

Variability and Heritability of Yield and Yield Components of Various Rice (Oryza sativa L.) Varieties in Port Harcourt, Nigeria

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Authors' contributions

This work was carried out in collaboration among all the authors. Authors OCC, DSON and EAA designed the study. DSON further supervised the research while EAA supplied majority of the rice lines used for the study. Authors ODO performed the statistical analyses. Author OCC wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Abstract

Field experiments were conducted at the Rivers State University Teaching and Research Farm Nkpolu, Port Harcourt, during the 2019 planting season under rainfed condition and complimented by irrigation in two different planting dates to access the genetic variability and heritability in yield and yield components of twenty-five rice varieties. The experiments were laid out in a randomized complete block design with three replications. Data were collected on eleven yield and yield components. Results from the analysis of variance indicated significant differences ($P \leq 0.01 \leq 0.05$) among the varieties for all parameters except plant height and tiller number in planting date one. Combined analysis of variance across planting dates showed that there was significant variation ($P \leq 0.01$) among the rice varieties for all parameters evaluated. The varietal mean performance for phenological parameters showed significant differences ($P \leq 0.05$) for all parameters except tiller number in planting date one. Variability evaluation of varieties for yield parameters showed significant differences ($P \leq 0.05$) for all parameters evaluated except for 100-grain weight in planting date two. The pooled mean values of the varieties differed significantly ($P \leq 0.05$) for all yield parameters evaluated. The highest grain yield per stand was recorded in UPIA 2 with 7.41 g/stand, and was significantly different from FARO 67 with the least (1.70 g/stand). The estimate of variance components showed that phenotypic variance (Vp) and phenotypic coefficient of variation (PVC) were higher than their corresponding genotypic variance (Vg) and genotypic coefficient of variation (GCV) for all the parameters studied. Heritability estimates in broad sense were found to be moderate for majority of the parameters, except leaf area (68.12%), panicle number (63.41%), spikelet fertility (50.23%) and grain yield per stand (55.87%) that had high heritability estimates and tiller number (15.93%) which had a low estimate. However, only leaf area, panicle number and grain yield per stand had high heritability estimates which were accompanied by high genetic advance. There was considerable variation among the 25 rice varieties evaluated. UPIA 2 and FARO 44 had the best agronomic performance. However, UPN 324, UPN 228, FARO 61 and 66 could be selected for onward improvement programme.

Keynote: Grain yield, heritability, *Oryza sativa*, variation, yield components
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Introduction

Rice belongs to the genus Oryzae which contains about 20 diverse species including *O. glaberrima*, *O. sativa*, *O. perennis*, *O.nivara*, etc. (Efisue *et al.,* 2008). Rice consumption and production has grown in popularity over the years (Kumar *et al.,* 2017), and has become one of the most important grain of the gramineae family in Nigeria, such that it can be considered as both cash (FAO, 2004) and food security crop (Oluwaseyi *et al.,* 2016, Balqees *et al.,* 2019).

Rice varietal improvement has come a long way in Nigeria over the past decades with evidences of success in the development of early maturing varieties having higher grain yield, better grain quality, high milling recovery and nutrient content much more than what was obtained in the local unimproved varieties, as is evident in the improved FARO lines (Oluwaseyi *et al.,* 2016). These improvement programs are always targeted towards an area of need in a particular environment or to tackle a prevailing problem in a crop of interest. In spite of the strides achieved so far in rice breeding, further and speedy improvement of rice varieties in Nigeria are imperative but have been hampered by a number of constraints and several factors militating against rice production/processing such as low yielding varieties, late maturing varieties, among other factors (Oluwaseyi *et al.,* 2016, Dimkpa*,* 2014).

Therefore, the need to develop varieties that address the major constraints to rice production is of paramount importance (Truong *et al.,* 2018, Dimkpa *et al., 2015*). In as much as we have a lot of improved varieties, there is also the need to evaluate the landraces and select for those traits that made them survivors in our environment and to collate germplasm suitable for peculiar agroecological zone for onward breeding programme because the improved varieties are not holistic in terms of all-important traits.

In view of the growing population, the basic objective of the plant breeders would always be towards yield improvement in staple food crops (Kahani & Hittalmani, 2016, Mukesh *et al.,* 2018). Yield and yield attributing parameters are the most widely targeted traits for rice improvement programmes in the world (Mukesh *et al.,* 2018). Grain yield is a quantitative trait, resulting from the interaction of many variables (Singh *et al.,* 2017). Variability is the centrepiece of plant breeding (Ubi *et al.,* 2011). In planning and executing any breeding programme for improvement on quantitative traits, evaluation of genetic variability available in crop species is the first step to select better performing lines among divergent groups and thereafter, quantify the extent of variability in the trait(s) of interest (Kahani & Hittalmani, 2016). Therefore, success of plant breeding activities entirely depends on the existence of genetic variability with respect to desired traits in the plant population to enhance the adoption of appropriate breeding strategies for the utilization of their inherent potential (Efisue *et al*., 2009; Adhikari *et al.,* 2018). Information on genetic variances and their effects have contributed to rice improvement and to the understanding of gene action involved in the expression of heterosis and economically important quantitative traits (Efisue *et al*., 2009).

The knowledge of heritability of a trait is important because it determines the extent to which plant improvement through selection is possible (Efisue *et al.,* 2009). It is not enough to have desirable trait(s) in a particular crop, but the stability of such traits such that they can be transferred from parents to progenies determines the success of any breeding programme. Heritability and genetic advance assist breeders to decide and select superior plants that can perform superior for the traits of interest in subsequent generations (Kahani & Hittalmani, 2016). Heritability estimates along with genetic advance is more precise in predicting the genetic gain under selection than heritability alone.

Variability, genetic diversity, expected genetic advance and heritability of the traits are therefore the basis of genetic improvement of traits of economic importance such as grain yield. The objectives of this study were therefore, to evaluate the yield and yield components of twenty-five rice varieties and assess the magnitude of genetic variability existing among them and to determine the heritability and genetic advance of the yield traits.

Materials and Methods

The experimental was carried out at the Rivers State University Teaching and Research Farm Nkpolu, Port Harcourt (4^0 46^1 N, 7^0 10^1 E) during the 2019 planting season under rainfed condition complimented by irrigation. Twenty-five rice varieties were used for this study These comprised of seventeen (17) anther cultured Korean rice lines (UPN) collected from the University of Port Harcourt Rice Germplasm, seven (7) improved rice varieties and one (1) Ebonyi landrace (Okporogwu) collected from Ebonyi State University Research Farm, Abakaliki, Ebonyi State (Table 1). The experiment was set up in plastic bags containing top soil mixed with pure sand in the ratio of 2:1 that was collected from the school farm, the bags were laid out in a randomized complete block design with three replications. There were two planting dates for the twenty-five (25) rice varieties, the early (June) and late (August). Each variety was planted in a 2650 cm^3 volume nursery bag and transplanted into a bigger bag of 6283 cm^3 volume after 4 weeks for increased surface area for the root development. NPK (15:15:15) was applied as a basal application of 200 kg ha^{-1}. Weeding was done by hand pulling on sight. The plants were irrigated equally in the absence of rainfall. The plants were shaded with palm frond from excessive sunlight and rainfall until transplanting. Three weeks after transplanting, Urea was applied at the rate of 65 kg ha^{-1} (converted to the volume of the container) and the second rate of 35 kg ha^{-1} (converted to the volume of the container) was applied at the beginning of booting stage. The agronomic characters were measured at weekly intervals. The 'Standard Evaluation System (SES) for Rice' reference manual (IRRI, 2002) was used for all trait measurements. Measured characters include: plant height - was recorded using meter rule (cm), measured from the soil surface to the tip of the tallest leaf; flag leaf - the length and width of the flag leaf were measured using meter rule and leaf area (cm^2) calculated from the values of the length and width, days to 50% flowering - recorded for all varieties from seeding date to the day when 50% flowered; tiller numbers were calculated per stand for each variety, panicle parameters - two randomly sampled panicles per variety were used for data recording for panicle traits at maturity and it includes panicle length, which was measured using meter rule, number of panicle, done by counting the panicles per stand, panicle weight, measured using an electronic balance and spikelet fertility which was calculated by dividing the number of filled seed by total seed per panicle and then converted into percentage. 100-grain weight (g), grain yield per stand (g/stand) was recorded after threshing.100-grains were counted, and weights were measured using electronic balance.

The data obtained were subjected to analysis of variance (ANOVA) using MINITAB, Version 17 statistical package. The means were separated using Tukey's Honestly Significant Difference (HSD) test at 5% level of significance. Mean square values from the ANOVA tables for each character were used in estimating the phenotypic, genotypic and the environmental variances as well as the genotype by planting date interaction using the following equations:

Single planting date

MSe = $\delta^2 e$

$\delta^2 g = \frac{MSg - MSe}{r}$

$\delta^2 p = \delta^2 g + \delta^2 e$

Combined planting dates

$\delta^2 e$ = MSe

$\delta^2 ge = \frac{MSge - MSe}{r}$

$\delta^2 g = \frac{MSg - MSge}{re}$

$\delta^2 p = \delta^2 g + \delta^2 ge + \delta^2 e$

Where: $\delta^2 e$ = environmental variance, $\delta^2 g$ = genotypic variance, $\delta^2 ge$ = genotype x environment variance, $\delta^2 p$ = phenotypic variance, MSe = mean square of error, MSg = mean square of genotype, MSge = mean square of GxE, e = number of environments, r = replications, Environments = planting dates.

Phenotypic and genotypic coefficients of variation were estimated according to the formulas of Singh and Chaudhary (1985) as follows:

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{\delta^2 p}}{\bar{x}} \text{ x } 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sqrt{\delta^2 g}}{\bar{x}} \text{ x } 100$$

Where: $\bar{x}$ = Sample mean of the character being evaluated

The PCV and GCV values were categorized as high, medium and low as indicated by Siva-Subramamian and Menon (1973) as follows:

High = >20%; Medium = 11-20%; Low = 0-10%

Heritability was estimated as the proportion of phenotypic variation that is due to genetic variation (Falconer and Mackay, 1996), and is defined as:

$$\text{Heritability in broad sense } (H^2_B) = \frac{\delta^2 g}{\delta^2 p} \text{ x } 100$$

Heritability was categorized as high, medium and low according to the classification of Elrod and Stanfield (2002) as follows: High = >50%; Medium = 21-50%; Low = 0-20%

Genetic advance (GA) was computed according to the formula of Singh and Chaudhary (1985):

$$GA = \frac{\delta^2 g}{\sqrt{\delta^2 p}} \times K$$

Where, K = 2.06 (selection differential at 5%)

Genetic advance as percentage of the mean (GAM) also known as expected genetic gain (EGG) was computed according to the formula used by Prabhu *et al.,* (2017).

$$GAM = \frac{GA \times 100}{\bar{x}}$$

GAM was categorized as high, medium and low based on the classification of Johnson *et al*., (1955): High = >20%; Moderate = 11-20%; Low = 0-10%

Table 1: Experimental materials used in the study

S/N	Variety	Source
1.	BG-90-2	Ebonyi State University
2.	FARO 44	Ebonyi State University
3.	FARO 61	Ebonyi State University
4.	FARO 66	Ebonyi State University
5.	FARO 67	Ebonyi State University
6.	UPN 250	University of port Harcourt
7.	UPN 266	University of port Harcourt
8.	UPN 295	University of port Harcourt
9.	UPN 318	University of port Harcourt
10.	UPN 323	University of port Harcourt
11.	UPN 313	University of port Harcourt
12.	UPN 253	University of port Harcourt
13.	UPN 288	University of port Harcourt
14.	UPN 347	University of port Harcourt
15.	UPN 324	University of port Harcourt
16.	UPN 228	University of port Harcourt
17.	UPN 336	University of port Harcourt
18.	UPN 300	University of port Harcourt
19.	UPN 268	University of port Harcourt
20.	UPN 345	University of port Harcourt
21.	UPN 349	University of port Harcourt
22.	UPN 257	University of port Harcourt
23.	Okporogwu	Ebonyi State University
24.	UPIA 1	University of port Harcourt
25.	UPIA 2	University of port Harcourt

Results

Evaluation of variability and yield and yield components

The mean squares obtained from the analysis of variance revealed that genotypic effect was significant ($P \leq 0.01$) and ($P \leq 0.05$) for all parameters evaluated in the two different planting dates except plant height and tiller number in planting date 1. Combined analysis of variance across planting dates showed that there was significant ($P \leq 0.01$) variation among the rice varieties for all parameters evaluated. Significant planting date effect was observed for leaf area, days to 50% flowering, tiller number, panicle number, panicle length, spikelet fertility, number of grains per panicle and grain yield per stand. Variety by planting date interaction effect was significant ($P \leq 0.01$) for all parameters except plant height, tiller number, panicle number and 100-grain weight.

The individual planting dates and pooled mean performance of 25 rice varieties evaluated for phenological parameters is presented in Table 2. Varieties were significantly ($P \leq 0.05$) different for all parameters except tiller number in planting date 1. The mean plant height of the varieties in planting date 1 and planting date 2 was 76.26 and 73.95 cm, which ranged from 61 cm (UPN 250) to 101.6 cm (UPIA 2) and 63.67 (UPN 268) to 106.07 cm (UPIA 2), respectively. Leaf area significantly varied from 8.38 to 38.39 cm^2 in planting date 1 and 9.15 to 39.73 cm^2 in planting date 2 both for UPN 345 and UPIA 2 with mean values of 22.45 and 18.01 cm^2, respectively. The number of days to 50% flowering significantly varied among the 25 varieties studied, and ranged from 71 to 102.67 days in planting date 1 and 76.33 to 99.33 days in planting date 2, with mean value of 95.43 and 84.65 days, respectively. FARO 44 had the shortest flowering time of 71 and 76.33 days in the different planting dates while much delay in flowering was observed in UPN 347 (102.67 days) in planting date 1 and in FARO 66 (99.33) in planting date 2.

The pooled mean values of the 25 rice varieties were also significant ($P \leq 0.05$) for all phenological parameters evaluated. Plant height ranged from 67.17 to 103.83 cm with a mean height of 75.09 cm. Leaf area ranged from 8.76 to 39.06 cm^2 with a mean value of 20.23 cm^2. The number of days to 50% flowering had a mean value of 90.04 days, ranging from 73.67 to 100.17 days. On the other hand, tiller number ranged from 5.50 to 8.83.

The results of variability in yield parameters (panicle number, panicle weight, panicle length, spikelet fertility, number of grains per panicle, 100-grain weight and grain yield per stand) observed among the 25 rice varieties are shown in Table 3. In the two different planting dates, varieties were significantly ($P \leq 0.05$) different for all yield parameters evaluated except 100-grain weight in planting date 2. The mean panicle number per plant in planting date 1 was highest (8) in UPIA 2, while UPN 336 had the least panicle number per plant of 2.67. FARO 44 on the other hand had the highest (6) mean panicle number per plant in planting date 2 while UPN 336 and UPN 257 had the least (2.33) mean panicle number per plant. Mean panicle weight for planting date 1 was 1.65 g while for planting date 2 was 1.73 g. UPIA 2 (28.93 cm) and UPN 253 (26.33 cm) had the longest panicles in planting dates 1 and 2, respectively while UPN 323 (17.73 cm) and UPN 345 (3.31 cm) were the varieties with the shortest panicles in planting dates 1 and 2, respectively. The mean spikelet fertility of the 25 rice varieties in planting dates 1 and 2 were 70.29 and 67.12, respectively and it ranged from 51.67 in BG-90-2 to 92.67 in FARO 44 and from 42.33 in UPN 318 to 92.33 in FARO 44, in planting dates 1 and 2, respectively. Number of grains per panicle was higher at planting date 1 than at planting date 2 with mean values of 95.69 and 80.85, respectively. UPN 228 with 174.33 grains per panicle and FARO 44 with 132 grains per panicle were the varieties with the highest number of grains per panicle in both planting dates 1 and 2, respectively. Conversely, FARO 61 and UPN 313 with 55 and 49.00 grains per panicle were the varieties with the least number of grains per panicle in both planting dates, respectively. Grain yield per stand in planting date 1 varied significantly ($P \leq 0.05$) and ranged from 1.49 to 7.27 g/plant with mean yield of 3.46 g/plant, while in planting date 2, it ranged from 1.63 to 7.61 g/plant.

The pooled mean values of the varieties differed significantly ($P \leq 0.05$) for all yield parameters evaluated. Panicle number ranged from 2.5 (UPN 336) to 6.83 (UPIA 2) with grand mean of 4.45. UPN 318 had the least panicle weight of 1.06 g, and differed significantly from UPIA 2 which had the highest panicle weight (2.7 g). Panicle length ranged from 15.54 cm in UPN 345 to 26.79 cm in UPIA 2 with a mean length of 20.43 cm. The mean spikelet fertility among the 25 rice varieties was 68.7, and ranged from 52.33 (UPN 266) to 92.50 (FARO 44). Number of grains per panicle had a mean value of 88.27, and ranged from 52.33 grains per panicle in UPN 313 to 133 grains per panicle in FARO 44. Okporogwu had the least (1.75 g) 100-grain weight differing significantly from FARO 44 which had the highest (2.75 g). The highest grain yield per stand was recorded in UPIA 2 with 7.44 g/stand, and was significantly ($P \leq 0.05$) different from all other varieties for this trait.

Heritability and Genetic advance

Pooled estimates of variance components, coefficients of variation, broad sense heritability, genetic advance and genetic advance as percent of the mean over two planting dates for 11 phenological and yield parameters in twenty-five rice varieties is presented in Table 4. The results showed the prominence of the environment and the genotype by environment interaction on the expression of some of the parameters. Only leaf area, panicle number, spikelet fertility and grain yield per stand have the contribution of genetic variance to phenotypic variance greater than 50 percent. Broad sense heritability estimate was found to be moderate (between 21 - 49%) for majority of the parameters studied while tiller number had low (<20%) heritability estimate.

Grain yield per stand had the highest phenotypic coefficient of variation (PCV) (44.43%) and genotypic coefficient of variation (GCV) (33.21%) values, whereas days to 50% flowering had the least PCV (7.42%) and GCV (4.48%) values. Leaf area, panicle number, panicle weight and grain yield per stand recorded high GCV and PCV, whereas number of grains per panicle had moderate GCV and high PCV. At 5% selection intensity, genetic advance ranged from 0.17 (100-grain weight) to 20.0 (number of grains per panicle). Although, comparisons cannot be made using these values since the units of measurement of these parameters are not the same. Genetic advance as the percentage of the mean (GAM), gives room for easy comparison among these parameters by equating the different units of measurements of genetic advance. It expresses the values of genetic advance as the percentage of the variety mean for each character. Results of GAM showed parameters such as leaf area, panicle number, panicle weight, number of grains per panicle and grain yield per stand with values greater than 20% had high genetic advance. Panicle length and spikelet fertility with values ranging between 11 and 19% had moderate genetic advance, while plant height, days to 50% flowering, tiller number, and 100-grain weight with GAM values less than 10% have low genetic advance.

Table 2: Mean values of phenological parameters of the 25 rice varieties

Variety	Planting date 1				Planting date 2				Combined			
	PH (cm)	LA (cm^2)	DTF	TN	PH (cm)	LA (cm^2)	DTF	TN	PH (cm)	LA (cm^2)	DTF	TN
BG-90-2	70.00ab	23.00c-e	97.00a-c	7.33a	65.33b	18.76c-e	92.67ab	7.00ab	67.67b	20.88cd	94.83a-e	7.17ab
FARO 44	81.33ab	30.25c	71.00e	7.00a	79.00b	30.84ab	76.33g	7.00ab	80.17b	30.54b	73.67i	7.00ab
FARO 61	69.33ab	23.02c-e	94.00b-d	9.00a	67.67b	14.35c-e	82.67c-g	6.33ab	68.50b	18.69c-f	88.33f-h	7.67ab
FARO 66	69.67ab	23.32c-e	101.00ab	9.33a	80.33b	15.44c-e	99.33a	8.33a	75.00b	19.38c-e	100.17a	8.83a
FARO 67	71.00ab	23.11c-e	94.67b-d	9.00a	78.67b	19.11c-e	90.67bc	6.00ab	74.83b	21.11cd	92.67b-f	7.50ab
UPN 250	61.00b	26.19bc	101.00ab	7.00a	73.33b	12.12de	88.00b-e	6.33ab	67.17b	19.15c-e	94.50b-e	6.67ab
UPN 266	76.67ab	21.12c-f	98.00a-c	8.33a	68.33b	15.51c-e	82.67c-g	6.67ab	72.50b	18.31c-f	90.33d-h	7.50ab
UPN 295	76.67ab	18.69d-g	94.33b-d	7.33a	72.00b	17.06c-e	90.00b-d	4.67b	74.33b	17.87c-f	92.17b-g	6.00ab
UPN 318	67.33ab	22.76c-e	95.67a-c	8.00a	80.00b	16.62c-e	78.67fg	4.67b	73.67b	19.69c-e	87.17f-h	6.33ab
UPN 323	75.33ab	18.18e-g	96.67a-c	7.33a	74.33b	14.17c-e	77.33g	6.00ab	74.83b	16.18d-f	87.00gh	6.67ab
UPN 313	78.00ab	22.48c-e	94.67b-d	6.67a	80.00b	13.50c-e	81.33e-g	6.67ab	79.00b	17.99c-f	88.00f-h	6.67ab
UPN 253	74.00ab	21.37c-e	93.67b-d	5.67a	75.00b	16.83c-e	77.67g	5.33ab	74.50b	19.10c-f	85.67h	5.50b
UPN 288	79.33ab	22.34c-e	98.33a-c	6.33a	73.00b	17.93c-e	87.00b-f	5.67ab	76.17b	20.14c-e	92.67b-f	6.00ab
UPN 347	70.33ab	26.78bc	102.67a	6.67a	69.67b	17.60c-e	87.33b-e	6.00ab	70.00b	22.19c	95.00a-d	6.33ab
UPN 324	79.67ab	21.14c-f	97.33a-c	8.00a	73.00b	20.79b-d	87.33b-e	6.33ab	76.33b	20.97cd	92.33b-g	7.17ab
UPN 228	72.00ab	24.46bc	97.33a-c	7.33a	76.67b	21.26b-d	81.33e-g	4.67b	74.33b	22.86c	89.33e-h	6.00ab
UPN 336	83.67ab	21.22c-f	92.00cd	9.33a	66.33b	23.11bc	78.00g	6.67ab	75.00b	22.17c	85.00h	8.00ab
UPN 300	84.33ab	23.94c-e	97.67a-c	8.67a	66.67b	15.26c-e	76.33g	6.00ab	75.50b	19.60c-e	87.00gh	7.33ab
UPN 268	73.00ab	15.31fg	94.67b-d	6.33a	63.67b	14.00c-e	76.67g	5.67ab	68.33b	14.66ef	85.67h	6.00ab
UPN 345	82.00ab	8.38h	96.33a-c	8.67a	72.67b	9.15e	78.00g	5.67ab	77.33b	8.76g	87.17f-h	7.17ab
UPN 349	83.67ab	22.42c-e	97.00a-c	7.00a	72.33b	17.98c-e	82.00d-g	5.33ab	78.00b	20.20c-e	89.50d-h	6.17ab
UPN 257	79.67ab	25.13bc	100.67ab	6.67a	67.33b	21.31b-d	94.67ab	6.67ab	73.50b	23.22c	97.67ab	6.67ab
Okporogwu	74.67ab	14.29gh	98.00a-c	8.67a	78.33b	12.62de	95.00ab	7.67ab	76.50b	13.45fg	96.50a-c	8.17ab
UPIA 1	72.33ab	23.97c-e	94.67b-d	9.67a	68.00b	15.13c-e	88.33b-e	6.67ab	70.17b	19.55c-e	91.50c-g	8.17ab
UPIA 2	101.60a	38.39a	87.33d	8.00a	106.07a	39.73a	87.00b-f	5.33ab	103.83a	39.06a	87.17f-h	6.67ab
S. E	1.43	0.65	0.72	0.20	1.15	0.77	0.80	0.15	0.92	0.53	0.70	0.14
Grand Mean	76.26	22.45	95.43	7.73	73.91	18.01	84.65	6.13	75.09	20.23	90.04	6.93

Means that do not share a letter are significantly different at $p \leq 0.05$ probability level.
PH = Plant height, LA = Leaf area, DTF = Days to 50% flowering, TN = Tiller number, S.E = Standard error

Table 3: Mean values of yield parameters of the 25 rice varieties

Variety	Planting date 1							Planting date 2						
	PN	PW	PL	SF	NOGPP	100GW	GYLD	PN	PW	PL	SF	NOGPP	100GW	GYLD
BG-90-2	4.67b-e	1.71b-e	20.10b-f	51.67g	69.33g-i	2.30ab	2.72fg	3.67b-e	1.84a-f	19.40a-d	63.67b-h	77.33c-h	2.60a	4.52c-e
FARO 44	6.67ab	2.48ab	24.35a-c	92.67a	134.00a-d	2.65a	5.95ab	6.00a	2.69a	24.77ab	92.33a	132.00a	2.86a	4.37c-e
FARO 61	4.33b-e	1.84a-e	21.13b-f	66.67d-g	55.00i	2.32ab	5.14bc	3.67b-e	1.46c-f	20.90a-d	63.33b-h	65.00f-h	2.12a	4.05c-g
FARO 66	6.67ab	2.11a-d	25.17ab	80.78a-e	151.00ab	2.05ab	5.12bc	5.33a-c	2.22a-e	20.13a-d	79.10a-c	73.33d-h	2.23a	4.72cd
FARO 67	6.33a-c	1.79a-e	24.38a-c	70.00b-g	119.67b-e	2.21ab	1.49g	4.67a-d	1.76a-f	19.10a-d	53.67e-h	111.33a-c	1.90a	1.91j-l
UPN 250	4.67b-e	1.75a-e	21.20b-f	56.37fg	120.00b-e	1.75b	2.58fg	4.33a-e	1.34c-f	18.37b-d	54.33e-h	61.33f-h	2.31a	2.58h-l
UPN 266	4.33b-e	1.87a-e	19.40d-f	59.33fg	109.67b-g	2.24ab	2.51fg	2.67de	1.82a-f	20.03a-d	45.33gh	105.00a-e	2.33a	1.63l
UPN 295	4.33b-e	1.10de	19.30d-f	73.01b-f	64.67hi	1.99ab	2.65fg	3.33c-e	1.50c-f	15.43cd	79.00a-c	55.67gh	2.13a	1.97j-i
UPN 318	5.33a-e	1.07de	20.07b-f	75.32a-f	67.33g-i	1.97ab	4.92b-d	4.33a-e	1.05f	18.23b-d	42.33h	64.67f-h	2.21a	4.28c-e
UPN 323	5.33a-e	1.55b-e	17.73f	79.17a-e	73.67g-i	2.63a	4.79b-e	4.33a-e	1.57b-f	17.90b-d	82.00a-c	53.67gh	2.64a	3.44d-i
UPN 313	4.33b-e	1.05de	22.87b-e	58.70fg	55.67i	2.14ab	2.64fg	3.00de	1.37c-f	18.00b-d	60.33c-h	49.00h	2.31a	3.33d-j
UPN 253	4.67b-e	1.77a-e	25.17ab	79.33a-e	103.00c-h	2.53ab	4.80b-e	3.67b-e	2.12a-f	26.33a	85.00ab	94.33b-f	1.89a	4.04c-g
UPN 288	4.67b-e	1.34c-e	21.93b-f	64.01e-g	75.33f-i	2.14ab	1.75g	3.67b-e	1.32d-f	21.80a-c	56.33d-h	86.33c-g	1.90a	1.83kl
UPN 347	4.67b-e	1.54b-e	22.00b-f	75.35a-f	85.33e-i	1.91ab	2.32fg	3.00de	1.48c-f	18.80a-d	60.00c-h	70.67e-h	1.78a	2.46i-l
UPN 324	5.67a-d	1.29c-e	21.13b-f	62.33e-g	88.33e-i	2.46ab	5.11bc	3.67b-e	1.90a-f	19.57a-d	59.67c-h	88.00c-g	2.17a	4.02c-h
UPN 228	5.67a-d	1.65b-e	22.70b-e	86.43a-c	174.33a	2.03ab	4.95b-d	5.67ab	1.69a-f	16.57cd	80.33a-c	67.33f-h	2.05a	4.95c
UPN 336	2.67e	2.09a-d	21.43b-f	57.00fg	118.33b-f	2.41ab	1.50g	2.33e	2.44a-c	15.11cd	79.67a-c	125.33ab	1.96a	3.56c-i
UPN 300	5.33a-e	1.47b-e	21.20b-f	58.50fg	94.33d-i	2.11ab	1.68g	4.33a-e	1.51b-f	18.03b-d	62.00c-h	95.33b-f	1.90a	2.77f-l
UPN 268	5.33a-e	1.82a-e	19.40d-f	68.00b-g	84.33e-i	1.96ab	2.80e-g	3.67b-e	1.83a-f	20.60a-d	68.33b-f	107.33a-d	2.10a	2.69g-l
UPN 345	3.00de	1.05de	17.77f	84.67a-d	69.33g-i	2.26ab	2.72fg	2.67de	1.42c-f	13.31d	74.33a-e	56.00gh	1.79a	3.12e-k
UPN 349	4.33b-e	2.35a-c	23.23b-e	67.67c-g	87.33e-i	2.33ab	2.35fg	2.67de	1.12ef	17.67b-d	65.00b-g	83.00c-h	1.98a	4.18c-f
UPN 257	3.67c-e	0.99e	21.53b-f	72.95b-f	100.67c-h	2.06ab	2.98d-g	2.33e	1.68a-f	19.11a-d	73.00a-e	94.67b-f	1.74a	2.49i-l
Okporogwu	5.33a-e	1.26de	18.73ef	62.00e-g	67.33g-i	1.68b	3.85c-f	4.00a-e	1.28d-f	15.23cd	50.39f-h	60.67f-h	1.82a	4.99bc
UPIA 1	6.00a-c	1.39c-e	23.90b-d	68.00b-g	82.67e-i	2.35ab	1.89fg	4.00a-e	2.27a-d	17.67b-d	69.90b-f	69.33f-h	2.69a	6.44ab
UPIA 2	8.00a	2.79a	28.93a	87.36ab	141.67a-c	2.01ab	7.27a	5.67ab	2.61ab	24.66ab	78.51a-d	74.67d-h	2.31a	7.61a
S. E	0.16	0.06	0.33	1.39	3.79	0.04	0.19	0.13	0.06	0.42	1.63	2.80	0.05	0.17
Grand Mean	5.04	1.65	21.79	70.29	95.69	2.18	3.46	3.87	1.73	19.07	67.12	80.85	2.15	3.68

Means that do not share a letter are significantly different at $p \leq 0.05$ probability level.
PN = Panicle number, PW = Panicle weight, PL = Panicle length, SF = Spikelet fertility, NOGPP = Number of grains per panicle, 100GW = 100-grain weight, GYLD = Grain yield per stand, S.E = Standard error

Table 3 (contd.): Mean values of yield parameters of the 25 rice varieties

Variety	Combined						
	PN	PW	PL	SF	NOGPP	100GW	GYLD
BG-90-2	4.17d-i	1.77c-f	19.75d-g	57.67ij	73.33f-j	2.45a-c	3.62c-g
FARO 44	6.33ab	2.59ab	24.56a-c	92.50a	133.00a	2.75a	5.16b
FARO 61	4.00d-i	1.65c-f	21.02c-f	65.00f-j	60.00ij	2.22a-d	4.60bc
FARO 66	6.00a-c	2.16a-d	22.65a-d	79.94a-e	112.17a-d	2.14a-d	4.92b
FARO 67	5.50a-e	1.78c-f	21.74b-e	61.83g-j	115.50a-c	2.06b-d	1.70j
UPN 250	4.50c-h	1.55c-f	19.78d-g	55.35ij	90.67c-g	2.03b-d	2.58g-j
UPN 266	3.50f-i	1.84b-e	19.72d-g	52.33j	107.33a-e	2.29a-d	2.07h-j
UPN 295	3.83e-i	1.30ef	17.37e-g	76.01b-g	60.17ij	2.06b-d	2.31h-j
UPN 318	4.83b-f	1.06f	19.15d-g	58.83h-j	66.00g-j	2.09a-d	4.60bc
UPN 323	4.83b-f	1.56c-f	17.82e-g	80.58a-e	63.67g-j	2.64ab	4.12b-f
UPN 313	3.67f-i	1.21ef	20.42c-f	59.52h-j	52.33j	2.23a-d	2.98e-i
UPN 253	4.17d-i	1.95b-e	25.75ab	82.17a-d	98.67b-f	2.21a-d	4.42b-d
UPN 288	4.17d-i	1.33ef	21.87b-e	60.17h-j	80.83e-i	2.02b-d	1.79ij
UPN 347	3.83e-i	1.51c-f	20.40c-f	67.67d-i	78.00f-j	1.84cd	2.39h-j
UPN 324	4.67b-g	1.60c-f	20.35c-f	61.00h-j	88.17c-h	2.32a-d	4.57bc
UPN 228	5.67a-d	1.67c-f	19.63d-g	83.38ab	120.83ab	2.04b-d	4.95b
UPN 336	2.50i	2.27a-c	18.27d-g	68.33c-i	121.83ab	2.19a-d	2.53g-j
UPN 300	4.83b-f	1.49d-f	19.62d-g	60.25h-j	94.83b-f	2.00b-d	2.23h-j
UPN 268	4.50c-h	1.83c-e	20.00d-g	68.12d-i	95.83b-f	2.03b-d	2.75g-j
UPN 345	2.83hi	1.23ef	15.54g	79.50a-f	62.67h-j	2.03b-d	2.92f-j
UPN 349	3.50f-i	1.73c-f	20.45c-f	66.33e-j	85.17d-i	2.16a-d	3.27d-h
UPN 257	3.00g-i	1.33ef	20.32c-f	72.97b-h	97.67b-f	1.90cd	2.74g-j
Okporogwu	4.67b-g	1.27ef	16.98fg	56.20ij	64.00g-j	1.75d	4.42b-d
UPIA 1	5.00b-f	1.83c-e	20.78c-f	68.95b-i	76.00f-j	2.52a-c	4.17b-e
UPIA 2	6.83a	2.70a	26.79a	82.93a-c	108.17a-e	2.16a-d	7.44a
S. E	0.11	0.04	0.29	1.07	2.42	0.03	0.13
Grand Mean	4.45	1.69	20.43	68.70	88.27	2.16	3.57

Means that do not share a letter are significantly different. PN = Panicle number, PW = Panicle weight, PL = Panicle length, SF = Spikelet fertility, NOGPP = Number of grains per panicle, 100GW = 100-grain weight, GYLD = Grain yield per stand, S.E = Standard error

Table 4: Pooled estimates of genetic variability and genetic parameters for 11 phenological and yield parameters in 25 rice varieties

Characters	Environmental variance (Ve)	Genotypic variance (Vg)	Genotype x environment variance (Vge)	Phenotypic variance (Vp)	Heritability in broad-sense (HB)	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Genetic advance GA	Genetic advance as percentage of mean GAM
Plant height (cm)	84.73	30.44	7.17	122.35	24.88	7.35	14.73	5.67	7.55
Leaf area (cm^2)	6.85	26.57	5.58	39.00	68.12	25.48	30.87	8.76	43.32
Days to 50% flowering	6.53	16.26	21.85	44.64	36.42	4.48	7.42	5.01	5.57
Tiller number	1.93	0.37	0.00	2.30	15.93	8.72	21.86	0.50	7.17
Panicle number	0.60	1.05	0.00	1.65	63.41	22.98	28.86	1.68	37.70
Panicle weight (g)	0.12	0.13	0.04	0.29	43.68	21.14	31.99	0.49	28.79
Panicle length (cm)	4.34	4.96	1.65	10.95	45.31	10.90	16.20	3.09	15.12
Spikelet fertility	45.54	88.15	41.80	175.49	50.23	13.67	19.28	13.71	19.95
Number of grains per panicle	159.20	283.20	408.23	850.63	33.29	19.06	33.04	20.00	22.66
100-grain weight (g)	0.10	0.03	0.01	0.14	22.04	8.23	17.54	0.17	7.96
Grain yield per stand (g/stand)	0.32	1.40	0.79	2.51	55.87	33.21	44.43	1.82	51.13

Discussion

The importance of variability studies in plant breeding and crop improvement cannot be overemphasized. The existence of genetic variability in a base population is germane to crop improvement as it is the basis on which plant breeding thrives. Hence, variability studies are needed as they are essential for kick-starting any efficient breeding programme. It is the presence of considerable genetic variability in the breeding material that will give room for better chances of developing desirable plant variety (Hosamani *et al.,* 2018).

The observed variation among the means of the evaluated varieties shows the diverse nature of the genotypes. This variation is what plant breeders latch onto in any selection programme. Plant height and leaf area are very important parameters in rice which have been reported to affect panicle parameters, and consequently yield. Jun *et al.* (2007) had attributed the increase in panicle parameters in some rice cultivars evaluated to the increased plant height and large leaf area of such rice cultivars. They stated that cultivars with good leaf area and increased plant height utilize more efficiently the energy from the sun for photosynthesis. Also, Efisue *et al.* (2014) noted that nitrogen response and plant lodging behaviour of rice is partly determined by the height of the plant. Hence, such rice varieties with increased height and large leaf area have the potential for high yield as a result of effective utilization of nitrogen and sunlight which would increase the rate of photosynthesis. A positive influence of plant height and leaf area was similarly observed in this study as UPIA 2 which differed significantly from other varieties for plants height and leaf area, respectively, displayed superiority in yield.

Panicle parameters which include panicle number, panicle weight, panicle length, spikelet fertility, and number of grains per panicle, are important yield attributes of rice which are essential to be considered when evaluating individual varietal performance. Fageria and Baligar (2001) noted that grain yield in rice is a function of many panicle parameters. Similarly, Oko *et al.* (2012) emphasized that panicle parameters affect the overall rice yield and are often used as pointers to assess the performance of any particular rice cultivar. The high panicle numbers observed in some varieties such as in UPIA 2 (6.83) and FARO 44 (6.33) are pointers that they are good materials to be incorporated into a breeding programme for yield improvement as panicle numbers determine the numbers of spikelets in rice plant. Similarly, the consistency of varieties such as UPIA 2, FARO 44, UPN 228, UPN 336 and FARO 66 for high panicle weight, number of grains per panicle and spikelet fertility is an indication that they are potentially high yielding, which was also revealed by their yield data.

In this study, results from ANOVA showed significant ($P \leq 0.05$ and $P \leq 0.01$) genotypic variation for majority of the parameters evaluated among the 25 rice varieties for each planting dates and for all parameters across the planting dates. This is an indication that considerable genetic variation exists among the varieties, which might be as a result of the differences in the genetic composition of the varieties. Such variations are beneficial to breeders for selecting better parental materials in a breeding programme. Similar results have been reported by Seyoun *et al.* (2012) and Kishore *et al.* (2015) in some rice genotypes and also by Konate *et al.* (2016) in 17 recombinant rice inbred lines and Tonegnikes *et al.* (2019) in some Korea rice germplasm. Effect of planting date and the interaction effect of variety by planting date were also significant ($P \leq 0.05$) for most of the parameters. This might be as a result of the effect of the prevailing climatic conditions in the two planting dates.

The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values are very useful in crop improvement through selection (Johnson *et al.,* 1955). These parameters are used for comparing the relative amount of phenotypic and genotypic variation observed in different characters. As observed in the study, the higher phenotypic variance (Vp) and phenotypic coefficient of variation (PCV) in relation to the corresponding genotypic variance (Vg) and genotypic coefficient of variation (GCV), respectively for all the parameters studied, is indicative the environment has a role to play in the expression of these parameters. Dutta *et al.* (2013), Singh *et al.* (2014), Tuhina-Khatun *et al.* (2015) and Konate *et al.* (2016) had reported similar results in rice. Also, the low to moderate GCV and PCV recorded for majority of the characters is a further proof that these characters were influenced by the environment, hence limiting the possibility for simple selection as their phenotypic expression would not be a good indicator of their genetic potential. However, selection maybe effective based on leaf area, panicle number, panicle weight, grain yield per stand and number of grains per panicle which had high GCV and PCV. Similar results of high GCV and PCV have been reported by Saha *et al.* (2019) (leaf area, number of grains per panicle and grain yield per plant), Singh and Verma (2018) (leaf area and number of grains per panicle) and Tuhina-Khatun *et al.* (2015) (grain yield per plant).

In quantitative genetics, and in particular, selective breeding, the concept of heritability is very important. The most important function of heritability estimates in genetic study of quantitative characters is its predictive role to indicate the dependability of the phenotypic value as a guide to breeding value (Falconer and Mackay, 1996; Al-Tabbal and Fraihat, 2012). Majority of the characters under study were found to have moderate heritability estimates which is at variance with the results reported by Seyoun *et al.,* (2012) and Konate *et al.,* (2016) in rice with higher estimates. Although, the authors only estimated heritability over a single planting date. The genotype by environment interaction (GEI) effect might be the reason for the observed variance, as GEI is a recognised source of variation that impedes heritability (Kang, 1997). Toker (2004) and Mudler and Bijma (2005) had emphasized the need to estimate heritability over pooled environments as it helps negate bias. They reiterated that although heritability estimates pooled over environments are often low in magnitude, they are very reliable in the prediction of genetic gain of characters in breeding programmes.

Heritability estimates alone however does not reflect expected genetic gain. Heritability estimates are to be considered simultaneously with genetic advance. Singh and Marayanan (1993) reiterated that high values of genetic advance as percentage of mean (GAM) are indicative of additive gene effect whereas low values are indicative of non-additive gene effect. Hence, high (>50) heritability estimate accompanied by high genetic advance in leaf area, panicle number, and grain yield per stand suggests that selection for these parameters might be more promising because they are controlled by additive gene action. Similar high heritability estimates coupled with high genetic advance had been reported by Kishore *et al.* (2015) in grain yield per plant and Singh and Verma (2018) in leaf area.

Conclusion

It could be concluded from this study that considerable amount of genetic variability exists among the studied rice varieties for grain yield and its components, which makes the rice varieties an option for selection as parent materials in breeding programs in this agro-ecological zone. The moderate broad sense heritability estimates obtained for majority of the parameters is an indication of the influence of the environment on the genetic potentials of the rice varieties hence, limiting the possibility of simple selection, though reliable because it is from pooled environment. This also justifies the essence of these varietal trial in Port Harcourt. Furthermore, high heritability accompanied by high genetic advance in leaf area, panicle number and grain yield per stand means that selection for these parameters will be promising being controlled by additive gene action.

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