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Genetic Variability Study Based on Yield and Yield Components of Lowland Rice (*Oryza sativa* L.)

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ABSTRACT

Genetic variability is the fundamental requirement for any plant breeding program to develop a superior cultivar. The effectiveness of selection depends basically upon the magnitude of genetic variability in the breeding materials. The aim of this study is to understand the variations in a population which would be helpful in making selection decisions during crop improvement by identifying the differences among genotypes for different traits. This study was carried out at the Faculty of Agriculture Research and Teaching Farm, University of Port Harcourt, Choba, Nigeria. Ten (10) lines (lowland rice) were established for their genetic variability. The experiment was conducted using Randomized Complete Block Design (RCBD) in three replications. Planting was done by seed dibbling and two seeds were sown per pot. The genetic materials used were FARO 52, FARO 59, FARO 61, FARO 66, NERICA 4, UPIA 1, UPIA 2, UPIA 3, UPN 345 and UPN 349. The analysis of variance revealed significant differences among all the genotype indicating that enough variability is present in the studied materials. Earliest maturing variety was observed in NERICA 4 which had 94 days while the variety with the longest days to maturity was observed in FARO 52 which had 131 days. Correlation analysis revealed the relationship between agronomic characters. The estimate of cluster analysis grouped the 10 lines into three clusters (A, B and C) revealed that lines in same cluster had similar genetic make-up while those in different clusters had different genetic makeup. Among all genotypes, NERICA 4 and UPIA 3 showed the best performance or desired traits which can be used to make crosses in breeding program.

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INTRODUCTION

Rice (*Oryza sativa L*.) is the most important cereal crop of the world and also a source of income and principal activity for 100 million households in Asia and Africa. It is the most widely consumed staple food for a large part of the world's human population (Watanabe, 1997). About 3.5 billion people depend on rice as a daily food staple for 20 % of their calories. It is the agricultural commodity with the third-highest worldwide productions, after sugarcane and maize (Watanabe, 1997).

The success of any crop improvement programme depends upon the nature and magnitude of genetic variability existing in breeding material with which plant breeder is working, choice of parents for hybridization and selection procedure (Hapsari *et al*, 2018). Genetic variability is essentially the first step of plant breeding for crop improvement which is immediately available for germplasm which is considered as the reservoir of variability for different characters (Vavilov, 1951). Phenotypic and genotypic coefficients of variation are useful in detecting amounts of variability present in germplasm.

Genetic variability is useful for different purposes, including the selection of parental combinations for creating progenies that are phenotypically superior and with significantly higher yield potential compared to their parents (Barrett and Kidwell, 1998; Mohammadi and Prasanna, 2003). Genetic variability studies that was conducted on low land rice shows the presence of significant variation among genotypes for all of the studied traits. Hence, an insight into the magnitude of variability present in available accessions of rice is of utmost importance to a plant breeder for starting a judicious breeding programme (Begna, 2021). Knowledge of genetic variability in rice will enable the breeder to select potential genotypes and to identify the most important characters for breeding programmes by exploiting the genetic variation and related attributes of different lowland rice genotypes as yield is a quantitative trait, greatly influenced by environmental fluctuations (Acquaah, 2004; Tedesse *et al*, 2014; Kumar *et al*, 2017). Therefore, the study on yield and contributing characters are greater importance for fixing characters that influence yield (Kumar *et al*, 2018). The objectives of this experiment are to determine the genetic variability among the rice genotypes and association with yield components.

MATERIALS AND METHODS

Experimental Site

This study was carried out at the Faculty of Agriculture Research and Teaching farm, University of Port Harcourt, Nigeria. The experimental site was located between latitude 4°31 to 5°00N and longitude 6°45 to 7°00 E, relative humidity of 78% and average rainfall ranges from 2500 – 4000mm with an average temperature of 27°C.

Experimental Design and Field Preparation

The experimental design was Randomize Complete Block Design (RCBD) in three replications. It was a potted experiment, planting was done by seed dibbling and three seeds were sown per pot and thinned to two seedlings after 3weeks of emergence. Manual irrigation system was introduced during low rainfall to maintain the soil capacity. To improve the soil nutrient, 5g of NPK 20:10:10 was applied at different growth stages (vegetative and reproductive stage) at an agronomic rate of 50kg/ha. Manual irrigation was applied to maintain soil field capacity. Basal fertilizer was applied at 5g per poly pot of NPK 20:10:10 (200kg/ha) and top-dressed with urea (46% N) 65 kg /ha at 5g per poly pot. Weeds were controlled manually by hand picking throughout the duration of the experiment. There are 10 entries that comprised 2 anther cultured derived lines from South Korea and 3 from University of Port Harcourt AGRA germplasm and 5 AfricaRice-IITA germplasm (Table 1).

Table 1: Varieties used in this study

S/NO	Variety	Origin/Source
1	UPIA 1	Uniport AGRA germplasm
2	UPIA 2	Uniport AGRA germplasm
3	UPIA 3	Uniport AGRA germplasm
4	UPN 345	Anther culture line (derived from South Korea)
5	UPN 349	Anther culture line (derived from South Korea)
6	NERICA 4	AfricaRice-IITA germplasm
7	FARO 52	AfricaRice-IITA germplasm
8	FARO 59	AfricaRice-IITA germplasm
9	FARO 61	AfricaRice-IITA germplasm
10	FARO 66	AfricaRice-IITA germplasm

Data Collection

Data was collected at appropriate time of crop development. All data measurement was based on standard evaluation system (SES) for rice reference manual (IRRI, 2002). Data collection was taken from two plants (plant I and plant II) of each variety per pot. Data measured was : days to 50%flowering, days to maturity, plant height, number of tillers plant, number of harvested tillers (effective tillers), and plant biomass . Others were number of panicle per plant, panicle length, number of grains per panicle, weight of 1000 grains and total grain yield.

3.5 Data Analysis

Data collected was subjected to Analysis of Variance (ANOVA) using Statistical Analysis System (SAS 2003) for mean separation. correlation analysis and cluster analysis using pair-wise distance matrixes between genotypes were again derived using the numerical taxonomy and multivariate analysis system (NTSYS-PC), Version 2.1 (Rohlf, 2000) and the Jaccard coefficient of similarity (Jaccard, 1908). Genetic diversity dendogram for the genotypes was created by unweighted pair group method with arithmetic mean (UPGMA) cluster analysis (Sneath and Sokal, 1973; Swofford and Olsen, 1990).

RESULTS

Performance of Lowland Rice Of Some Agronomic Characters

Days to 50% flowering was significantly different across the varieties, FARO 52 and UPIA 2 could be medium maturing. The earliest flowering variety were UPIA 3 and NERICA 4 which had the least days to flowering. NERICA 4 had 64.67 days while 67 days for UPIA 3. Based on plant height, NERICA 4 had the highest height followed by FARO 59 and the least was observed in UPIA 1 (Table 2). The highest Leaf Area Index was observed in NERICA 4 and the least was observed in FARO 61. (Table 2)/

Table 2: Performance of lowland rice of some agronomic characters

Variety	DF	DM	PH (cm)	NT	LAI
UPIA 3	67.00±1.15^{f}	97.00±1.54^{f}	90.67±96^{b}	9.00±1.53^{b}	7.30±0.82^{b}
NERICA 4	64.67±1.20^{f}	94.00±2.31^{f}	118.67±0.88^{a}	7.67±2.33^{b}	9.48±0.57^{a}
UPN 345	74.00±2.30^{e}	104.00±2.31^{e}	97.67±1.20^{b}	16.00±2.33^{b}	7.48±0.35^{b}
UPIA 2	97.00±0.57^{ab}	127.00±1.73^{ab}	84.33±1.33^{bc}	17.00±1.15^{a}	6.05±0.46^{bc}
FARO 61	95.00±1.15^{bc}	125.00±2.89^{c}	86.67±2.40^{bc}	14.00±2.08^{b}	4.65±0.53^{c}
FARO 52	101.00±0.57^{a}	131.00±0.58^{a}	81.67±0.33^{bc}	26.00±9.45^{a}	5.09±0.33^{c}
UPIA 1	88.67±0.88^{e}	119.00±1.15^{d}	69.33±7.54^{c}	18.00±3.06^{a}	4.76±0.77^{c}
FARO 66	91.00±0.58^{cd}	121.00±0.58^{d}	85.67±3.28^{bc}	16.67±1.86^{a}	6.29±0.19^{bc}
FARO 59	74.00±2.30^{e}	104.00±2.31^{e}	98.00±8.02^{b}	9.67±2.03^{b}	6.79±0.59^{bc}
UPN 349	76.00±1.73^{e}	106.00±2.31^{e}	80.33±10.80^{bc}	13.33±1.67^{b}	4.94±1.30^{c}
MEAN	82.83	112.00	89.30	14.73	6.28
LSD	4.13	5.59	17.82	10.37	2.20
%CV	2.98	2.91	11.72	40.30	20.58

Note: *Letters of different alphabets are significantly different from one another. DF days to 50% flowering, DM days to maturity, PH: plant height, NT: Number of tillers, and LAI: Leaf area index. LSD: Least Significant Difference. %CV: Coefficient of Variance.*

Agronomic Performance of Lowland Rice (*O. sativa*)

Plant Biomass was significantly different across the varieties. FARO 61 had the highest plant Biomass, followed by NERICA 4 and the least was observed in UPIA 3 (Table 3). Number of Effective tillers which was the harvestable tillers was significantly different across the varieties, FARO 52 had the highest number of effective tillers, followed by UPIA 2 and the least was observed in NERICA 4. FARO 52 had the highest number of panicles per plant, followed by UPIA 2 and the least was observed in FARO 59. For length of panicles and number of grains per panicles, there was no significant difference across the varieties. NERICA 4 had the highest average grain weight per panicle and the least observed in FARO 52. NERICA 4 had the highest Weight of one thousand (1000) grains per plant and the least was observed in FARO 52., while UPIA 2 had the highest grains yield, followed by UPN 349 and the least grain yields was observed in FARO 59 .(Table 3).

Table 3: Agronomic Performance of Lowland Rice (*O. sativa*)

Variety	PB (g)	NET	NP	LP (cm)	NG	WG(g)	WOTG(g)	TYG(kg/ha)
UPIA 3	40.83±11.35^{b}	10.00±4.51^{ab}	11.00±2.29^{b}	41.67±18.22^{a}	87.40±7.73^{a}	1.63±0.19^{ab}	23.33±1.67^{b}	9.27±0.52^{a}
NERICA 4	63.46±3.15^{a}	5.50±0.29^{b}	11.33±1.45^{b}	50.67±20.19^{a}	78.00±12.16^{a}	2.50±0.50^{a}	30.67±1.76^{a}	8.93±0.81^{ab}
UPN 345	49.73±4.67^{ab}	10.00±1.76^{ab}	10.83±1.09^{b}	44.00±16.50^{a}	112.33±11.02^{a}	1.83±0.17^{ab}	19.33±0.88^{b}	9.83±1.04^{a}
UPIA 2	45.13±9.62^{ab}	15.83±2.62^{a}	17.00±3.21^{a}	56.43±23.78^{a}	98.40±3.89^{a}	2.00±0.00^{ab}	19.67±1.20^{b}	10.73±0.29^{a}
FARO 61	66.43±0.81^{a}	10.33±1.17^{ab}	11.00±0.58^{b}	52.00±21.55^{a}	82.80±6.45^{a}	1.60±0.20^{ab}	22.67±1.20^{b}	7.43±0.88^{ab}
FARO 52	57.07±5.07^{ab}	16.17±0.73^{a}	17.67±2.17^{a}	38.80±7.44^{a}	86.73±11.75^{a}	1.33±0.33^{b}	17.00±1.00^{b}	8.43±1.77^{ab}
UPIA 1	62.33±7.97^{ab}	12.33±2.52^{ab}	11.00±0.50^{b}	45.67±17.17^{a}	80.10±4.46^{a}	2.10±0.49^{ab}	20.00±2.52^{b}	8.40±1.42^{ab}
FARO 66	47.00±2.08^{ab}	10.17±1.01^{ab}	13.67±0.67^{ab}	52.07±21.97^{a}	84.33±3.18^{a}	1.60±0.20^{ab}	19.67±0.33^{b}	9.90±0.17^{a}
FARO 59	60.93±1.79^{ab}	5.50±0.57^{b}	8.50±1.32^{b}	45.67±22.73^{a}	79.40±4.30^{a}	1.80±0.20^{ab}	19.33±3.71^{b}	5.30±0.80^{b}
UPN 349	50.73±8.99^{ab}	8.50±1.53^{b}	9.33±2.31^{b}	44.73±25.14^{a}	89.07±21.72^{a}	1.67±0.33^{ab}	17.33±3.17^{b}	10.17±1.95^{a}
MEAN	54.37	10.43	12.13	47.17	87.85	1.81	20.90	8.84
LSD	19.33	6.11	5.04	59.11	30.65	0.86	6.03	3.08
%CV	20.87	34.37	24.40	73.58	20.49	27.82	16.94	20.45

Means with different alphabet are significantly different at p ≤ 0.05
PB: plant biomass, NET: Number of effective tillers, NP: Number of panicles/plant, LP: Length of Panicles, NG: Number of gains per panicle, WG = average grain weight/panicle, WOTG: weight of 1000 grain, TYG:= total yield of gains. LSD: Least Significant Difference. %CV: Coefficient of Variance

Correlation coefficient performance of low land rice of some agronomic characters

There was a positively high significant correlation at (P<0.01) relationship observed between plant height and leaf area index, and significant negative correlation was observed between plant height and number of tillers at (r = -0.363*). There was negative significant correlation (r = -0.491**) between number of effective tillers and plant height and of weight of one thousand grain, while a significant and positive correlation was observed between the number of tillers per plant and total grain yield. Significant positive correlation between weight of one thousand grains and plant height, Leaf Area Index (LAI) and number of effective tillers. (Table 4).

Table 4: Correlation coefficient performance of lowland rice of some agronomic characters

	PH	LAI	NT	PB	NET	NP	LP	NG	WG	WOTG	TYG
PH											
LAI	0.831**										
NT	-0.363*	-0.331ns									
PB	-0.094ns	-0.237ns	-0.089ns								
NET	-0.491**	-0.356ns	0.450*	-0.071ns							
NP	-0.179ns	-0.113ns	0.260ns	-0.024ns	0.766ns						
LP	0.154ns	0.139ns	-0.003ns	0.014ns	0.064ns	0.123ns					
NG	0.274ns	0.336ns	0.227ns	-0.338ns	0.041ns	0.038ns	0.284ns				
WG	0.339ns	0.475**	0.009ns	0.006ns	-0.127ns	-0.196ns	0.299ns	0.369*			
WOTG	0.733**	0.687**	-0.232ns	-0.011ns	-0.365*	-0-203ns	0.308ns	0.110ns	0.546**		
TYG	-0.150ns	-0.041ns	0.339ns	-0.275ns	0.393*	-0.337ns	-0.149ns	0.203ns	0.140ns	-0.051ns	1.00

PH: plant height, LAI: Leaf area index, NT: Number of tillers, PB: plant biomass, NET: Number of effective tillers, NP: Number of panicles, LP: Length of Panicles NG: Number of gains, WG: Weight of grains, WOTG: weight of one thousand grain TYG: Total yield of gains.

Cluster Analysis of Some Low Land Rice

Three major clusters (A, B and C) were observed. The first (A) cluster contains FARO 59, UPIA 3, FARO 52, FARO 66, FARO 61 and UPIA 2. The second cluster (B) contains UPIA 1 and UPN 349 while the last cluster (C) contains NERICA 4 and UPN345. The highest number of genotypes is cluster A (Figure 1).

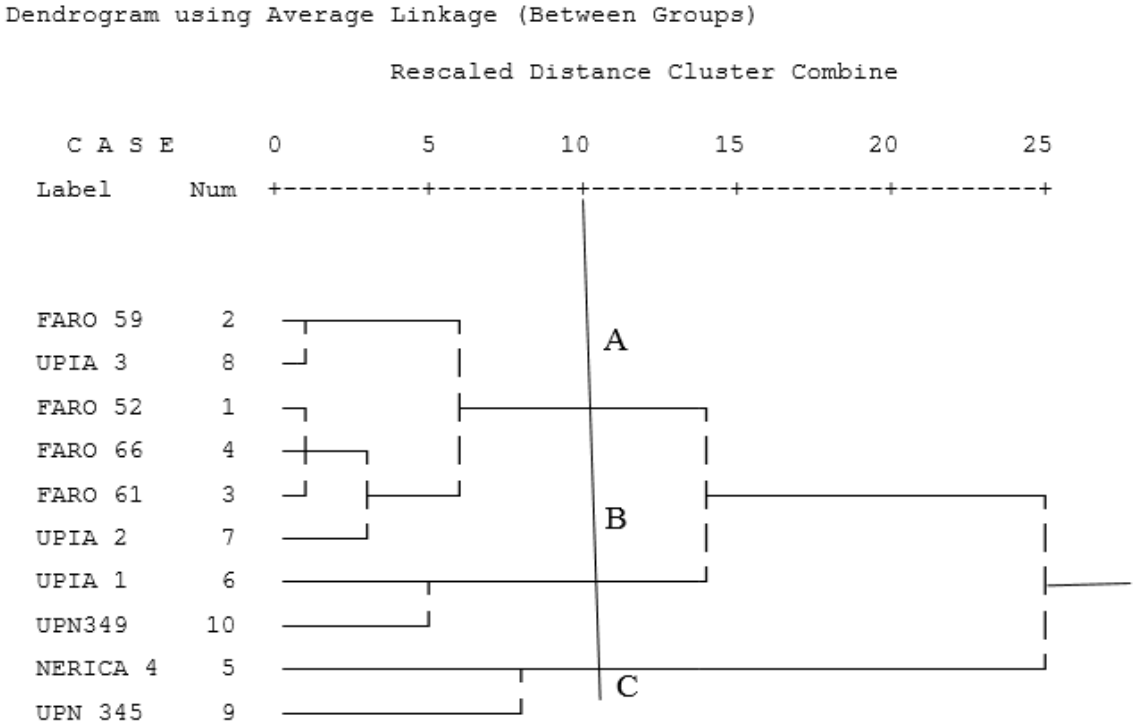

Figure 1: Cluster analysis of the performances of low land rice

DISCUSSION

The success of any crop improvement programme depends upon the nature and magnitude of genetic variability existing in breeding material with which plant breeder is working, choice of parents for hybridization and selection procedure (Hapsari *et al*, 2018). Genetic variability is essentially the first step of plant breeding for crop improvement which is immediately available for germplasm which is considered as the reservoir of variability for different characters (Vavilov, 1951). The present study revealed significant variability among the evaluated rice genotypes for key agronomic traits such as days to 50% flowering, days to maturity, plant height, effective tillers and leaf area index. FARO 52had the longest days to 50% flowering (101 days), whereas NERICA 4 was the earliest (64.67 days). Similarly, NERICA 4 matured much earlier (94 days) compared with FARO 52 (131 days). These result is aligns with the findings of Ahiakpa *et al.* (2018), who reported that NERICA 4 and related genotypes exhibited shorter flowering and maturity durations compared with traditional varieties, thus making them more suitable for short rainy seasons. Plant height varied significantly across the genotypes, with NERICA 4attaining the highest height (118.67cm) and UPIA 1 the shortest (63.33cm). This observation agrees with the findings of Matsunami *et al* (2009), who reported wide variation in plant height among NERICA cultivars under varying ecosystems, attributing the differences to genetic diversity and environmental adaptation.

Plant height is an important factor that determines rice response to nitrogen. It plays a vital role in logging behavior that affects yield performance (Efisue and Cynthia, 2020). Taller plants enhances light penetration and canopy photosynthesis which can improve productivity (Chandrasekaran *et al,* 2007). From the experiment, plant height showed significant difference across the genotypes, with NERICA 4 attaining the highest height (118.67 cm) and UPIA 1 the shortest (69.33 cm). This result aligns with the work of Matsunami *et al* (2009), who reported wide variation in plant height among NERICA cultivars under varying ecosystems, attributing the differences to genetic diversity and environmental adaptation. The coefficients of variation (CV)

showed significant variability in planicle length (73.58%), tiller number (40.30%) and effective tiller (34.37%), indicating considerable genetic diversity suitable for breeding program. Similarly, high genetic variability in agronomic traits were observed in Nigerian rice germplasm by both Onyia *et al.* (2017) and Adewusi *et al*. (2024), where significant differences among genotypes were reported, supporting their potential use in selection and improvement.

Yield components such as effective tillers, panicle number, grain weight, and 1000 grain weight showed significant diversity. Tiller production is a vital yield component since it contributes directly to the number of panicles. However, the efficiency of tiller conversion into productive panicles is equally important. The number of tillers per plant was significantly different, with FARO 52 producing the highest number of tillers while NERICA 4 produced the least. This aligns with Efisue (2019), who stated that effective tiller number is a strong determinant of grain yield than total tiller count in rice improvement trials. Peng *et al* (1994) also emphasized that few tillers often leads to reduced panicle formation and lower yield, whereas excessive tillers may result to high unproductive tillers and poor grain yield. Conversely, NERICA 4 produced the heaviest grains (2.50 g) and highest 1000 grain weight (1. 76 g). This aligns with the result of Ahiakpa *et al*. (2018) who observed that NERICAs often outperform landraces in grain yield component despite producing fewer tillers. Total grain yield per plant was highest in UPIA 2 (10.73 g), followed by UPN 349 and FARO 66, while the lowest yield was recorded in FARO 59 (5.30 g). This variation aligns with Onyia *et al*. (2017), who reported that grain yield differences among Nigerian rice genotypes are significantly associated with variations in panicle traits and grain filling efficiency.

CONCLUSION

Genetic variability in any crop is pre requite for selection of superior genotypes over the existing cultivars. The extent of variability with respect to ten varieties were measured in terms of analysis of variance, Correlation and Cluster analysis. Analysis of variance revealed significant differences for all the characters indicating sufficient variability among the genotype and cluster analysis revealed genetic similarities and differences among genotypes. From the experiment, the superior performance of NERICA 4 (early maturity, plant height, leaf are index, and grain weight) and UPIA 3 (total yield) may be promising for improving rice productivity.

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