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RESEARCH ARTICLE

Effects of genotype by year interaction on physiological performance of selected Nigerian rice (*Oryza sativa* L.) varieties grown under guinea savannah agro-ecology

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Abstract

Twenty-two rice varieties were evaluated in a field trial under rain-fed conditions at the National Agricultural Seeds Council, Sheda, Abuja in 2017 and 2018 cropping years to provide a comparative measure for effects of genotype by year interaction on physiological performance of selected Nigerian rice. The experimental field was laid out using Randomized Complete Block Design in three replicates. Significant variation were detected among varieties during and across the cropping years evaluated for all the eight seed quality attributes. Higher values of rate of germination, seedling vigour, 100 seed weight, seedling shoot length, coleoptile length and number of roots were observed in 2017 cropping season compared to 2018 cropping year with superiority advantage of 18.39, 12.49, 9.37, 20.00, 31.07, 14.09 and 45.71, respectively. FARO 41 had consistent and highest performance for most of seed quality attributes (rate of germination (83.50%) seedling vigour (13.25%), seed germination (89.53%) and number of roots (3.25). Seed germination was strongly related to seedling vigour, seedling root length, 100 seed weight and number of roots (r=0.21-0.86**). The study concluded that FARO 41 as well as FARO 31 with superior performance in seed quality attributes are thus recommended for seed improvement programme.

Key words: Variability, rice, vigour, seed yield, seed improvement

Introduction

Rice is the staple food for over half the world's population and the most important among all the cereal crops (Khush, 1997; Dogara and Jumare, 2014). Approximately 480 million metric tons of milled rice is produced annually. Globally, about 160 million hectares are estimated to be under rice production with an annual production of approximately 500 million metric tons (Kirby *et al.,* 2017).

Rice is very important in Nigeria, based on the various ways it can be used. The capability to produce more rice has aided in development of numerous communities, while its failure has led to the spread of starvation, death and political uncertainty in many countries including Nigeria (Seck *et al.,* 2012; Oludare, 2014).The acceptance of rice as food has witness an upsurge lately by becoming a major crop in many countries in America and Africa (Seck *et al.,* 2012).

The demand for rice has increased steadily over the years, thus playing a major role in many countries in terms of strategic food security planning policies. In recent years, rice crop yield has slowed considerably therefore failing to keep up with the population growth thus leading to shortages and higher prices that have adversely affected smallholder rice farmers (Denkyirah, 2015; Lee and Kobayashi, 2017).

The physiological seed quality refers to the ability of seed to germinate at the desired time and to assure an adequate level of initial growth (vigour) of all essential parts of the seedlings. Physiological quality of the seed also includes germination capacity, viability and characteristics related to dormancy and vigour (Adetumbi, 2013; Lawal *et al.*, 2018).

Several Federal Agriculture Research Oryza (FARO) varieties have been released for cultivation in Nigeria. They have been recommended for dry upland and moist environments based on their high yielding, disease and lodging resistance with good cooking properties. The choice of rice varieties for production lies with the farmers. Low yields per hectare and variation in growth parameters have been reported by farmers on the field which could be due to differences in the genetic constitution apart from other several factors ranging from biotic and abiotic. There is the need to provide a comparative measure of yield components, physical, physiological and biochemical components of the Nigerian cultivated rice varieties which would enhance better utilization of these genetic materials and thereby increasing the yield output. Low yield per ha in upland and lowland varieties of rice has been reported by farmers in guinea savannah which could be due to several factors. Besides, most of the rice varieties released to farmers are not consistent in yield performances from year to year and several complaints have been received by National Agricultural Seed Council (NASC) on the low seed yields and other seed attributes of available released rice varieties. Therefore, there is the need for assessment of these varieties in order to provide information on the seed physiological potential of these rice varieties grown under guinea savannah under two cropping years. Objectives of the study was therefore to determine the seasonal effect on seed physiological quality parameters of some selected Nigerian rice varieties grown under guinea Savannah agro ecology.

Materials and methods

Twenty-two freshly harvested seed samples of the rice varieties grown in guinea savannah ecology in the 2017 and 2018 growing years were utilized for the study. Clean seed lots of each cultivated varieties were evaluated separately for this study. The experiment was arranged in a completely randomized design in three replicates. The 22 varieties and the two cropping years were factors evaluated. The laboratory study was carried out in the Seed Testing Laboratory of National Agricultural Seeds Council (NASC) Sheda, Abuja. Freshly harvested seed samples, after 30 days of harvest, were packaged inside aluminum foils for two weeks and afterwards tested for moisture content using halogen moisture meter (modeling). The moisture in each seed lots was regulated to 10.50 – 11.00% using oven drying method before laboratory seed analysis.

Seed quality determination and data collection

Seed lots under each of the two cropping years were analyzed for seed physiological quality attributes as follows-

Standard germination (%) were recorded as three replicates of 100-seed of each cultivar in 9cm diameter petri dishes inside moist paper towels with 100mls of distilled water and thereafter placed inside an incubator at 20-25^{o}C. Germination counts were taken after three, five and seven days of sowing (ISTA, 1995). Germination percentage was calculated based on the equation according to ISTA (1995).

$$SG = \frac{\text{Number of germinated seed x 100}}{\text{Number of seed sowed}}$$

Rate of germination (%) is calculated as speed of germination after 3-4 days of sowing and expressed in percentage of seed sown as reported by Adebisi (2004).

Seedling vigour index was determined according to the procedure of Adebisi (2004).

$$SV\ (1) = \frac{\text{Standard germination x seedling length}}{100}$$

Seedling shoot/root length (cm) was calculated on ten normal seedlings selected randomly after 7 days of sowing and their length measured from the shoot hypocotyl region to the top of cotyledon in centimeter and the root length was also determined in centimeter.

Weight of 100 seeds per variety was also determined in gramme (g)

Coleoptile length (cm) was measured as the average length of ten normal seedlings was selected to measure the coleoptiles length in centimeter.

Number of roots per seedling was the average number of roots per seedling were counted and recorded.

Data obtained were analyzed using SPSS for windows statistical software (version 25) package and analyzed for 2-way Analysis of Variance while treatment means were separated using Tukey's HSD test at 5% level of probability. The relationships between various pairs of traits were estimated using correlation analysis under each and across cropping years. Principal Component Analysis (PCA) was also computed to identify trait mostly responsible for the major variation within the entries.

Results and discussion

The present study focuses on the evaluation of the twenty-two rice varieties were evaluated in a field trial under rain-fed conditions at the National Agricultural Seeds Council, Sheda, Abuja in 2017 and 2018 cropping years to provide a comparative measure for effects of genotype by year interaction on physiological performance of selected Nigerian rice. The mean square from the combined Analysis of Variance (ANOVA) (not shown) of seed physiological quality parameters of 22 cultivated rice varieties over two year showed that the cropping year, variety and cropping year x variety interaction effect were highly significant for all physiological component evaluated except for seed germination which had a significant variety effect. Lawal (2020), reported that the existing variability would provide opportunity to select desirable varieties with good seed quality attributes within and across the cropping years.

The effect of cropping years on seed physiological quality parameters across the 22 cultivated rice varieties is presented in Table 1. The result indicates that significant differences existed between cropping year for rate of germination, seedling vigour index, 100 seed weight, seed germination days, seedling root length, coleoptile length and number of roots which all recorded higher values in 2017 compared to the values in 2018.

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Table 1: Cropping year effect on seed quality parameter of rice across varieties

Parameter	Cropping year (2017)	Cropping year (2017)	Superiority advantage (%)	Standard error	Tukey's HSD (0.05)
Rate of germination (%)	78.836	64.342	18.39	0.46	0.76
Seedling vigour index (%)	10.949	9.581	12.49	0.12	0.15
100 seed weight (g)	2.860	2.592	9.37	0.01	0.15
Seed germination	82.697	66.215	20.00	0.29	0.48
Seedling root length (cm)	13.853	9.549	31.07	0.13	0.22
Seedling shoot length (cm)	13.265	13.968	5.01	0.15	0.25
Coleoptile length (cm)	1.207	1.037	14.09	0.02	0.03
Number of root	4.005	2.172	45.71	0.04	0.07

However, seedling shoot length values (13.97cm) was higher in 2018 compared to 2017cropping year (13.27cm). The differences observed in all the eight seed quality attributes were due to influence of growing conditions during seed production in 2017 and 2018 cropping years. This suggests that Nigerian rice varieties grow best in moderately favorable weather conditions which favored seed quality as revealed in the two cropping years (2017 and 2018) considered under guinea savanna but the weather condition in 2017 had higher favorable effect on both seed yield and quality.

In Table 2, the mean performance of 22 cultivated rice varieties under two cropping years reveals that in 2017 and 2018, FARO 31 had the highest rate of germination of 93.66 and 89.50%, respectively. Also, highest seedling vigour index value for 2017 was observed in FARO 41, closely followed by 12.73% in FARO 59. In 2018, seedling vigour index was highest in FARO 41 and FARO 59 (13.91 and 13.28%) respectively. Table 3 shows that in 2017, highest 100 seed weight values was recorded in FARO 52 with a weight of 3.62g while other varieties recorded higher 100 seed weight values include FARO 22 (3.19g). In 2018, the highest 100 seed weight value of 3.21g was observed in FARO 22 which was not statistically different from those values observed in FARO 61 (3.10g), FARO 45 (2.87g), FARO 48 (2.87g) and FARO 52 (2.86). The lowest 100 seed weight in 2018 was recorded in FARO 27 and FARO 64 with values of 1.77 and 1.78g, respectively. With regards to seed germination, in 2017 cropping year (Table 4) FARO 31 and WAB 189 with 94.00 % recorded the highest values. Furthermore, in 2018, seed germination was highest (92.60 %) in FARO 31 closely followed by 87.50 % in FARO 41. The implication of this performance is that genotypes with high seed quality attributes can be considered in future seed improvement strategy (Adebisi, 2004). The mean performance of 22 Nigerian cultivated rice varieties for seedling root length and seedling shoot length in two cropping years under guinea savannah agro-ecological conditions is presented in Table 4. The result indicates that seedling root length ranged from 10.92 cm in 2017 for FARO 59 to 17.28cm for FARO 27. The result further reveals that for 2018, seedling root length values were generally lower compared to 2017 and highest value was recorded in FARO 22 (14.38cm). However, the result reveals that seedling shoot length in 2017 was highest in FARO 59 (15.22cm). While in 2018, seedling shoot length was highest in FARO 59 (16.22cm).

Table 2: Mean performance of 22 cultivated rice varieties for rate of germination and seedling vigour index in two cropping years under savannah agro ecological conditions

Rice varieties	Rate of germination		Varietal mean	Seedling vigour index		Varietal mean
	2017	2018		2017	2018	
FARO 62	72.66e	74.00c	73.33efgh	11.65c	10.60d	11.13b-e
FARO 60	88.67b	57.50g	73.08efgh	12.38bc	9.26e	10.83b-e
FARO 52	25.00f	77.00bc	51.00l	4.82f	11.86c	8.34ghij
FARO 61	71.73e	68.03de	70.50ghi	10.71d	9.03e	9.87d-g
FARO 41	89.66b	86.50a	88.08ab	13.62a	12.86b	13.25a
FARO 22	80.66cd	78.50b	79.58cdef	10.50d	11.17cd	10.84b-e
WAB 189	90.66ab	37.00i	63.83ijk	8.69e	5.90g	7.29j
FARO 21	79.66d	63.50ef	71.58fghi	10.35d	8.82ef	9.59e-i
FARO 63	88.00b	73.50cd	80.75bcde	11.95bc	10.29de	11.12b-e
FARO 64	88.66b	35.00i	61.83jk	12.63b	4.43gh	8.53f-g
FARO 50	83.66c	49.50h	66.58ijk	11.23c	8.87ef	10.05d-g
FARO 27	76.66de	29.50j	53.08l	12.07bc	3.75h	7.92hij
FARO 57	74.66e	61.00f	67.83ghij	11.68c	8.28f	9.99d-g
FARO 48	80.66cd	69.50d	75.08d-g	11.42c	9.44e	10.43d-g
FARO 47	79.00d	38.00i	58.50kl	10.04d	5.30g	7.67ij
FARO 59	77.66de	65.50e	71.58fghi	12.73ab	12.30b	12.52b-e
FARO 44	77.00d	68.50de	72.75efgh	11.36c	9.83de	10.59b.e
FARO 58	72.66e	68.00de	70.33ghi	9.04e	11.17cd	10.11e-h
FARO 65	80.66cd	79.00b	69.33ghij	11.62c	8.00f	9.82abc
FARO31	93.66a	89.50a	91.58a	11.45c	13.28ab	12.37abcd
PAC 832	88.00b	79.00b	83.50abc	11.61c	12.32bc	11.97a-e
FARO 45	74.66e	89.00a	81.83bcd	9.24e	13.91a	11.58a-e

Means followed by the same alphabet along the column are not different from another at 5% probability level.

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Table 3: Mean performance of 22 cultivated rice varieties for 100 seed weight (g) and seed germination in two cropping years under guinea savannah ecology

Rice varieties	100 seed weight (g) 2017	2018	varietal mean	Seed germination (%) 2017	2018	Varietal Mean
FARO 62	2.80e	2.57e	2.688d-g	80.66e	77.00ef	78.83def
FARO 60	2.90e	2.67d	2.787b-e	89.66bc	64.00k	76.83efg
FARO 52	3.62a	2.86cd	3.245a	35.66h	77.75ef	56.70l
FARO 61	3.19c	3.10 b	3.151a	78.32f	70.22gh	74.27fgh
FARO 41	2.97de	2.77c	2.874bcd	91.66b	87.50b	89.58ab
FARO 22	3.46b	3.21a	3.338a	83.00de	78.75e	80.87de
WAB 189	2.527h	2.05g	2.289h	94.00a	37.25m	65.62j
FARO 21	2.78f	2.65de	2.720c-g	73.66g	63.50k	68.58ij
FARO 63	2.76f	2.60de	2.681d-g	91.00bc	73.75g	82.37cd
FARO 64	2.20i	1.78h	1.994i	91.00bc	37.75m	64.37jk
FARO 50	2.88e	2.27f	2.577efg	87.00c	55.00l	71.00hi
FARO 27	2.17i	1.77h	1.974i	81.667de	29.50n	55.58l
FARO 57	2.97de	2.76d	2.871bcd	83.00de	64.25k	73.62gh
FARO 48	2.94e	2.87c	2.909bc	88.00c	71.75hi	79.87def
FARO 47	3.17c	2.50e	2.840bcd	81.00e	38.50m	59.75kl
FARO 59	2.77f	2.74d	2.759b-f	83.66d	70.50hi	77.08efg
FARO 44	2.64g	2.38f	2.510j	78.00f	69.25j	73.62ghi
FARO 58	3.06d	2.83cd	2.947b	77.00f	69.00j	73.00ghi
FARO 65	2.94e	2.27f	2.609efg	74.00g	72.00h	73.00ghi
FARO31	2.42h	2.71d	2.569fg	94.00a	92.60a	93.33a
PAC 832	2.72f	2.69d	2.709c-g	88.76c	84.77c	86.75bc
FARO 45	2.99d	2.87c	2.934b	84.40de	82.25d	83.33cd

Means followed by the same alphabet along the column are not different from another at 5% probability level.

The mean performance of 22 Nigerian cultivated rice varieties for coleoptile length (mm) and number of roots in two cropping years under savannah agro ecological conditions (not shown) ranged from 1.01cm in 2017 for FARO 44 to 1.7cm for FARO 59. In 2018, highest coleoptile length value was recorded in FARO 45, PAC 832, FARO 48, FARO 21 and FARO 22 with values of between 0.72 and 0.77 cm. also, the average number of roots in 2017 cropping year shows that FARO 65 and FARO 31 and PAC 832 were with highest values of (4.60-4.70) closely followed by FARO 45, FARO 58 and FARO 48 and FARO 22 with 4.40 number of roots.

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Table 4: Mean performance of 22 cultivated rice varieties for seedling root length and shoot length two cropping years under derived savannah ecology

Rice varieties	Seedling root length(cm)			Seedling shoot length(cm)		
	2017	2018	Varietal mean	2017	2018	Varietal mean
FARO 62	13.08cd	11.52c	12.30b-g	14.46ab	13.27c	13.86ab
FARO 60	13.87bc	7.49ef	10.68d-i	13.83b	13.15c	13.49ab
FARO 52	12.44d	11.23c	11.83b-h	13.51bc	15.11ab	14.49ab
FARO 61	13.16c	9.31de	11.23b-h	13.54bc	12.47c	13.01ab
FARO 41	11.84de	7.15f	9.49i	14.86ab	14.55b	14.70ab
FARO 22	14.40bc	14.38a	14.39a	12.64c	14.15bc	13.39ab
WAB 189	11.89de	8.34e	10.11ghi	9.25d	15.81ab	12.53b
FARO 21	14.29b	8.67de	11.48b-i	14.04b	13.90bc	13.97ab
FARO 63	12.74cd	6.94f	9.84hi	13.14bc	13.88bc	13.97ab
FARO 64	13.98c	9.41d	11.69b-i	13.88b	10.97d	12.42b
FARO 50	13.74c	9.52d	11.63b-i	12.92bc	14.67b	13.79ab
FARO 27	17.28a	8.50de	12.89bcd	14.78ab	12.80c	13.79ab
FARO 57	16.88a	5.26g	11.07c-i	14.06b	12.26c	13.16ab
FARO 48	13.50cd	13.98a	13.74ab	12.99bc	12.76c	12.87b
FARO 47	14.79b	11.46c	13.12abc	12.37c	13.53bc	12.95b
FARO 59	10.92e	9.80d	10.36fghi	15.22a	16.22a	15.12a
FARO 44	13.64c	7.21f	10.42e-i	14.58ab	14.06bc	14.32ab
FARO 58	16.86a	8.31e	12.58b-f	11.75c	16.01a	13.88ab
FARO 65	12.68d	12.78b	12.73b-d	13.37bc	13.31c	13.88ab
FARO31	14.61bc	10.65cd	12.63b-e	12.23c	13.76bc	12.99b
PAC 832	13.71c	9.27de	11.49b-i	12.35c	15.36ab	13.85ab
FARO 45	14.46bc	8.90de	11.60b-i	12.05c	15.29ab	13.67ab

Means followed by the same alphabet along the column are not different from another at 5% probability level.

In the corresponding 2018 cropping year, the average number of roots among the 22 varieties was statistically similar with values of between 2.08 and 2.40. This findings is in consonance with the report of Okelola *et al*., (2019). The performance of the varieties across the cropping years showed that FARO 41 had consistent and highest performance for most of seed quality attributes (rate of germination (83.50%) seedling vigour (13.25%), seed germination (89.53%) and number of roots (3.25), followed by FARO 31 with higher rate of germination and seed germinations (93.33%) with moderate to high seedling growth parameters. Hundred seed weight values of FARO 52 and 61 were the heaviest compared to other varieties. Generally, FARO 52 and WAB 189 were varieties with lowest rate of germination, seed germination and seedling vigour parameters. The variability in seed quality attributes could be due to differences in the genetic composition of the seeds. The implication of this performance is that genotypes with high seed quality attributes can be considered in future seed improvement strategy (Adebisi, 2004).

The correlation coefficient between seed physiological attributes of 22 Nigerian cultivated rice varieties across two cropping years are presented in Table 7. Rate of germination recorded a positive and significant correlation values with seedling vigor index (r=0.84**), 100 seed weight (r=0.31**), Seed germination (0.94**) and number of roots (r=0.44**). It further reveals that seedling vigor index was positively and significantly correlated with 100 seed weight (r=0.31**), seed germination (0.86**), seedling root length (r =0.21) and number of roots (r=0.28**). Similarly, 100 seed weight showed highly significant and positive correlation values with seed germination (0.36**), seedling root length (r =0.30) and number of roots (r=0.23**). Seed germination was positively and significant correlated with seedling root length (r =0.33) and number of roots (r=0.49**). Also, seedling root length, seedling shoot length and coleoptile length were all positively correlated with number of roots with values of r= 0.81**, r=0.23** and r=0.30** respectively. Notably, the number of roots recorded good relationship with all the seed quality parameters implying that increase in all seed quality parameters will directly lead to proportional increase in number of seedling roots in cultivated rice. Similar observations were reported by Muthuvijayaragavan and Jebaraj (2022) in Rice.

Table 7: Correlation coefficients between seed quality parameters of cultivated rice varieties across two cropping years under guinea savannah ecology

Seed quality Parameters	**Seedling vigour index**	**100 seed weight (g)**	**Seed germination (%)**	**Seedling root length (cm)**	**Seedling shoot length (cm)**	**Coleoptile length (cm)**	**Number of root**
Rate of germination	0.84**	0.31**	0.94**	0.33**	0.01	0.03	0.44**
Seedling vigour index		0.31**	0.86**	0.21**	0.47*	0.07	0.28**
100 seed weight			0.36**	0.30**	0.01	0.11	0.23**
Seed germination				0.38**	0.01	0.05	0.49**
Seedling root length (cm)					0.12	0.20	0.81**
Seedling shoot length (cm)						0.14	0.23**
Coleoptile length (cm)							0.30**

*, ** Correlation significant at 1 and 5% probability level, respectively

Similar observations were earlier documented on seed quality attributes by Okelola *et al.,* (2019) in NERICA rice.

Combined multivariate analysis of seed physiological attributes across two cropping years is presented in Table 8. First three principal components had eigen values greater than 1. These three axis with eigen values of 5.276, 1.673 and 1.093 jointly accounted for 80.927% of the total variation among the varieties. The first PC accounted for 52.758% of the variability and was related to rate of germination (0.968), seedling vigor index (0.871), 100 seed weight (0.427), seed germination (0.987), seedling root length (0.463) and number of roots (0.562). The second PC accounted for 16.732 % of the total variation and was dominated by seedling vigour index (-0.437), seedling root length (0.535), Seedling shoot length (-0.754), Coleoptile length (0.475) and number of roots (0.621). The third PC was dominated by 100 seed weight (-0.625), seedling root length (-0.426) and coleoptile length (0.690). This principal component explained an additional 10.927% of the variability. In this study, all the seed quality which have been confirmed through the two principal component axes with cumulative of 69.49%, accounted for major variation over the 22 rice varieties evaluated. These seed qualities parameters could be used as dependable criteria due to their significant contribution to the total variation. Similar trends were observed by various authors Adebisi *et al.*, (2008), Abdul Rafiu (2015); Lawal *et al.*, (2018), Dudhe *et al.*, (2018), Adebisi *et al.*, (2022) in sesame, cayenne pepper, groundnut and rice, respectively.

Table 8: Principal components analysis explaining variation in seed quality components of cultivated rice varieties across cropping years

Variable	PC1	PC2	PC3
Eigen value	5.276	1.673	1.093
Variance (%)	52.758	16.732	10.927
Cumulative (%)	52.758	69.490	80.927
Rate of germination (%)	0.968	-0.071	0.121
Seedling vigour index (%)	0.871	-0.437	0.059
100 seed weight (g)	0.427	-0.043	-0.625
Seed germination (%)	0.968	-0.071	0.121
Seedling root length (cm)	0.463	0.535	-0.426
Seedling shoot length (cm)	0.041	-0.754	0.015
Coleoptile length (cm)	0.055	0.475	0.690
Number of roots	0.562	0.621	-0.019

The study concluded that effect of genotype x year interaction was significant for all the eight seed quality attributes evaluated. Seed germination was strongly related to seedling vigour, seedling root length, 100 seed weight and number of roots and should be used as selection criteria in rice improvement. Also, FARO 41 as well as FARO 31 with superior performance in seed quality attributes are thus recommended for seed improvement programme.

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