okorie, (2001); Waruhiu et al, (2004); Anegbeh et al, (2005) and Njoku and okorie, (2021) that variations exist among the pomological characters. These indicated differences in the physical and morphological characteristics of the fruits across the study locations. These variations are important because pomological characteristics provide useful information for assessing fruit quality, identifying promising accessions and selecting desirable plant materials for further improvement (Tables 1–5). Fruit weight is an important pomological attribute

because it provides a general indication of fruit size and potential economic value. In this study, Rivers State, particularly Etche, consistently recorded comparatively high fruit weights throughout the three years. Etche recorded 39.04 g, 39.16 g and 38.99 g in 2013, 2014 and 2015, respectively. These values indicate remarkable consistency in fruit weight across the study period. Similarly, Anwai in Delta State recorded 34.78 g in 2013 and increased to 38.38 g in 2015, while Nsukka in Enugu State recorded its highest fruit weight of 38.99 g in 2015. The relatively high fruit weights recorded in these locations suggest that they may constitute promising sources of large-fruited D. edulis populations (Tables 1–5). In contrast, some locations recorded relatively lower fruit weights. For example, Oba in Enugu State recorded 10.24 g in 2013, while Ngwa in Abia State recorded 14.62 g in the same year. Similarly, Alayi in Abia State recorded 15.77 g in 2015. The differences observed among locations may reflect variations in the characteristics of the sampled plant populations and potentially differences in environmental and growing conditions (Tables 1–5). Pulp weight followed a pattern generally similar to fruit weight. Etche in Rivers State consistently recorded high pulp weights of 28.72 g, 28.90 g and 28.40 g across the three years. Anwai in Delta State also recorded high pulp weights, particularly in 2015 (27.90 g). These observations indicate that locations with relatively heavier fruits also tended to record higher pulp weights. This relationship is particularly important because pulp constitutes the edible and economically valuable portion of African pear. The relatively high pulp weights recorded in Etche and Anwai suggest that these locations may be useful sources ofplanting materials for traits associated with greater pulp production (Tables 1–5). Pulp thickness also varied across the locations. Etche recorded 4.90 mm in both 2013 and 2014 and 5.00 mm in 2015, representing the highest values recorded among the locations throughout the study period. In comparison, several locations, including Oba in Enugu State and Alayi in Abia State, recorded relatively lower values. The relatively greater pulp thickness observed in Etche is consistent with its high pulp weight and fruit weight. This suggests that selection based on pulp thickness, in addition to fruit weight, may be useful in identifying desirable African pear populations for fruit quality improvement (Tables 1–5). Fruit longitudinal circumference, fruit length and fruit diameter further demonstrated differences among the sampled locations. Etche consistently recorded high fruit circumference values of 16.58 cm, 16.51 cm and 16.59 cm from 2013 to 2015. Anwai also recorded relatively high circumference values, reaching 16.25 cm in 2015. In terms of fruit length, Anwai recorded 7.19 cm in 2015, while Nsukka recorded 7.43 cm in the same year. These findings suggest that the sampled locations differ in fruit dimensions, with Etche, Anwai and Nsukka showing relatively desirable characteristics in different aspects of fruit size (Tables 1–5).

Seed weight and number of seeds also varied among locations and years. In Imo State, Umuduru recorded the highest seed weight of 12.58 g in 2015, while Oboro in Abia State recorded 12.49 seeds in the same year. The highest seed weight recorded in Delta State was 10.24 g at Anwai in 2015, while Amachala in Enugu State recorded 10.65 g. In Rivers State, Etche consistently recorded relatively high seed weights and number of seeds. These variations demonstrate that seed-related characteristics do not necessarily follow exactly the same distribution pattern as fruit and pulp characteristics. Consequently, the selection of desirable African pear populations should consider both fruit and seed attributes, depending on the intended breeding or utilization objectives (Tables 1–5). An important observation from the results is that the location with the highest fruit weight did not necessarily record the highest value for every other pomological characteristic. For instance, although Etche consistently recorded the highest fruit and pulp weights in Rivers State, other locations recorded comparatively high values for particular characteristics. This indicates that the selection of superior *D. edulis* populations should be based on a combination of desirable traits rather than a single characteristicThe observed variations suggest the existence of useful differences among the sampled *Dacryodes edulis* populations, which may be considered in the selection of promising locations or accessions for further evaluation and improvement..The results of this study had highlighted required information for African pear improvement.The high variability indicated great potential for further improvement through the development of cultivars with high qualities in pomological characteristics (such as big fruit size, pulp weight, pulp thickness, etc), colour and shape. Therefore Researchers and policy makers in partnership with local people (Owners of African pear trees) should make more quantitative assessment of Pulp weight, pulp thickness, fruit diameter, fruit circumference and fruit length which were important characteristics associated with fruit weight across the study locations. More research should be directed towards the improvement of AP fruits.

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