Genotypic And Phenotypic Variability For Seed Vigour Traits And Seed Yield In West African Rice (*Oryza sativa* L.) Genotypes

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ABSTRACT: The study was conducted to assess the genotypic and phenotypic coefficients of variation and estimate broad sense heritability (h^2_B) and genetic advance as percent of the mean for eleven seed vigour traits and seed yield in 24 genotypes of West African rice (*Oryza sativa* L). Cleaned seeds of each genotypes were evaluated for five seed vigour traits in the seed laboratory using completely randomized design with three replications while seed vigour traits and seed yield per plant was assessed in the field laid out in a randomized complete block design with thee replications in the late 2003 and early 2004 cropping seasons in the Fadama (Lowland valley environment) at the Teaching and Research Farm of the University of Agriculture, Abeokuta, Southwest Nigeria. Highly significant differences were observed among the genotypes for all the seed vigour traits and seed yield per plant in both seasons. The phenotypic coefficient of variability (PCV) was generally higher than the genotypic coefficient of variability (GCV) for most of the traits which indicates that environmental effect constitute a major portion of the total phenotypic variation. Considering GCV, h^2B and GA (as percent of the mean) as the best estimators of the amount of advance expected from selection seedling vigour index (53.02), speed of germination index (0.99) and energy of germination (0.69) gave the highest values in the late season while seedling vigour index (35.75), speed of emergence (0.99) and energy of germination (0.61) gave the highest values in the early season. This shows that a satisfactory selection programme for improvement of these seed quality characters is possible in West African rice at each specific season. [The Journal of American Science. 2007;3(3):34-41]. (ISSN: 1545-1003).

Key words: genetic advance, genotype, heritability, seed quality

1. Introduction

Rice (*Oryza sativa* L.) is the most important staple food for about half of the human race (Hawksworth, 1985). It ranks third after wheat and maize in terms of worldwide production. Efforts have been made at encouraging and boosting local rice production in Nigeria and this has led to a tremendous increase in area planted, output and productivity in paddy rice production in the last two decades. Since 1980, Nigeria has become the largest rice producing country in West Africa and third largest in Africa, after Egypt and Madagascar (WARDA, 1996). In spite of these improvements, local rice production has not kept up with domestic consumption demands of the Nigerian populace, and consequently, rice is still imported (Singh *et al*., 1997).

Nigeria, along with many countries across the world has ecologies that are suitable for different rice varieties and that can be harnessed to boost rice production to meet domestic demands, and even to produce a surplus for export (Annonymous, 1997). However, farmers have identified a number of constraints, as limiting to rice production efforts. These include low level of research, work, pest and disease management, soil fertility management, unavailability of simple and cheap farm implements; access to institutional and infrastructure support and credit facilities among others. Addressing at least most of these problems is a good first step towards attaining the target of rice self-sufficiency.

Early investigation and on farm production of rice seeds have pointed out low germination and poor seedling establishment among the problems being faced by the farmers. Low seed vigour has been identified as the factor mostly responsible for poor germination and uneven seedling establishment (Ellis, 1992). A close relationship was reported between seed vigour and seed yield in West African rice (Okelola, 2005). He observed distinct characteristics in seed vigour and seed yield and identified seed germination, speed of germination index, seedling vigour index, energy of germination, seedling emergence and seedling establishment as the most desirable seed vigour traits in the new West African rice varieties.

The level of research work on seed quality of West African rice is low. Also little information is available on seed physiological traits of the newly developed West African rice genotypes. Crop improvement is dependent not only on the magnitude of phenotypic variability but also on the extent to which the desirable characters are heritable. Hence, it is essential to partition the observed variability into its heritable and non-heritable components by appropriate genetic analysis.

This research work was conducted with the objective of partitioning the observed variability in seed vigour traits and seed yield of 24 diverse genotypes of West African rice into heritable and non-heritable components and estimating the broad sense heritability with genetic advance expected from selection as a percent of the mean of a set of seed vigour traits and seed yield.

2. Materials and Methods

Twenty-four genotypes of West African rice (*Oryza sativa* L.) sourced from the West African Rice Development Association (WARDA) sub-station in International Institute of Tropical Agriculture (IITA), Ibadan were used in this study.

Seeds of each genotype were divided into two parts: one part for field test and the second part for laboratory test.

Field Test.

The experiment was carried out during the late (November/December), 2003 and early (May/June), 2004 planting seasons in the fadama (Lowland valley) environment at the Teaching and Research farm of the University of Agriculture, Abeokuta, located on the latitude $7^0 15^1$N and longitude $3^0 25^1$E. It lies in the derived savanna zone of Southwest Nigeria, and has a bimodal rainfall distribution with peaks in June/July and September for the field study.

The genotypes were grown in a randomized complete block design plot with three replications. Each plot was 3m x 0.2m size and consisted of two rows with spacing of 20cm between rows and a space of 1m between each genotype. The total land area was $390m^2$. Seeds were hand drilled along the rows while seedlings were thinned at 30days after planting to 20cm x 20cm plant spacing. Following thinning, a post emergence fertilizer application of N.P.K. 15-15-15 was applied by drilling at a rate of 200kg N/ha. Urea was applied as top dressing at 65kg/ha at booting. All pre and post-stand establishment management such as land preparation, weeding, bird and rodent control was done as required.

Observations were made on seven different seed vigour traits. Seed emergence was recorded at 5, 7, 9 and 11 days and the established seedlings were counted finally after 14 days from planting. Emergence index was calculated according to Mock and Eberhart, 1972 as

$$El = \frac{\sum \text{(plants emerged in a day) (Days after planting)}}{\text{Plants emerged by 9 days after planting}}$$

Emergence percentage (E%) was calculated as the percentage of seedling emerged 9 days after planting (DAP) relative to the number of seeds sown. Speed of emergence was determined according to Dadlani *et al.* (1990) as percentage of number of seeds emerged 5 DAP relative to number of seed emerged by 11 DAP. Seedling establishment was calculated as the percentage of seedlings established 14 DAP relative to number of seed sown (Yamauchi *et al.,* 1996). Plant height and seedling dry weight were measured at 30 DAP. Seed yield was determined as seed yield per plant and then expressed as seed yield per ha.

2.1 Laboratory Test

The following laboratory vigour tests were also conducted: standard germination test according to the procedure of (ISTA, 1995) rules. The seedling vigour index-1 was calculated by multiplying the germination percentage with seedling length and then divided by 100. Speed of germination index was calculated as described by AOSA (1983):

$$SGI = \frac{\text{No. of germinated seed}}{\text{Days of first count}} + \ldots\ldots\ldots\ldots + \frac{\text{No. of germinated seeds}}{\text{Days of final count}}$$

Energy of germination was recorded as the percentage of germinating seeds 3 days after planting relative of the number of seeds sown (Ruan *et al.,* 2002) and 100-seed weight,. Each test was conducted in three replications in a completely randomized design.

2.2 Data analysis

The data on each trait were subjected to analysis of variance, which was used to partition the gross (Phenotypic) variability into the components due to genetic (hereditary) and non-genetic (environmental) factors and to estimate the magnitude of these. Genotypic variance is the part of the phenotypic variance that can be attributed to genotypic differences among the phenotypes. Similarly, phenotypic variance is the total variance among phenotypes when grown over the range of environments of interest (Dudley and Moll 1969). Hence, variance components (genotypic, phenotypic and error variance) were estimated using the formula of Wricke and Weber (1986) and Prasad *et al.* (1981) as follows:

$$Vg = [MSG – MSE / r]$$
$$Vp = [MSG / r]$$
$$Ve = [MSE / r]$$

Where MSG, MSE and r are the mean squares of genotypes, mean squares of error and number of replications, respectively. Phenotypic (PCV) and genotypic (GCV) coefficient of variation were evaluated according to the methods of Burton (1952), Johnson *et al.* (1955) and Kumar *et al.* (1985) as

$$PCV = [\sqrt{Vp} / X] \times 100$$
$$GCV = [\sqrt{Vg} / X] \times 100$$

Where Vp, Vg and X are the phenotypic variances, genotypic variances and grand mean per season, respectively for the characters under consideration. Broad sense heritability (h^2B) expressed as the percentage of the ratio of the genotypic variance (Vg) to the phenotypic variance (Vp) was estimated on genotypic mean basis as described by Allard (1999). Genetic advance (GA) expected and GA as percent of the mean assuming selection of the superior 5% of the genotypes were estimated in accordance with the methods of illustrated by Fehr (1987) as

$$GA = K (Sp) h^2 B$$
$$GA \text{ (as \% of the mean)} = (GA / x) \times 100$$

Where k is a constant (which varies depending upon the selection intensity and, if the latter is 5%, it stands at 2.06). Sp is the phenotypic standard deviation ($\sqrt{vp}$), h^2B is the heritability ratio and x refers to the season mean of the character.

3. Results

In this study, data were collected for 11 seed vigour traits as well as seed yield under two different seasons. (dry and wet). The variation displayed is shown in Table 1. The analysis of variance showed highly significant differences among genotypes for all the traits evaluated in both seasons. The results suggest the possibility of improving seed vigour traits through genotypic selection.

Estimates of the variance components for the 12 traits in the two seasons showed that phenotypic and genotypic variances were close to each other for most characters (Table 2) in each of the seasons. The magnitude of error variance was relatively lower than the genotypic variance for all the characters evaluated in each season.

It is difficult to compare the variance among the range of various characters because they are not unit free (Baye 1996). Thus estimates of phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), heritability (in broad sense) and genetic advance as a percentage of mean were evaluated and compared (Table 3). The lowest and highest phenotypic coefficients of variation (PCV) in the first season occurred with emergence index (1.30) and seedling vigour index-1 (53.02), respectively. At the second season, PCV ranged from 2.23 for emergence index to 38.22 for seedling vigour index–1. The genotypic coefficient of variation (GCV) combined genotypic variance with the units of measurement and the mean of the characters. The genotypic coefficient of variation at the first season ranged from 1.30 for emergence index to 53.02 for seedling vigour index–1. At the second season, GCV varied from 1.82 for emergence index to 35.75 for seedling vigour index–1. Emergence index and speed of emergence generally had the lowest GCV under the two seasons. Seedling vigour index–1, speed of germination index, energy of germination and seed yield /plant generally showed high PCV and GCV values in both seasons. Higher GCVs indicate that worthwhile improvement could be achieved for such characters through simple selection. The lower GCVs of some characters in both seasons indicated them to be less amenable to improvement by selection in specific season. Relatively, low values of PCV and GCV were observed for most characters under study in the second season compared to the first season.

Although GCV provides information on the genetic variability present in various quantitative characters, it is not possible to determine the amount of the variation that was heritable from only the genotypic coefficient of variation. In the first season, estimates of broad sense heritability ranged from 30.01% for speed of emergence to 99.73% for speed of germination index (Table 3). In the second season, broad-sense heritability values ranged from 72.09% for emergence index to 99.68% for speed of emergence. Generally, the higher heritability estimates for most of the traits in the two seasons indicated that environmental factors did not greatly affect phenotypic variation for the traits; rather genetic constitution of the varieties was responsible for the variations.

From the result in Table 3, genetic advance (GA) as percentage of mean ranged from 2.10% for emergence index to 69.01% for energy of germination in the first season. However, in the second season GA as percentage of mean varied from 3.31% for emergence index to 60.88 for energy of germination. Genetic advance as percent of means showed the same trend as PCV and GCV in both seasons. Considering heritability and GA together in the first season, percentage germination, speed of germination index, seedling vigour index –1, energy of germination and seed yield / plant all combined high heritability with high genetic advance. High heritability of 78.64% and low GA of 2.10% were observed for emergence index and 100 seed weight in the first season whereas low heritability (30.01%) and low GA (4.63%) were recorded with speed of emergence. In the second season, speed of germination index, seedling vigour index–1, energy of germination, emergence percentage, and seed yield/plant showed high heritability combined with high GA. However, 100 seed weight, emergence index, speed of emergence and plant height showed high heritability but had low genetic advance.

Table 1. Range, means, standard error and mean squares for 12 seed vigour traits and seed yield in 24 genotypes of West African rice (*Oryza sativa* L.) in late 2003 and early 2004 cropping seasons

Characters	Season	Range	Mean	SE(±)	Mean square Values for genotypes
Germination percentage	A	12.42-77.12	55.45	14.58	437.62**
	B	24.31-78.49	61.04	14.77	108.85**
100-seed weight (g)	A	2.16-3.43	2.71	0.32	23.53**
	B	2.38-3.78	2.93	0.32	50.00**
Speed of Germination	A	0.02-1.35	1.08	0.33	1106.91**
	B	0.06-1.33	1.14	0.30	900.00**
Seedling vigour index	A	0.21-0.92	0.68	0.36	195.50**
	B	0.22-0.96	0.74	0.28	10.34**
Energy of Germination (%)	A	9.36-812	51.07	17.25	358.56**
	B	9.88-75.82	54.70	16.43	184.92**
Emergence Index	A	1.06-1.11	1.09	0.01	12.05**
	B	1.06-1.15	1.10	0.02	8.75**
Speed of emergence	A	44.91-61.89	54.42	4.08	2.29**
	B	42.54-69.79	57.14	6.83	95.87**
Emergence Percentage	A	25.76-67.30	54.14	9.35	13.19**
	B	25.10-73.11	56.50	11.39	944.95**
Seedling Establishment (%)	A	25.10-66.95	53.00	10.28	384.57**
	B	25.01-72-01	56.54	11.30	665.73**

Plant height/plant (cm)	A	28.33-46.13	37.29	5.30	139.14**
	B	29.60-45.80	38.46	4.80	271.49**
Seedling weight/plant (g)	A	0.80-2.68	2.13	0.48	13.60**
	B	1.00-2.96	2.31	0.50	22.00**
Seed Yield /plant (g)	A	21.65-74.38	56.36	15.33	116.99**
	B	22.96-77.91	57.88	15.83	66.28**

A = Late cropping season of 2003
B = Early cropping season of 2004
**: Significant at 1% level of probability

Table 2. Estimates of phenotypic (Vp), genotypic (Vg) and error (Ve) variances for 12 seed vigour traits in 24 genotypes of West African rice (*Oryza sativa* L.) in late 2003 and early 2004 seasons

Characters	Season	Vp	Vg	Ve
Germination (%)	A	212.67	212.18	0.49
	B	218.18	216.17	2.00
100-seed wt (g)	A	0.10	0.10	0.04
	B	0.10	0.10	0.02
Speed of Germination index	A	0.11	0.11	0.01
	B	0.09	0.09	0.01
Seedling vigour index	A	0.13	0.13	0.01
	B	0.08	0.07	0.08
Energy of Germination (%)	A	297.61	296.78	0.83
	B	269.98	268.52	1.46
Emergence Index	A	0.02	0.02	0.01
	B	0.06	0.04	0.05
Speed of emergence	A	16.62	9.35	7.27
	B	46.69	46.20	0.49
Emergence Percentage	A	87.34	80.72	6.62
	B	129.77	129.64	0.14
Seedling Establishment (%)	A	105.76	105.48	0.28
	B	127.60	127.41	0.19
Plant height (cm)	A	28.06	27.86	0.20
	B	23.03	22.95	0.10
Seedling weight (g)	A	0.23	0.21	0.02
	B	0.25	0.23	0.01
Seed Yield (g)	A	235.09	233.08	2.01
	B	250.54	246.76	3.78

A = Late cropping season of 2003
B = Early cropping season of 2004

Table 3. Estimates of phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), heritability (h^2B) and genetic advance (GA) as percent of means for 12 seed vigour traits in 24 genotypes of West African rice (*Oryza sativa.* L) in late 2003 and early 2004 seasons

Characters	Season	PCV	GCV	H^2B	GA (% of Mean)
Germination (%)	A	26.30	26.27	99.32	53.81
	B	24.20	24.09	97.29	48.50
100-seed wt (g)	A	11.67	11.67	88.25	21.21
	B	10.79	10.79	94.23	20.95
Speed of germination index	A	30.71	30.71	99.73	63.09
	B	26.32	26.32	99.67	54.03
Seedling vigour index-1	A	53.02	53.02	98.48	67.57
	B	38.22	35.75	75.70	59.60
Energy of germination	A	33.78	33.73	99.17	69.01
	B	30.04	29.96	98.39	60.88
Emergence Index	A	1.30	1.30	78.64	2.01
	B	2.23	1.82	72.09	3.31
Speed of emergence	A	7.49	5.62	30.01	4.63
	B	11.96	11.90	96.93	23.88
Emergence (%)	A	17.26	16.60	80.26	28.54
	B	20.16	20.15	99.68	41.40
Seedling establishment (%)	A	19.40	19.39	99.22	39.65
	B	19.98	19.96	99.55	40.97
Plant height (cm)	A	14.21	14.16	97.87	28.64
	B	12.48	12.46	98.90	25.42
Seedling weight (g)	A	22.52	21.51	80.77	37.46
	B	21.65	20.76	87.50	39.02
Seed Yield (g)	A	27.21	27.09	97.48	54.63
	B	27.35	27.14	95.61	53.86

A = Late cropping season of 2003
B = Early cropping season of 2004

4. Discussion

The magnitude of error variance was relatively lower than the genotypic variance for all traits. Similar results of higher genotypic variance than error variance for some characters were reported by Nayakar (1976) for niger, Singh and Yadava (1986) for sunflower and Baye (2002) for V*ernonia galamensis.* These lower error variances indicate that the genotypic component was the major contributor to the total variance for these characters in each of the two seasons. It can be concluded that most of the variability observed in the phenotype for the different characters has more of a genetic than a non-genetic basis. The variability due to genotypic variance indicates considerable scope for selection.

The phenotypic coefficient of variability (PCV) was generally higher than the genotypic coefficient of variability (GCV) for all traits except a few in each season. The same trend was reported by Berry *et al.* (1970) for *V. anthelmintica;* Gupta and Godawat (1981); Satapath *et al.* (1987) for linseed and Baye (2002) for *V. galamensis.* This suggests that environmental effects constitute a major portion of the total phenotypic variation in some traits. Thus, the selection of superior genotypes based on such traits would not be effective.

The variations of the 24 genotypes in seed vigour traits and seed yield trait suggest that selection for several of these traits may be effective. However, improvement efficiency is related to magnitude of GCV, heritability and genetic advance (Johnson *et al.* 1955). In this study, for traits with high values of GCV, heritability and GA such as percentage germination, speed of germination index, seedling vigour index–1, energy of germination and seed yield/plant, there is a possibility of improving these genotypes through direct selection for the above traits at each specific season. These traits also showed more or less stable expressions in both seasons in terms of average performance and / or range variability exhibited and hence could be used for general improvement of West African rice.

Most traits however showed inconsistent expression in the two seasons, which suggest that an efficient approach towards improvement of this crop should also be season specific. Nevertheless, overestimation of genetic variation and heritability are conceivable since the genetic variance include the total genetic environment interaction variance. The use of h^2 B is likely to give a gross overestimation of the genetic advance likely to be obtained through selection because of the influence of heterozygosity. Similar result of high heritability and high genetic advance for some seed yield traits were reported by Singh (1986); Varshney *et al.* (1986) using *Brassica* species and Baye (2002) using *V. galamensis.*

The present study indicates that there is genetic variability for the different traits under consideration but it is unlikely that these accessions encompass the full range of diversity to be found in West Africa. Thus collection, conservation and further evaluation for the selection of better germplasm for superior seed quality and seed yield are essential.

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