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# Digital Seed Morphometric Analysis of Nigerian Cultivated Rice (*Oryza sativa* L.) Varieties Grown Under Guinea Savannah Agro-ecology

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**Abstract:** This study investigated the varietal differences for morphometric properties among Nigerian cultivated rice varieties. Twenty-two rice varieties were grown under rain fed conditions in guinea agro-ecology at National Agricultural Seed Council, Abuja, Nigeria in 2017 and 2018. After 30 days of harvest, seed samples were collected for morphometric evaluation. The seed samples were evaluated in laboratory of the Department of Plant Breeding and Seed Technology, Federal University of Agriculture, Abeokuta in 2017 and 2018 using completely randomized design in three replicates. Seeds obtained from the 22 varieties in two years were assessed for: six morphometric (physical) characters: seed projected area, seed straight length (mm), seed curve length (mm), seed straight width (mm), seed curved width (mm), seed width length (mm) and seed perimeter (mm) using an Epson Scanner connected to a computer device to acquire image of the seeds. A reagent instrument from Reagent Instrument Inc. Canada was used for the digital image analysis by running the custom written software WinSEEDLETM (Pro Version). Data obtained were subjected to Analysis of Variance and means were separated using Tukey's HSD at 5% probability level. Pearson's correlation coefficient and principal component analyses were also used. Significant varietal differences were observed for all seed physical characters evaluated. Seed physical characters (projected area, curve length, seed width, seed length and perimeters) were higher in 2018 compared to 2017. WAB 189 had superior physical characters. FARO 62 and FARO 22 had the least values for most of the seed physical characters. Most of the seed morphometric characteristics were strongly associated with one another. PC1 with seed projected area, straight length, seed straight width, seed curved width and seed perimeter contributed to the total variation observed. The study concluded that WAB 189 and FARO 50 with superior seed physical characters should be used for future seed improvement programme.

**Keywords:** Digital Imaging, Computer, Morphometry, Seed Shape, Physical Character

## 1. Introduction

Rice is the world's most important food crop and a primary food source for more than one third of world's population [1]. It is the staple food crop for more than 60% of the population and provides 20% of calories and 15% of protein [2]. Rice is a chief source of carbohydrates and protein which also provides minerals and fibers. In ancient days farmers grows only landraces and which gives limited yield. After green revolution, the high yielding fertilizer responsive and short statured rice varieties introduced in the country, this event helped in attaining self-sufficiency in grain production at the cost of loss of conventional varieties [2]. Apart from yield, people preferring varieties with acceptable grain qualities. In Nigeria rice has consumption per capita of 32kg indicating 4.7% increase in the past decade making the total consumption to be 6.4 million tonnes in 2017 as against 3.7 million tonnes produced per year [3].

Genetic variability is a prerequisite for any improvement in crop. The development of one or more varieties depends on the final selection of superior plants by the plant breeder who uses several techniques to create the genetic variation and to select from within that variation [4]. Rice is rich in genetic diversity with thousands of varieties grown throughout the world and its economic importance related to agro-ecological adaptation, house hold food security, ceremonies, nutritional diversification, income generation and employment [5].

The physical characteristic of seed is a wide knowledge that can be useful in the farming, harvesting and storage or in processing such as drying, freezing and others. Considering either bulk or individual units of seed material, it is important to have an accurate estimation of seed shape, seed size, seed volume, seed density, seed gravity and seed surface area [6].

The application of digital imaging information technology to seed germination testing is important. This technology is reviewed in light of recent interest in the development and adoption of sustainable agro-systems joined with a modern strategy of “precision agriculture”, which provides new complex information tools for better crop production [7]. Basic concepts on the patterns of image analysis descriptors of imbibing seed performance are described with the objective of demonstrating the potential of this technique to be adequate for overcoming problems encountered with a standard seed germination test [8]. The application of different image analysis system prototypes in monitoring seed germination of Brassica, as well as several other crop species, has provided encouraging results, highlighting the reliability of this technique to quickly acquire digital images and to extract numeric descriptors of germination and radical growth events [9].

Various methods (e.g., use of charge-coupled device camera, flat-bed scanner, X-ray scanning or nuclear magnetic resonance imaging) can be used to obtain seed images showing external or internal features of certain quality factors, such as size, colours and defects [10]. Bio-morphological seed features may be analysed by computer-aided image analysis systems and data quickly processed and stored in the hard disk, plotted or statistically elaborated [11]. These data include relationships among seed size and shape and growth time-course and understanding of growth patterns that produce curvature and inflection points.

The application of computational techniques to the study of seed germination covers three aspects: computer-assisted image analysis systems, descriptive simulation modelling, and combined relation modelling between morphological changes and biological processes [12] A variety of computational techniques has been provided to capture digital seed images, to set the thresholds of image object definition, the so-called segmentation procedure, to measure image analysis parameters and establish their patterns in connection with the geometry variation of a germinating seed. These techniques also foresee human computer interaction, which is required to localize and visualize time-lapse image sequence and alignment, and to track a portion of the image obtained at different times [12].

As a result, new hardware architectures and algorithms have been developed for high speed extraction of raw data, i.e. digital images, and numeric data, such as dimensional measurements, shape factors and colour space primary density. Integration of image analysis data with those obtained by other biological systems could contribute to up-grading the ‘information technology’ which accounts for acquisition, recording and processing, and communication of information [13]. This basic knowledge could also be included in the complex system of ‘precision agriculture’, where farmers, seed industries, seed-gene banks, seed analysts and researchers require new information networks and tools to reduce costs and environmental impacts, while enhancing and protecting plant biodiversity in the establishment of sustainable agro-ecosystems [13].

Information on genetic variability and relationships in crop plants are important for effective selection of parental lines for improvement programs by plant breeders. Traditionally, agro-morphological traits have been used to distinguish crop varieties [14]. Agro-morphological traits are highly influenced by environmental factors [15]. Therefore, the study was initiated to determine the varietal differences among rice varieties using seed metric (shape factor) characteristics grown under guinea savannah agro-ecology.

# 2. Materials and Methods

### *2.1. Seed Materials and Source*

Seeds of twenty-two freshly harvested Nigerian cultivated rive varieties produced from 2017 and 2018 cropping years in guinea savanna ecology were used for this assessment.

### *2.2. Location and Duration*

The experiment was carried out in the laboratory of Plant Breeding and Seed Technology, FUNAAB. Harvested seeds after 30 days of harvest at the end of each cropping years were subjected to the same physical characteristics evaluation using computer digital image system (WinSEEDLETM, Pro Version).

### *2.3. Experimental Design and Factor*

The evaluation was carried out in a completely randomized design (CRD) in three replicates. Two factor viz varieties (22 levels) and cropping years (2 levels) were evaluated. Prior to evaluation, cleaned 100 seed were randomly selected from each variety lot in each replication with moisture content of almost 11%. The moisture content was determined using oven drying method according to [16].

### *2.4. Seed Weight Determination*

One hundred seeds in three replicates from each cultivar were evaluated to determine the average seed weight in gramme using sensitive balance in the laboratory of Plant Breeding and Seed Technology, FUNAAB in both cropping seasons.

### *2.5. Seed Morphometry (Shape Factor) Evaluation Procedure*

The digital imaging of the seeds was done on the illuminating box of the seed image electric scanner at the laboratory of Plant Breeding and Seed Technology Department, FUNAAB. An Epson Scanner were connected to a computer device to acquire image of the seeds. A reagent instrument from Reagent Instrument Inc. Canada was used for the digital image analysis by running the custom written software WinSEEDLETM (Pro Version). For every replication, 100 seeds were placed on the lightening hood in such a way that embryo axis of the seed faced the image analysis system while the longitudinal axis ran parallel to the surface of the scanner. Seeds were automatically analyzed by the scanner and the seed morphometric (shape factors) characteristics recorded by the WinSEEDLETM. The procedure was repeated three times for all the cultivars in each cropping year.

### *2.6. Data Collection*

The following seven seed morphometric (shape factors) characteristics were determined using the digital seed image electric scanner as reported by [17].

Seed projected area (mm), seed straight length (mm), seed curved length (mm), seed straight width (mm), seed curved width (mm), seed width length (mm) and seed perimeter.

### *2.7. Statistical Analysis*

Data obtained from the seven seed morphometric (shape factors) attributes were subjected to 2-way Analysis of Variance and treatment means were separated using Tukey's Honest Significant Difference (HSD) Test at 5% probability level. Correlation coefficient analysis was performed on the data to determine relationships between the characteristics. Principal Component Analysis was performed to determine seed shape attributes contributing majorly to variation within the cultivated varieties.

## 3. Results

The mean square values from the combined Analysis of Variance for seed metric (shape factor) characteristics of the 22 cultivated rice varieties under two cropping years are presented in Table 1. From the Table, the result shows that cropping year effect was highly significant for project area, curved length, straight width, width length and perimeter whereas variety effect was highly significant on the seven seed shape factors evaluated. The result further indicates that cropping year x variety interaction effect was highly significant on all the seed morphometric (shape factors) characteristics evaluated in this study.

The effect of cropping year on seed shape factors in the 22 cultivated rice varieties is presented in Table 2. A perusal of the data shows that seed produced in 2018 cropping year had significant higher projected area (26.30 mm), straight width (3.30 mm), width length (0.36 mm) and perimeter (29.09 mm). However, values for seed straight length, curved length and curved width between the two cropping years (2017 and 2018) were statistically similar.

In Table 3, the Mean performance of the 22 cultivated rice varieties for seed projected area and straight length in two cropping years under guinea savannah ecology shows that projected area ranged between 17.69mm$^2$ in 2017 for FARO 31 to 26.077 mm$^2$ for WAB 189 whereas it was 17.860 mm$^2$ for FARO 62 and 33.467 mm$^2$ for WAB 189 in 2018. The highest mean projected area of 29.77 mm$^2$ was recorded for WAB 189 while the lowest value of 17.86 mm$^2$ was recorded for FARO 62 across the two cropping years. As for the Straight Length (mm), the result further shows that Straight Length ranged between 9.36mm in 2017 for WAB 189 to 11.45mm for FARO 21 whereas it was 8.35mm for FARO 22 and 13.52mm for FARO 57 in 2018. The highest mean straight length of 11.73mm$^2$ was recorded for FARO 57, though not statistically different from straight length of 11.19 and 11.13 were obtained in FARO 21 and PAC 832 respectively while the lowest value of 8.47mm was recorded for FARO 22 across the two cropping years.

Table 4 data show that in 2017 cropping year, curved length was highest in WAB 189 with value of 11.97mm, closely followed by FARO 65 with 11.19mm seed curved length whereas FARO 52 had least value 9.52mm. In the corresponding 2018 cropping year, the highest seed curved length was in FARO 27 (14.21mm) followed by WAB 189 (11.97mm) and FARO 31 (11.96mm) while FARO 62 recorded the lowest values (8.70mm). The varietal performance across cropping years show that FARO 27 (12.34mm), and WAB 189 had highest values while FARO 62 was with lowest value (9.11mm).

Still in Table 4, seed straight weight in 2017 cropping year was highest in FARO 63 (3.43mm) as well as FARO 59 (3.32mm) and FARO 57 (3.11mm) whereas FARO 62 had the lowest seed straight width of 2.62mm. In the contrary, in 2018 cropping year, FARO 58 had the highest value of 16.45mm, followed by WAB 189 (4.05mm) while FARO 62 showed the lowest value of (2.67mm). On the mean performance across cropping years, WAB 189 (3.66mm) as well as FARO 59 (3.43mm) were with highest values whereas most of the other varieties had statistically similar values of between 2.80 and 3.36mm but FARO 62 had the lowest value of 2.59mm.

The mean performance of cultivated rice varieties for seed width length and seed perimeter (Table 5) shows that in 2017 cropping year, WAB 189 had the highest value (0.39mm) followed by FARO 22 (0.33mm) and FARO 65 (0.32mm) whereas FARO 61 showed the lowest value (0.25mm). In the corresponding 2018 cropping year, WAB 189 displayed the highest value of 0.44 mm, closely followed by FARO 61 (0.42mm) and FARO 22 (0.41mm) while FARO 31 (0.30mm) had the least value. The varietal mean across cropping years shows that WAB 189 was with highest value (0.42mm), followed by FARO 22 (0.37) while other varieties were statistically similar in their values but FARO 31 (0.27 mm) had the lowest value. For the seed perimeter, in 2017 cropping season, FARO 61 (50.23 mm) had highest value followed by FARO 52 (46.80 mm) while other varieties were statistically similar in values, but FARO 62 had the least values (22.23 mm). In 2018 cropping year, seed perimeter was highest in FARO 57 (42.30 mm), followed by WAB 189 and FARO 22 with values of 35.13 mm and 33.82 mm, respectively while FARO 62 showed lowest value (21.25 mm). On the overall performance across cropping years, FARO 52 and FARO 61 were with highest values of 38.65 m and 37.44 mm, respectively, followed by FARO 57 (33.03 mm) whereas FARO 62 and FARO 22 had least values of 21.74 and 21.76mm, respectively.

Table 6 data show that seed curved width recorded no significant difference among the 22 rice varieties in 2017 with values ranging from 3.31mm in FARO 65 to 2.52mm in FARO31. In 2018, seed curved width (mm) ranged between 0.01 mm (FARO 45, PAC 832, FARO 31 and FARO 65) to 4.44 mm for WAB 189. The varietal mean reveals that the highest mean seed curved width of 3.93 mm was recorded for WAB 189 while the lowest value of 1.16mm was recorded for FARO 45.

The correlation coefficients between seed shape factors seed metrics of 22 cultivated rice varieties across two cropping years are presented in Table 7. Projected Area showed high significant and positive correlation values with straight length (r=0.38**), curved length (r=0.55**), straight width (r=0.72**), width length (r=0.52**) and perimeter (r=0.26**). It further reveals that straight length was positively correlated with curved length and perimeter (r=0.79** and r=0.37**) but negatively correlated with width length (r=-0.39**). Similarly, curved length had high significant correlation values with straight width and perimeter (r=0.29** and r=0.43**). Straight width was positively correlated with curved width and (r=0.23**) and width length (r=0.64**) while seed curved width exhibited a high significant positive correlation with width length (r=0.27**).

The results of combined multivariate analysis to explain variation among seed shape component of the cultivated rice varieties across two cropping years are presented in Table 8. The result reveals that the first two principal components had eigen values greater than 1. These two axes with eigen values of 2.89 and 2.13 jointly accounted for 68.94% of the total variation among the genotypes. The first PC (PC1) accounted for 38.42% of the variability and was related to projected area (0.87), straight length (0.66), curved Length (0.81), straight width (0.69), width length (0.27) and perimeter (0.52). The second PC accounted for 30.52% of the total variation and was dominated by projected area (0.30), straight length (-0.64), curved length (-0.44), straight width (0.59), curved width (-0.41), width length (0.89) and perimeter (0.33). The third PC was dominated by projected area (0.24) and curved width (-0.88). This principal component explained an additional 13.35% of the variability. The fourth PC (PC4) accounted for an additional 10.10% of total variation and was dominated by perimeter (0.73).

***Table 1.*** *Mean square values of seed shape factors of cultivated rice varieties grown in two cropping years under guinea savanna environment.*

| Source of variation | DF | Seed Project area | Seed Straight length | Seed Curved length | Seed Straight width | Seed Curved width | Seed Width length | Seed Perimeter |
|---|---|---|---|---|---|---|---|---|
| Replicate | 2 | 1.05ns | 0.01ns | 0.41 | 0.89ns | 0.04ns | 0.00 | 0.39n |
| Cropping (Y) | 1 | 923.06** | 0.05ns | 6.97** | 3.54** | 0.08ns | 1.59** | 163.75** |
| Variety (V) | 21 | 40.14** | 3.49** | 3.53** | 0.28** | 3.33** | 0.01** | 115.02** |
| Y x V | 21 | 12.12** | 1.41** | 1.64** | 0.12** | 2.95** | 0.02** | 137.83** |
| Error | 84 | 4.47 | 0.27 | 0.38 | 0.05 | 0.05 | 0.00 | 4.30 |

** significant at 1% probability level,
*significant at 5% probability level,
Ns not significant.

***Table 2.*** *Effect of cropping year on seed shape factors in cultivated rice varieties grown in under guinea savanna environment.*

| Seed Parameters | 2017 cropping year | 2018 cropping year | SE | Tukey's HSD (0.05) |
|---|---|---|---|---|
| Projected Area | 20.98b | 26.30a | 0.28 | 0.56 |
| Straight length (mm) | 10.07a | 10.03a | 0.06 | 0.10 |
| Curve length (mm) | 10.29a | 10.48a | 0.08 | 1.33 |
| Straight width (mm) | 2.97b | 3.30a | 0.03 | 0.05 |
| Curved width (mm) | 2.99a | 2.94a | 0.03 | 0.05 |
| Width length (mm) | 0.29b | 0.36a | 0.00 | 0.003 |
| Perimeter (mm) | 26.77b | 29.09a | 0.26 | 0.43 |

Means followed by the same alphabet along the column are not different from another at 5% probability level.
S. E: Standard error
LSD: Least significant difference.

***Table 3.*** *Mean performance of cultivated rice varieties for seed projected area (mm$^2$) and straight length in two cropping year under guinea savannah ecology.*

| Varieties | Project Area (mm$^2$) | | Varietal | Straight length (mm) | | Varietal |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | mean | 2017 | 2018 | mean |
| FARO 62 | 17.87d | 17.86g | 17.86f | 9.36c | 8.36f | 8.86gh |
| FARO 60 | 21.29b | 26.34d | 23.81bcde | 10.46bc | 10.34c | 10.39bcde |

| Varieties | Project Area ($mm^2$) | | Varietal | Straight length (mm) | | Varietal |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | mean | 2017 | 2018 | mean |
| FARO 52 | 18.70cd | 29.15c | 23.92bcd | 9.69c | 10.22c | 9.95d-g |
| FARO 61 | 17.93d | 23.16e | 20.54def | 9.64c | 8.77ef | 9.20fgh |
| FARO 41 | 19.94c | 22.59ef | 21.26cdef | 10.52b | 9.39de | 9.95d-g |
| FARO 22 | 17.77d | 20.78f | 19.27ef | 8.60d | 8.35f | 8.47d-g |
| NAB 189 | 26.08a | 33.47a | 29.77a | 9.90c | 10.38c | 10.14b-f |
| FARO 21 | 21.39b | 29.38bc | 25.38abc | 11.45a | 10.94bc | 11.19ab |
| FARO 63 | 23.52b | 24.55de | 24.03bcd | 9.91c | 10.14c | 10.02def |
| FARO 64 | 21.15b | 29.94b | 25.54abc | 9.84c | 9.78d | 9.81efg |
| FARO 50 | 20.68c | 26.43d | 23.55bcde | 9.30d | 10.37c | 9.91efg |
| FARO 27 | 20.36c | 24.28e | 22.32b-f | 10.66b | 9.39de | 10.02cdef |
| FARO 57 | 22.19b | 28.57cd | 25.38abc | 9.59c | 13.52a | 11.73a |
| FARO 48 | 21.58b | 22.88e | 22.23b-f | 9.99c | 9.17e | 9.58e-h |
| FARO 47 | 21.47b | 23.75de | 22.62bcde | 9.65c | 9.41de | 9.53e-h |
| FARO 59 | 21.60b | 28.89c | 25.24abc | 9.98c | 10.59c | 10.28b-f |
| FARO 44 | 22.50b | 27.62cd | 25.06bcd | 10.36bc | 10.55c | 10.46-e |
| FARO 58 | 22.03b | 27.93cd | 24.98bcd | 9.567c | 9.57de | 9.58e-f |
| FARO 65 | 22.48b | 28.04c | 25.26abc | 9.90c | 9.72d | 9.81efg |
| FARO31 | 17.69d | 26.30d | 21.99bcde | 10.98ab | 11.14b | 11.06a-d |
| PAC 832 | 21.96b | 31.22b | 26.59abc | 11.13ab | 11.13b | 11.13abc |
| FARO 45 | 21.35b | 25.50d | 23.43bcd | 10.01c | 9.67d | 9.84efg |
| SE | 1.22 | | | 0.298 | | |

Means followed by the same alphabet along the column are not different from another at 5% probability level.
2017 and 2018 cropping years.

***Table 4.*** *Mean performance of 22 Nigerian cultivated rice varieties for seed curve length (mm) and seed straight width in two cropping year under guinea savannah ecology.*

| Varieties | Curve length (mm) | | Varietal | Straight width (mm) | | Varietal |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | mean | 2017 | 2018 | mean |
| FARO 62 | 9.52d | 8.707f | 9.113e | 2.62d | 2.67f | 2.59e |
| FARO 60 | 10.55c | 11.19c | 10.87bcd | 2.81cd | 3.68c | 3.14bcd |
| FARO 52 | 10.04c | 11.32c | 10.68bcd | 3.00bc | 3.60c | 3.30abc |
| FARO 61 | 10.02cd | 9.51e | 9.77de | 2.83c | 3.29d | 3.06bcd |
| FARO 41 | 10.50c | 9.94e | 10.22cde | 2.94c | 2.97e | 2.95cde |
| FARO 22 | 9.94cd | 11.34c | 10.64bcd | 3.20b | 3.16de | 3.18bcd |
| NAB 189 | 11.97a | 11.96b | 11.97ab | 3.26ab | 4.05 | 3.66a |
| FARO 21 | 10.39c | 10.62d | 10.50cd | 2.82c | 3.51cd | 3.16bcd |
| FARO 63 | 10.19c | 10.29de | 10.25cde | 3.43a | 3.29d | 3.36abc |
| FARO 64 | 9.64d | 10.85cd | 10.25cde | 3.01bc | 3.33d | 3.17bcd |
| FARO 50 | 9.96cd | 9.98de | 9.97de | 2.78cd | 3.33d | 3.057bcd |
| FARO 27 | 10.47c | 14.21a | 12.34a | 2.94c | 3.15de | 3.05bcd |
| FARO 57 | 10.57c | 9.84e | 10.21cde | 3.11b | 2.91e | 3.013bcde |
| FARO 48 | 10.02c | 10.09e | 10.05de | 3.16bc | 3.09e | 3.12bcd |
| FARO 47 | 10.35c | 11.49bc | 10.92bcd | 2.84c | 3.42cd | 3.13bcd |
| FARO 59 | 10.63bc | 11.40bc | 11.01bcd | 3.32ab | 3.55c | 3.43ab |
| FARO 44 | 9.99cd | 10.49de | 10.24cde | 2.92c | 3.48cd | 3.20bcd |
| FARO 58 | 10.45c | 10.39de | 10.42cd | 2.98c | 6.45a | 3.21abcd |
| FARO 65 | 11.19b | 11.68bc | 11.44abc | 2.94c | 3.5cd | 3.04bcde |
| FARO31 | 9.97cd | 11.97b | 10.97bcd | 2.87c | 0.09h | 2.80de |
| PAC832 | 10.67bc | 10.30de | 10.48cd | 3.05bc | 0.49g | 3.22abc |
| FARO 45 | 10.70bc | 10.39de | 10.55cd | 2.81c | 3.20de | 3.00bcde |

Means followed by the same alphabet along the column are not different from another at 5% probability level.
2017 and 2018 cropping years.

***Table 5.*** *Mean performance of cultivated rice varieties for Seed width length (mm) and Perimeter in two cropping year under guinea savannah ecology.*

| Varieties | Seed width length (mm) | | Varietal | Perimeter (mm) | | Varietal |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | mean | 2017 | 2018 | mean |
| FARO 62 | 0.27i | 0.35k | 0.31fghi | 22.23ef | 21.25g | 21.74g |
| FARO 60 | 0.27i | 0.36i | 0.31d-h | 22.92e | 30.38cd | 26.65ef |
| FARO 52 | 0.28h | 0.37g | 0.33c-h | 46.80b | 30.45cd | 38.65a |
| FARO 61 | 0.25j | 0.42b | 0.34c-f | 50.23a | 24.65f | 37.44ab |
| FARO 41 | 0.27i | 0.34n | 0.30ghi | 50.61a | 25.39ef | 32.99bc |
| FARO 22 | 0.33b | 0.41c | 0.37b | 20.67f | 22.95fg | 21.76g |
| WAB 189 | 0.39a | 0.44a | 0.42a | 23.32e | 33.82b | 28.32g |

| Varieties | Seed width length (mm) | | Varietal | Perimeter (mm) | | Varietal |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | mean | 2017 | 2018 | mean |
| FARO 21 | 0.25i | 0.36i | 0.30ghi | 27.72c | 35.13b | 31.42cd |
| FARO 63 | 0.32c | 0.35j | 0.34c-f | 25.81cd | 27.88de | 26.85ef |
| FARO 64 | 0.30f | 0.39e | 0.35bc | 24.46de | 30.43cd | 27.43def |
| FARO 50 | 0.29g | 0.34n | 0.31d-h | 22.50ef | 28.20de | 25.58efg |
| FARO 27 | 0.32d | 0.37g | 0.34cd | 23.05e | 28.03de | 25.54efg |
| FARO 57 | 0.30f | 0.27q | 0.29ij | 23.78e | 42.29a | 33.04bc |
| FARO 48 | 0.29g | 0.36e | 0.33c-g | 22.89e | 26.07egf | 24.48efg |
| FARO 47 | 0.28h | 0.39d | 0.34cde | 21.66ef | 25.10ef | 23.38fg |
| FARO 59 | 0.30f | 0.36h | 0.33c-g | 23.09e | 31.66c | 27.38def |
| FARO 44 | 0.28h | 0.34i | 0.33e-i | 24.45de | 29.19d | 26.82ef |
| FARO 58 | 0.31e | 0.38f | 0.35bc | 24.24de | 28.84d | 26.54ef |
| FARO 65 | 0.32c | 0.37g | 0.35bc | 2477de | 29.39d | 27.08def |
| FARO31 | 0.24k | 0.30p | 0.27j | 25.66d | 30.39c | 28.03de |
| PAC 832 | 0.28h | 0.32o | 0.30hi | 23.93de | 30.43c | 27.18def |
| FARO 45 | 0.27i | 0.34m | 0.31d-i | 23.81de | 26.76e | 25.28efg |

Means followed by the same alphabet along the column are not different from another at 5% probability level.
2017 and 2018 cropping years.

***Table 6.*** *Mean performance of cultivated rice varieties for seed curved width in two cropping years under guinea savannah ecology.*

| Varieties | 2017 Cropping Year | 2018 Cropping Year | Varietal mean |
|---|---|---|---|
| FARO 62 | 2.54a | 2.76a | 2.65d |
| FARO 60 | 2.89a | 3.77a | 3.33bc |
| FARO 52 | 2.91a | 3.99a | 3.45bc |
| FARO 61 | 2.92a | 3.65a | 3.29bc |
| FARO 41 | 3.06a | 3.16a | 3.12bc |
| FARO 22 | 2.95a | 3.37a | 3.16bc |
| WAB 189 | 3.11a | 4.44a | 3.93a |
| FARO 21 | 3.03a | 3.80a | 3.43bc |
| FARO 63 | 3.02a | 3.47a | 3.24bc |
| FARO 64 | 2.92a | 3.52a | 3.22bc |
| FARO 50 | 3.16a | 3.77a | 3.47abc |
| FARO 27 | 3.24a | 3.41a | 3.33bc |
| FARO 57 | 3.04a | 3.00a | 3.02cd |
| FARO 48 | 2.90a | 3.43a | 3.16bc |
| FARO 47 | 2.88a | 3.72a | 3.30bc |
| FARO 59 | 3.04a | 3.91a | 3.48abc |
| FARO 44 | 3.10a | 3.93a | 3.52ab |
| FARO 58 | 3.00a | 3.59a | 3.29bc |
| FARO 65 | 3.31a | 0.01b | 1.65e |
| FARO31 | 2.52a | 0.01b | 1.26ef |
| PAC 832 | 3.03a | 0.01b | 1.52ef |
| FARO 45 | 2.90a | 0.01b | 1.16f |

Means followed by the same alphabet along the column are not different from another at 5% probability level.
2017 and 2018 cropping years.

***Table 7.*** *Correlation coefficients among seed shape factor (seed metric characteristic) of cultivated rice across two cropping years.*

| Shape Factors | Straight length | Curved Length | Straight width | Curved width | Width length | Perimeter |
|---|---|---|---|---|---|---|
| Projected area | 0.38** | 0.55** | 0.72** | 0.03 | 0.52** | 0.26** |
| Straight length | | 0.79** | 0.08 | -0.09 | -0.39** | 0.37** |
| Curved length | | | 0.29** | -0.06 | -0.18 | 0.43** |
| Straight width | | | | 0.23** | 0.64** | 0.14 |
| Curved width | | | | | 0.27** | 0.01 |
| Width length | | | | | | -0.13 |

** significant at 1% probability level,
*significant at 2% probability level.

***Table 8.** Principal components analysis showing variations explained by seed shape factors in Nigerian cultivated rice varieties.*

| | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| Eigen value (%) | 2.889 | 2.128 | 0.935 | 0.707 |
| Variance (%) | 38.421 | 30.520 | 13.351 | 10.102 |
| Cumulative variance (%) | 38.421 | 68.941 | 82.292 | 92.394 |
| Projected area | 0.873 | 0.302 | 0.235 | 0.053 |
| Straight length | 0.658 | -0.636 | 0.004 | -0.289 |
| Curved length | 0.814 | -0.440 | 0.013 | 0.193 |
| Straight width | 0.688 | 0.596 | 0.061 | 0.012 |
| Curved length | 0.092 | -0.408 | -0.881 | -0.218 |
| Width length | 0.274 | 0.898 | 0.124 | 0.078 |
| Perimeter | 0.524 | 0.334 | 0.283 | 0.730 |

Significant contribution (0.30 and above). PC - Principal Component.

# 4. Discussion

Considerable significant differences observed among the varieties and between the two cropping years for the shape factors (seed projected area, seed straight length, seed curved length, seed straight width, seed width length and seed perimeter) suggest that there is ample opportunity for selection of Nigerian cultivated rice varieties with superior morphometry characteristics. The result are similar to the findings reported by [18] in some rice varieties.

The result further showed that seed morphometric evaluated were able to reliably distinguish Nigerian cultivated rice varieties seed from each other due to significant differences between the results obtained in 2017 and 2018 for all the physical attributes except seed straight length and seed curved width. Significant genotype x cropping year interaction in all the six morphometric (shape factors) characteristics revealed that the differences in these physical characters among the varieties were due to differences in the growing conditions of the two cropping years. The growing conditions in 2018 favored expression of greater seed physical characteristics (seed project area, curve length, seed width, width length and perimeter compared to 2017 cropping year. These observations are similar to findings of [17, 19] in their experiments on tropical maize inbred lines and [18] in rice varieties. Therefore, the seed shape factors (seed morphometric characteristics) are unique discriminatory attributes for Nigerian cultivated rice varieties.

Data on correlation coefficients between most of the physical characteristics were positive and significant. Seed projected area exhibited positive and strong relationships with all other seed shape factors except curved width. Also, very strong positive association that existed between seed straight length, curved length and seed perimeter and the good relationship observed between seed straight width and between curved width and width length indicate that association between seed physical attributes and their potential usefulness as discriminators in Nigerian cultivated rice varieties. [20] had observed that seed metrics were important discriminators of *Zosteramarina, Jathropa*. Similar observations were also reported by [19] in maize hybrids and [18] in rice varieties.

The result of the principal component analysis (PCA) revealed that different seed morphometric characteristics contributed differently to the total variation as shown by their eigen values as well as loading on different principal axes. The PCA result further revealed that in the Nigerian cultivated rice varieties, seed morphometric attributes such as seed projected area, straight length, curved length, straight width, width length and perimeter contributed substantially to the discrimination among the varieties. These observations suggest that these parameters are the main seed morphometric characteristics to select for effective discrimination among the Nigeria cultivated rice varieties. [19] had reported earlier that seed length, seed diameter, seed area and seed circumference had large contribution to the observed variation in the three principal axes. In another study, [17] also reported that seed area, seed length, seed perimeter and flatness index contributed majorly to the variability in the first two principal component axes of tropical inbred maize genotypes. In a recent report by [18] seed projected area, curved length, seed straight width, curved seed width, seed width length and seed parameter recorded major contribution to variation within the evaluated rice varieties.

# 5. Conclusions

Differences in all the seed morphometric characteristics among the varieties were influenced by the growing conditions of 2017 and 2018 cropping years with greater seed projected area, curve length, seed width, width length and perimeter in 2018 compared to 2017 cropping year.

Across the cropping years, WAB 189 was identified with robust seed projected area (29.77mm), seed curved length and 12.34mm seed straight width, seed width length and seed curved width but moderate values in seed perimeter and straight length while FARO 62 and FARO 22 distinctively had the least values for most of the seed physical characteristics.

Most of the seed morphometric characteristics were strongly associated with one another.

Seed morphometric characteristics such as seed projected area straight length, curved length, straight width, width length and perimeter contributed significantly to the discrimination among the 22 Nigerian cultivated rice varieties.

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