

Genetic variability and heritability of yield and yield components in some rice genotypes

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ABSTRACT

Sixteen genotypes of rice (*Oryza sativa* L.) were evaluated during 2008 and 2009 growing seasons at Ed-duim and Kosti to assess genetic variability and heritability of grain yield and its components in these locations. A randomized complete block design with three replicates was used in each location. The analysis of variance mean squares revealed highly significant ($P < 0.01$) differences for most of the studied traits in both seasons, indicating that these genotypes are highly variable. Genotypes differed significantly in grain yield. Genotypes NERICA 4 and NERICA 14 were the highest yielders (4.66 and 3.73 t/ha, respectively). Days to 50% maturity had the highest genotypic variance followed by number of grains per panicle and days to 50% flowering. The highest phenotypic variance was obtained by number of grains per panicle and days to 50% maturity. Broad sense heritability estimates varied among the studied traits. The highest heritability estimate (75%) was observed for days to 50% flowering, while the lowest (42.35%) was shown by grain yield. Days to 50% flowering and 1000 grain weight showed the highest heritability and hence could be used as selection criteria for grain yield improvement. The results suggested NERICA 14 and NERICA 4 as promising genotypes for further testing over locations and years.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's main staple food crops, with nearly 2.5 billion people depending on it as their main food (FAO, 2004). Rice in Sudan has been grown since 1905, but on a very limited acreage and information about methods of production are lacking. Swamp and upland varieties were first tried at the Gezira Research Station Farm in 1951. Later, extensive rice trials were carried out at Malakal and several varieties were selected at the Gezira Research Station. Recently, different genotypes from West African Rice Development Association (WARDA) and International Rice Research Institute (IRRI) are being evaluated for yield and earliness although, 82 aerobic rice varieties and lines were introduced in an attempt to save irrigation water and to reduce human diseases risks in the irrigated schemes. Also, FAO is planning to rehabilitate the White Nile research farm to improve rice production.

Genetic diversity is a pre-requisite for any crop improvement program, as it helps in the development of superior recombinants (Manonmari and Fazlullah Khan, 2003). Genetic divergence among the genotypes plays an important role in selection of parents having wider variability for different characters (Nayak *et al.*, 2004). Genetic diversity can be evaluated with morphological traits, seed protein, isozymes and DNA markers. Nuruzzaman *et al.* (2002) studied variability for eight quantitative characters in 14 rice genotypes. They found significant mean squares indicating strong variability among the genotypes for the traits studied.. Heritability (h^2) of a trait is important in determining its response to selection. High heritability estimates have been found to be helpful in making selection of superior genotypes on the basis of phenotypic performance. Johnson *et al.* (1955) suggested that heritability estimates along with genetic advance (%) of the mean were more helpful in predicting the effect of selecting the best individual. Qamar *et al.* (2005) reported that broad sense heritability estimates was generally high for all the traits studied except grain yield per plant (45.88 %) in the aromatic rice group.

The present study, therefore, aimed at assessing genetic variability and heritability of yield and yield components in some rice genotypes.

MATERIALS AND METHODS

The experiment was conducted during 2008 and 2009 seasons at two locations: Ed-duim, Faculty of Agriculture and Natural Resources farm, University of Bakht Alruda (long. 32°20'E, lat. 13° 39' N and 380 msl) and Kosti Research Station farm of the Agricultural Research Corporation (ARC) (long. 32° 46,' lat. 13° 6' N) to evaluate 16 rice genotypes (Table 1). The genetic material used in this study was kindly provided by Prof. Ahmed Mohamed Mustafa as part of his rice breeding research program in the ARC, Sudan.

The genotypes were tested in a randomized complete block design with three replicates. Seeds were directly sown in 8 m² plot with a spacing of 20x20 cm. Triple super phosphate was applied at the rate of 43kg P₂O₅/ha before sowing. Nitrogen, in the form of urea, was applied in two equal doses; one after 21 days from sowing and the second one after one month from the first one at the rate of 86 kg N/ha in each location.

Data collection and analysis

Parameters measured

Five plants were selected randomly from each plot, and the following agronomic traits were measured:

- 1- Days to 50% flowering (DTF): This character was recorded only in season 2009. It was estimated as the number of days from sowing to the time when 50% of the plants/plot started to flower.
- 2- Days to 50% maturity (DTM): This character was recorded only in season 2009. It was the number of days from sowing to the time when 50% of the panicles reached full maturity (panicles color turned yellow).
- 3- Plant height (PH) (cm).
- 4- Panicle length (PL) (cm): Average length per panicle.
- 5- Number of tillers/plant (NTP).
- 6- Total number of grains/ panicle (NGP).
- 7- Number of filled grains/panicle (NFG): Filled grains from each panicle were counted and recorded.
- 8- Percentage of unfilled grains/panicle (PUG):

$$\text{PUG} = \frac{\text{Number of unfilled grains/panicle}}{\text{Total number of grains/panicle}} \times 100$$

- 9- Number of panicles/ m² (NP/m²).
 10- 1000-grains weight (TGW) (g): Determined by weighing 1000 grains samples taken at random from the bulk of grains from five plants harvested in each plot.
 11- Grain yield (GY) (t/ha): Measured from the harvested area of one m² for each plot and converted to t/ha.

Data were subjected to analysis of variance using SAS computer program. Means were separated using Duncan's Multiple Range Test at 5% level of significance. Broad sense heritability (h^2_B) was calculated using Blab stat computer program.

Table 1. Rice genotypes evaluated for yield and yield components at Ed-duim and Kosti during 2008 -2009.

Genotypes	Origin
NERICA 2	WARDA
NERICA 4	WARDA
NERICA 5	WARDA
NERICA 12	WARDA
NERICA 14	WARDA
NERICA 15	WARDA
NERICA 17	WARDA
YUNLU 22	China
YUNLU 24	China
YUNLU 26	China
YUNLU 30	China
YUNLU 33	China
YUNLU 34	China
WAB-1-38-19-14-P2-HB	IRRI
WAB880-1-38-19-8	IRRI
WAB891SG12	IRRI

WARDA= West African Rice Development Association.

IRRI= International Rice Research Institute.

RESULTS AND DISCUSSION

Analysis of variance for individual locations revealed significant variations among the 16 rice genotypes for most of the studied traits, indicating that these genotypes are highly variable especially for the traits that are significant, thus genetic improvement through selection could be promising.

Genetic variability and heritability of yield and yield components in some rice genotypes

In the first season, the mean squares were highly significant ($P>0.01$) for all traits except number of tillers/plant and panicle length (cm) at Ed-duim (Table 2). However, at Kosti all the traits showed no significant differences, except 1000-grain weight and grain yield which showed highly significant differences. The significant differences in the traits between the two locations demonstrated that genotypes responded differently to the variation in environmental conditions of location. The most consistent performance was observed for the traits 1000-grains weight and grain yield in both locations.

Table 2. Mean squares of agronomic traits of 16 rice genotypes evaluated at Ed-duim and Kosti during 2008 growing season.

Traits	Ed-duim	Kosti
Plant height (cm)	71.01**	156.84 ^{ns}
Number of tillers/plant	4.79 ^{ns}	1.066 ^{ns}
Panicle length (cm)	5.28 ^{ns}	3.631 ^{ns}
Number of grains/panicle	170.38**	131.72 ^{ns}
Number of filled grains/panicle	127.38**	99.68 ^{ns}
Percentage of unfilled grains/panicle	122.17*	163.77 ^{ns}
Number of tillers/m ²	9366.3**	5810.63 ^{ns}
1000-grains weight(g)	31.59**	49.37**
Grain yield (t/ha)	1.59**	1.12**

*, ** Significant at the 0.05 and 0.01 probability levels, respectively. ns: Not significant.

In the second season, the mean squares were highly significant for the traits plant height, number of filled grains/panicle, days to 50% flowering, days to 50% maturity and 1000-grain weight at Ed-duim (Table 3), while at Kosti, only panicle length, days to 50% maturity and 1000-grains weight showed significant variations. These results indicated appreciable environmental differences between the two seasons, though reflected that the performance of genotypes varied with locations.

Table 3. Mean squares of agronomic traits of 16 rice genotypes evaluated at Ed-duim and Kosti during 2009 growing season.

Traits	Ed-duim	Kosti
Plant height (cm)	192.93**	153.10 ^{ns}
Number of tillers/plant	1.22 ^{ns}	0.931 ^{ns}
Panicle length (cm)	4.46 ^{ns}	6.66*
Number of grains/panicle	843.25 ^{ns}	534.75 ^{ns}
Number of filled grains/panicle	861.24**	206.66 ^{ns}
Percentage of unfilled grains/panicle	188.73 ^{ns}	94.38 ^{ns}
Number of tillers/m ²	1189.78 ^{ns}	11188.75 ^{ns}
1000-grains weight(g)	23.46**	16.46*
Grain yield (t/ha)	1.24 ^{ns}	5.34 ^{ns}
Days to 50% flowering	111.53**	84.38 ^{ns}
Days to 50% maturity	116.68**	336.64**

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

ns : Not significant.

Broad sense heritability

Genotypic variance, phenotypic variance and broad sense heritability estimates were reported in Table 4. Genotypic variance (VG) ranged from 0.11 to 47.00. Days to 50% maturity had the highest VG followed by number of grains per panicle and days to 50% flowering. Phenotypic variance (VP) ranged from 0.28 to 94.40. Highest VP was obtained in number of grains per panicle followed by days to 50% maturity. The difference was low for 1000-grain weight. Grain yield had a moderate amount of difference between VG and VP, while number of grains per panicle had a considerable high difference between VG and VP. These results imply that traits with low difference in VG and VP show that variability is more due to genetic cause.

Phenotypic variance was higher than genotypic variance for all the examined traits. These results agreed with those reported by Zahid *et al.* (2006). Days to 50% flowering, 1000-grain weight, plant height and days to 50% maturity showed high (75, 72.06, 66.06 and 66 %) heritability estimates, respectively. These findings agreed with the results obtained by Vange (2008) for days to 50% flowering and days to 50% maturity. This indicated that selection of these traits would be more effective as compared to traits like

number of tillers/plant, panicle length, number of grains/panicle and number of tillers/m² that have moderate heritability.

Iftikhar *et al.* (2001) reported high heritability(h^2_B) estimates for plant height, 1000-grain weight and days to maturity, which support the present findings. The lowest heritability estimate was given by number of filled grains/panicle (19.12), indicating that this trait is highly affected by varying environmental conditions. Heritability estimate for grain yield was medium (42.35). Qamar *et al.* (2005) reported 45.88% heritability for grain yield per plant in aromatic rice. Grain yield is known to have low heritability and it is highly influenced by the environment. High heritability estimates have been found to be effective in the selection of superior genotypes on the basis of phenotypic performance.

Table 4. Genotypic variance (VG), phenotypic variance (VP) and broad sense heritability (h^2_B) for 11 traits of 16 rice genotypes over seasons and locations.

Trait	VG	VP	h^2_B (%)
PH	19.23	29.12	66.05
NTP	0.11	0.28	42.66
PL	0.40	0.82	48.82
NGP	38.00	94.40	40.00
NFG	6.43	33.60	19.12
PUG	6.90	18.90	36.54
DTF	33.00	44.00	75.00
DTM	47.00	71.00	66.00
NT/m ²	6.71	18.10	36.00
TGW	4.82	6.68	72.06
GY	0.18	0.44	42.35

PH = Plant height(cm), NTP = Number of tillers/plant, PL = Panicle length(cm), NGP = Number of grains/panicle, NFG = Number of filled grains/panicle, PUG = Percentage of unfilled grains/panicle, DTF = Days to 50% flowering, DTM = Days to 50% maturity, NT/m² = Number of tillers/m², TGW = 1000-grains weight, GY=Grain yield(t/ha).

Mean separation and ranking

Number of grains per panicle was significantly different in both seasons (Tables 5 and 6). Genotype YUNLU 30 scored the maximum number of grains per panicle (115.8) in season 2009 (Table 6), while the lowest number of grains/panicle (39.5) was exhibited by genotype NERICA 2 in season 2008 (Table 5). Number

of grains per panicle and 1000-grain weight have positive genotypic and phenotypic correlations with grain yield (Bhatti *et al.*, 2005). Adequate number of fertile grains/panicle and heavy grains are important traits, which should be considered in selection for high yield (Surek *et al.*, 2003).

It was observed that number of filled grains per panicle were greatly higher in season 2009. The highest number of filled grains (84.5) was given by the genotype YUNLU 30 in season 2009 (Table 6), while NERICA 2 scored the lowest value (17.3) for such trait in the first season 2008. For high yield in rice, the plant should have a large number of filled grains/panicle (Ramalingam *et al.*, 1993).

The percentage of unfilled grains per panicle were significantly different in both locations and seasons. Higher percentage was observed in the first season (2008). This could be due to the high temperature during flowering time in this season. Genotype NERICA 5 showed maximum average mean of unfilled grains/panicle (37%) in both seasons (Tables 5 and 6), while the lowest percentage (18.5) was observed in genotype NERICA 14 in both seasons (Tables 5 and 6). In order to increase yield, it is important to reduce spikelet sterility or to increase spikelet fertility (Luzikihupi, 1998).

Genotype NERICA 17 exhibited the highest mean (32 g) of 1000-grain weight in season 2008 (Table 5), while NERICA 12 scored the highest value (30.1 g) in season 2009 (Table 6). Heavy 1000-grain weight is an important trait, which should be considered in selection for high yield. Genotype NERICA 5 showed the lowest means (20.0 and 22.3 g), respectively, in both seasons (Tables 5 and 6). Bagali *et al.* (1999) reported a positive association of 1000-grains weight with grain yield.

Significant variations were observed in number of panicles/ m² between the two seasons and in both locations. This could be due to the different environmental conditions. NERICA 17 produced the highest number of panicles/m² in season 2008 (447.5) (Table 5), while NERICA 4 scored the highest value (393.6) in season 2009 (Table 6). The genotype YUNLU 30 showed the lowest value (272.5) of number panicles/ m² (Table 6). Vange (2008) reported that the number of panicles/m² was positive and was significantly correlated with yield and it can serve as an indicator in selecting for high yield in the material studied.

Genetic variability and heritability of yield and yield components in some rice genotypes

Grain yield largely depends on climatic conditions. The data in Table 6 show that the environmental conditions for producing high grain yields were better in season 2009 than in 2008. It was observed that genotypes NERICA 14 and NERICA 4 were more consistent in high grain yield and they scored the maximum yields in both seasons with means of 3.73 and 4.66 t/ha, respectively (Tables 5 and 6). The outstanding performance of NERICA 14 for grain yield seems to be due to its lower percentage of unfilled grains per panicle in the two seasons. YUNLU 30 scored the highest grain yield in season 2008 (3.26 t/ha) but the yield was reduced in the second season due to the low number of panicles per meter square (272) (Table 6). NERICA 5 gave the lowest 1000 grain weight, highest percentage of unfilled grains per panicle and generally low grain yield (1.90 t/ha).

In conclusion, NERICA 14 and NERICA 4 appear as promising genotypes for further improvement while days to 50% flowering and 1000 grain weight showed the highest heritability and they could be used as selection criteria for grain yield improvement.

Table 5. Yield and its components of 16 rice genotypes, evaluated at EDduim and Kosti in season 2008 (combined over locations).

Genotypes	NGP		NFG		PUG	
	Rank	Mean	Rank	Mean	Rank	Mean
NERICA 2	16	39.5 d	16	17.3f	7	28.5abc
NERICA 4	7	51.5abcd	3	31.8abc	11	24.5abc
NERICA 5	15	41.2cd	15	20.0ef	1	37.0a
NERICA 12	1	60.5a	1	37.8a	14	23.5bc
NERICA 14	6	52.2abcd	8	28.7bcd	16	18.5c
NERICA 15	12	45.3bcd	9	27.2bcde	9	26.5abc
NERICA 17	13	45.3abc	13	23.2cdef	6	29.0abc
YUNLU 22	14	44.7bcd	14	22.8def	5	30.0abc
YUNLU 24	5	53.2abcd	12	25.8bcde	8	28.3abc
YUNLU 26	2	56.3ab	2	33.7ab	4	30.8abc
YUNLU 30	10	48.3abcd	6	30.3abcd	12	24.5abc
YUNLU 33	3	55.0abc	7	29.3bcd	13	24.2abc
YUNLU 34	4	45.0abcd	5	30.8abcd	15	20.2c
WAB880-1-38-19-8	8	51.1abcd	4	31.3abcd	2	35.5ab
WAB891SG12	9	49.8abcd	11	26.4bcde	3	34.0ab
WAB-1-38-19-14-P2-HB	11	48.3abcd	10	26.8bcde	10	24.8abc

Table 5. Continued.

Genotypes	TGW		NP/m ²		GY	
	Rank	Mean	Rank	Mean	Rank	Mean
NERICA 2	15	20.8ef	2	443.3a	13	2.66fg
NERICA 4	14	23.0def	7	405.0abc	5	2.90bcde
NERICA 5	16	20.0f	10	382.5abc	16	1.90g
NERICA 12	2	31.6a	5	405.8abc	4	3.05bcd
NERICA 14	11	25.0bcde	13	377.5abc	1	3.73a
NERICA 15	3	29.1ab	16	312.5c	8	2.65def
NERICA 17	1	32.0a	1	447.5c	15	1.93g
YUNLU 22	13	23.3def	8	398.3abc	9	2.38efg
YUNLU 24	9	24.3bcde	6	405.0abc	12	2.26fg
YUNLU 26	6	26.6bcd	11	380.8abc	10	2.30fg
YUNLU 30	12	24.0cdef	3	425.8ab	2	3.26ab
YUNLU 33	5	28.3abc	12	377.5abc	7	2.70cdef
YUNLU 34	10	25.0bcde	15	340.8bc	11	2.28fg
WAB880-1-38-19-8	7	25.7bcd	9	394.1abc	3	3.22abc
WAB891SG12	8	25.6bcde	14	372.0abc	14	2.08g
WAB-1-38-19-14-P2-HB	4	28.6abc	4	416.6ab	6	2.70cdef

NGP, number of grains/panicle; NFG, number of filled grains/panicle; PUG, percentage of unfilled grains/panicle; TGW, 1000-grain weight; NP/m², number of panicles/m² and GY, grain yield (t/ha).

Table 6. Yield and its components of 16 rice genotypes, evaluated at EDduim and Kosti in season 2009 (combined over locations).

Genotypes	NGP		NFG		PUG	
	Rank	Mean	Rank	Mean	Rank	Mean
NERICA 2	5	99.5ab	10	64.7abc	7	28.5abc
NERICA 4	4	101.3ab	4	75.7abc	11	24.5abc
NERICA 5	6	99.0ab	8	66.8abc	1	37.0a
NERICA 12	11	90.7ab	9	66.5abc	14	23.5bc
NERICA 14	7	98.7ab	2	81.7ab	16	18.5c
NERICA 15	2	103.8ab	5	74.7abc	9	26.5abc
NERICA 17	14	87.3ab	12	60.5bc	6	29.0abc
YUNLU 22	16	81.7b	15	56.8c	5	30.0abc
YUNLU 24	12	90.3ab	11	64.3abc	8	28.3abc
YUNLU 26	15	85.3b	14	59.5bc	4	30.8abc
YUNLU 30	1	115.8a	1	84.5a	12	24.5abc
YUNLU 33	9	94.3ab	7	73.3abc	13	24.2abc
YUNLU 34	8	94.5ab	6	74.2abc	15	20.2c
WAB880-1-38-19-8	10	93.7ab	16	53.3c	2	35.5ab
WAB891SG12	13	89.0ab	13	60.2bc	3	34.0ab
WAB-1-38-19-14-P2-HB	8	103.5ab	3	77.0abc	10	24.8abc

NGP, number of grains/panicle; NFG, number of filled grains/panicle; PUG, percentage of unfilled grains/panicle; TGW, 1000-grain weight; NP/m², number of panicles/m² and GY, grain yield (t/ha).

Table 6. Continued.

Genotypes	TGW		NP/m ²		GY	
	Rank	Mean	Rank	Mean	Rank	Mean
NERICA 2	12	24.1cde	14	292.5ab	15	2.75ab
NERICA 4	9	24.3cde	1	393.6a	1	4.66a
NERICA 5	16	22.3e	13	294.8ab	16	2.41b
NERICA 12	1	30.1a	10	307.5ab	13	3.16ab
NERICA 14	2	28.3ab	11	306.6ab	5	4.33ab
NERICA 15	7	26.3bcd	12	295.0ab	8	3.83ab
NERICA 17	5	27.0abc	5	337.5ab	14	3.08ab
YUNLU 22	10	24.3cde	2	369.1ab	9	3.75ab
YUNLU 24	3	27.6abc	9	311.3ab	6	4.33ab
YUNLU 26	8	26.0bcde	6	323.3ab	7	3.91ab
YUNLU 30	15	22.6de	16	272.5b	12	3.16ab
YUNLU 33	14	24.0cde	4	245.5ab	2	4.41a
YUNLU 34	11	24.3cde	3	353.8ab	3	4.33ab
WAB880-1-38-19-8	4	27.3abc	15	288.3ab	11	3.41ab
WAB891SG12	13	24.0cde	8	312.5ab	10	3.50ab
WAB-1-38-19-14-P2-HB	6	27.0ac	7	314.6ab	4	4.33ab

NGP, number of grains/panicle; NFG, number of filled grains/panicle; PUG, percentage of unfilled grains/panicle; TGW, 1000-grain weight; NP/m², number of panicles/m² and GY, grain yield(t/ha).

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التباين الوراثي ودرجة التوريث للإنتاجية ومكوناتها لبعض سلالات الأرز خالد عبدالله محمد حسن¹، أبو الحسن صالح إبراهيم² و أحمد محمد المصطفى³

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الخلاصة

اختبرت 16 سلالة من الأرز في الحقل في موسمي 2008 و2009 في الدويم وكوستي بهدف تقييم التباين ودرجة التوريث لإنتاجية الحبوب ومكوناتها في بيئة هذه المواقع. استخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات في كل موقع. أظهرت نتائج تحليل التباين فروقات معنوية ($P < 0.01$) بين السلالات لمعظم الصفات التي درست. هذا يدل على وجود اختلافات وراثية كبيرة بين هذه السلالات. اختلفت السلالات معنويا في إنتاج الحبوب. كان 14 NERICA 4 أكثرها إنتاجية (4.66 و3.73 طن/هكتار على التوالي). اظهرت صفة عدد الايام حتى 50% نضج أعلى تباين وراثي تبعتها عدد البذور في السنبله وعدد الأيام حتى 50% ازهار. أعلى تباين مظهري ظهر في صفة عدد البذور في السنبله ثم عدد الايام حتى 50% نضج. اختلف معامل التوريث على المدى العريض بين الصفات المدروسة. أعلى معامل توريث لوحظ لعدد الأيام حتى 50% ازهار (75%)، بينما أظهر إنتاج الحبوب درجة توريث متوسطة (42.35%) كذلك يمكن استخدام الصفات عدد الأيام حتى 50% نضج ووزن الالف حبة كمعايير للانتخاب لتحسين الانتاجية لانها اظهرت درجة توريث عالية. تقترح الدراسة الاصناف 4 NERICA و 14 NERICA كأصناف واعدة.