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Full Length Research Paper

Evaluation of intra and interspecific rice varieties adapted to valley fringe conditions in Burkina Faso

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The immense potential of the lowlands in Burkina Faso for durable intensification of rice cropping have not been realised due to biotic and abiotic stress constraints. To this end, the rice research program in Burkina Faso evaluated 16 intra-and interspecific lowland progenies in 2002 and 2003. The aim of the study is to introduce new lowland NERICAs through a participatory approach and to identify ideotypes that are adapted to lowland conditions. Variability was found among the 16 rice varieties with respect to the 9 variables that were evaluated. A principal components plot and clustering analysis technique were used to group 16 intra-and interspecific lowland progenies. The interspecific varieties formed the most interesting group and showed a better capacity for adaptation to the diversity of lowlands. They had good yields, sometimes higher than those of intraspecific varieties and check. Thus, the results obtained were quite satisfactory as the varieties possess good agronomic traits that are well adapted to intensified lowland rice farming. The recent naming of some of these interspecific varieties as NERICA-L (New Rice for Africa Lowland) by Africa Rice Center confirmed their status. Thus from this study, a new set of interspecific lines that are adapted to lowland conditions and which the national research programs in Burkina Faso can use in various tests for satisfying farmers' needs are discussed.

Key words: Hybridisation, inter-specific, insect, blast, NERICA, *Oryza glaberrima, Oryza sativa,* sterility, yield.

INTRODUCTION

Rice consumption is increasing fast in Burkina Faso because the rapidly rising urban population is shifting from traditional cereals to rice. Thus, rice has been coming up as a major staple food in Burkina Faso and demand has grown at an annual rate of 3% between 1973 and 1992 compared with an annual population growth rate of 2.9%, which can be explained by changing consumer preferences (WARDA, 1996; Randolph, 1997). Currently, in-country production covers about 60% of the demand, and 40% is met from imports (Segda et al., 2005). Hence, there is an urgent need to increase and improve the production of rice in Burkina Faso and in Africa as a whole, in order to meet up with the high demand (Ogunbayo et al., 2005; 2007). Burkina Faso has three major rice ecologies - upland (10% of land area with 5% of the country's rice production), irrigated (23% of area and 53% of production) and rainfed lowland (67% of area and 42% of production) (Sié, 1999). Irrigated systems were introduced in the 1960s, and the development was accentuated from the 1970s onward. Average yields of irrigated rice in Burkina Faso were estimated at 4.0 to 4.5 t ha $^{-1}$ and in general two crops per year are grown (Illy, 1997; Wopereis et al., 1999). Thus, rainfed lowland is the major rice ecology in the country, combining the characteristics of upland and irrigated systems. The declining and unpredictable rainfall pattern has led to the disappearance of traditional *Oryza sativa* cultivars. However, some farmers still grow *Oryza glaberrima*, which has good agronomic traits, that is, acceptable grain quality, plant vigor, and resistance to major biotic and abiotic stresses (Pham, 1992; Besançon,

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1993; Adeyemi and Vodouhe, 1996; Sié, 1999). In 1992, the Africa Rice Center (WARDA) and its partners started the Interspecific Hybridization Project (IHP) in an attempt to combine the useful traits of both cultivated rice species (*O. sativa* and *O. glaberrima*). Crossing the two species is complicated by their incompatibility, which leads to hybrid mortality. This problem was overcome through backcrossing with the *O. sativa* parent coupled with anther culture, resulting in the first interspecific rice progenies from cultivated varieties (Jones et al., 1997a, b, c). In addition to the upland NERICA varieties, WARDA and national programs developed NERICA varieties well adapted to irrigated and rainfed lowlands, one of the most complex rice ecologies in the world. Key to this success was the unique research and development partnership model forged between WARDA and the national programs through the Rice Research and Development Network for West and Central Africa (ROCARIZ), which facilitated the shuttle-breeding approach to accelerate the selection process and achieve wide adaptability of the lowland NERICAs (WARDA, 2006) . To meet the demand of rice farmers and consumers, the rice research program in Burkina Faso started evaluating intra-and interspecific lowland progenies obtained from WARDA, Senegal, in 2000. This study aimed to identify, through a participatory approach, high yielding varieties with resistance to biotic and abiotic stresses.

MATERIALS AND METHODS

The plant materials comprised of 16 genotypes which include nine interspecific lines (*O. glaberrima* × *Oryza sativa indica*), six intraspecific (*O. sativa* × *O. sativa*) lines and one check. The check variety (TOX 3055-10- 1-1-1) had been released and extensively used in Burkina Faso. The experiment was carried out in valley fringe at the Banfora research station in the southern region of Bobo-Dioulasso in Burkina Faso during 2002 - 2003 wet season. Seeds were sown directly, three seeds per hill and thinned to one seedling at a spacing of 0.25 m within and between rows. The randomized complete block design with three replications was used with 16 rows of 5 m and plot area was 20 m^2 .

A pre-drilling base application of 200 $kg.ha^{-1}$ of NPK (15-15-15) was made, followed by a total of 100 $kg.ha^{-1}$ of urea in two applications of 35 kg/ha at 14 days after seeding and 65 $kg.ha^{-1}$ at the panicle initiation. Two manual weeding were carried out and no chemical treatment was applied. Plants in the middle rows in each plot were harvested. The IRRI Standard evaluation system (IRRI, 1996) for rice was used to score quantitative traits, disease and insect pest damage. Agronomic traits evaluated were plant height at maturity; tillering; days to flowering; number of panicles p/m^2; sterility and yield. Reaction to the specific diseases and insects that were observed were: Stem borer; gall midge and leaf blast. The data collected were subjected to statistical analysis using SAS (SAS, 1999) and GGE biplot version 5.2 (Yan, 2003). A GGE biplot was constructed using the first two principal components (PC1 and PC2) derived from subjecting the environment-centered data to singular -value decomposition and it resulted in analysis from several angles: (i) The polygon view of a GGE biplot allowed visualization of the which-won-where pattern (that is, which variety had the highest yield in which environment); (ii) the average environment coordination view allowed simultaneous visualization of the mean performance and stability of the treatments, the discriminating ability vs. representativeness of the environments; and (iii) the environment vector view allowed visualization of the interrelationship among environments (Yan et al., 2000; Yan, 2001, 2002; Yan and Kang, 2003). In addition, attempting to characterize the environments and to relate the mean yield of the environments to the ecology, a biplot based on an environment × factor two-way table was constructed, which was similar to that based on a genotype × trait two-way table described by Yan and Rajcan (2002). All biplots presented in this paper were generated using the software GGEbiplot package that runs in a Windows environment. Principal components grouping of the traits was used to examine the percentage contribution of each trait to total genetic variation and to spot characters that reflected the greatest proportion of variations among the 9 variables. This is because the PCA has been reported to be able to choose independent (orthogonal) axes that are minimally correlated and then represent linear combinations of the original characters (Akoroda, 1983).

The relative discriminating power of the axes and their associated characters were measured by the Eigen values and factor scores, respectively. The similarity coefficient was used to construct a dendrogram by the unweighted pair group method with arithmetic average (UPGMA) according to (Sneath et al., 1973; Swofford et al., 1990).

RESULTS

2002 wet season

Table 1 presents the means of nine characters measured in sixteen rice varieties. Highly significant differences were observed in plant height, flowering date, leaf blast and sterility while non-significant difference was observed in tiller number, stemborer, AfRGM and yield was significant. However, ten varieties including four intra-specifics and six interspecifics had higher number of tillers compared to average (137 tillers). Plant height varied from 73 to 118 cm. Out of the materials tested, nine (9) varieties including two intraspecific (V3 and V4) and 7 interspecifics (V8, V10, V11, V12, V13, V14 and V15) had values below the average (91cm) thus, they were semi-dwarf varieties. Based on IRRI Standard Evaluation System (1996) all varieties tested with the exception of 9 varieties mentioned above have medium height. The average value for panicle number was 46 and seven lines including one intra-specific and 6 interspecifics recorded high panicle number which were above the average number. Out of the materials tested four varieties had flowering days above an average (87) while the rest were equal or below the average. For sterility, eight varieties had value below average. The average yield recorded was 1642 kg/ha.

The correlation matrix showed that plant height was positively and significantly associated with yield. However, plant height had negative but significant association with sterility. While flowering date were also positively and highly significant correlated to leaf blast. Sterility was positively and significantly correlated to leaf blast (Table 2).

Table 3 presents the principal components analysis showing the contribution (factor scores) of each character

Table 1. Means of nine characters measured in sixteen rice varieties (2002).

S/No	Variety	Tiller	Pan/ m^2	Height (cm)	Flw DAS	Sterility	Leaf Blast	Stem-borer	AfRGM	Yield (t ha^{-1})
1	WAT 1176-B-FKR-B-B	167	41	113	90	2	2	2	13	2293
2	WAT 1184-B-FKR-B-B	104	56	118	86	1	1	1	23	2133
3	WAT 1191-B-FKR-B-B	173	40	88	88	1	3	1	16	2347
4	WAS 105-B-IDSA-B-WAS-2-1-FKR-B-B	161	46	90	90	1	2	0	16	2247
5	WAS 114-B-IDSA-B-WAS-5-1-FKR-B-B	118	44	97	87	1	2	1	18	2267
6	WAS 129-B-IDSA-B-WAS-1-1-FKR-B-B	142	62	97	85	1	1	1	17	1840
7	WAS 122-IDSA-1-WAS-6-1-FKR-B-B	129	37	94	84	1	1	1	20	933
8	WAS 122-IDSA-1-WAS-2-FKR-B-B	142	49	90	82	1	1	1	17	1520
9	WAS 122-IDSA-1-WAS-1-1-B-FKR-B-B	151	32	94	85	1	1	1	22	1280
10	WAS 161-B-6-4-FKR-B-B	124	57	76	87	4	2	2	23	933
11	WAS 161-B-9-3-FKR-B-B	141	37	73	86	5	2	1	17	1387
12	WAS 161-B-6-3-FKR-B-B	141	48	80	82	3	1	1	15	1413
13	WAS 163-B-5-3-FKR-B-B	141	24	85	89	4	2	1	19	1093
14	WAS 191-8-3-FKR-B-B	140	70	77	83	4	2	0	18	1387
15	WAS 191-9-3-FKR-B-B	114	60	88	80	3	1	0	15	1493
16	TOX 3055-10-1-1-1 (Check)	101	37	91	107	6	9	1	17	1707
	Mean	137	46	91	87	2	2	1	18	1642
	Significance	*ns*	*ns*	**	**	**	**	*ns*	*ns*	*

*, **; Significant at 5 and 1% probability levels, respectively.

Table 2. Correlation coefficients of nine traits used in characterizing sixteen rice varieties (2002).

Character	Tiller at 60 DAS	Pan m^2	Plant Height (cm)	Flw date	Sterility	Leaf Blast	Stemborer	AfRGM	Yield (t ha^{-1})
Tiller at 60 DAS	1.000								
Pan m^2	-0.226	1.000							
Plant height (cm)	-0.092	-0.036	1.000						
Flw date	-0.206	-0.395	0.134	1.000					
Sterility	-0.345	-0.066	-0.563*	0.450	1.000				
Leaf Blast	-0.294	-0.255	-0.075	0.933**	0.591*	1.000			
Stemborer	0.071	-0.301	0.236	0.209	0.030	0.063	1.000		
AfRGM	-0.415	-0.005	0.046	-0.061	-0.069	-0.140	0.196	1.000	
Yield (t ha^{-1})	0.245	0.086	0.577*	0.239	-0.423	0.142	-0.061	-0.428	1.000

*, **; Significant at 5 and 1% probability levels, respectively.

among the 16 varieties. The three principal components accounted for about 68.84% of total variance with the first and second principal component taking 29.84 and 22.79%, respectively. The relative discriminating power of the principal axes as indicated by the eigen values was highest (2.63) for axis 1 and lowest (1.53) for axis 3. The first principal component that accounted for the highest proportion (29.84%) of total variation was mostly correlated with flowering date, sterility and leaf blast. They have early cycle and mode-rately resistance to sterility and leaf blast. Characters that were mostly cor-related with the second principal component were plant height and yield and third principal component were tiller and AfRGM.

Figure 1 presents the morphological dendrogram showing the minimum distance between cluster groups and genotypes were divided into three major groups.

Table 4 shows characteristics of morphological groups defined by topology. In group 1 tiller number at 60 days ranged from 104 to 173 m^2; panicle number ranged from 40 to 56; plant height ranged from 88 to 118 cm indicating that varieties are semi-dwarf to medium height type; flowering occurred between 86 to 90 while grain yield ranged from 2133 to 2347 kg ha^{-1}; sterility ranged from 1 to 3; leaf blast ranged from 1 to 3; stem-borer ranged from 0 to 3 and AfRGM ranged from 13 to 23

Table 3. Principal components analysis showing the contribution (factor scores) of each character among the sixteen rice varieties (2002).

Character	Prin1	Prin2	Prin3
Leaf blast	-0.933	0.252	-0.046
Flowering date (FLW)	-0.860	0.421	0.155
Sterility	-0.837	-0.341	-0.194
Yld (t ha^{-1})	0.159	0.886	0.033
Plant height (cm)	0.260	0.651	0.641
AfRGM	0.006	-0.506	0.705
Tiller at 60 DAS	0.331	0.379	-0.624
Panicle number (Pan m^{-2})	0.356	-0253	0.064
Stem Borer	-0.212	0.143	0.305
Eigen value	2.686	2.051	1.459
Variance (%)	29.840	22.794	16.206
Cumulative (%) variance	29.840	52.634	68.840

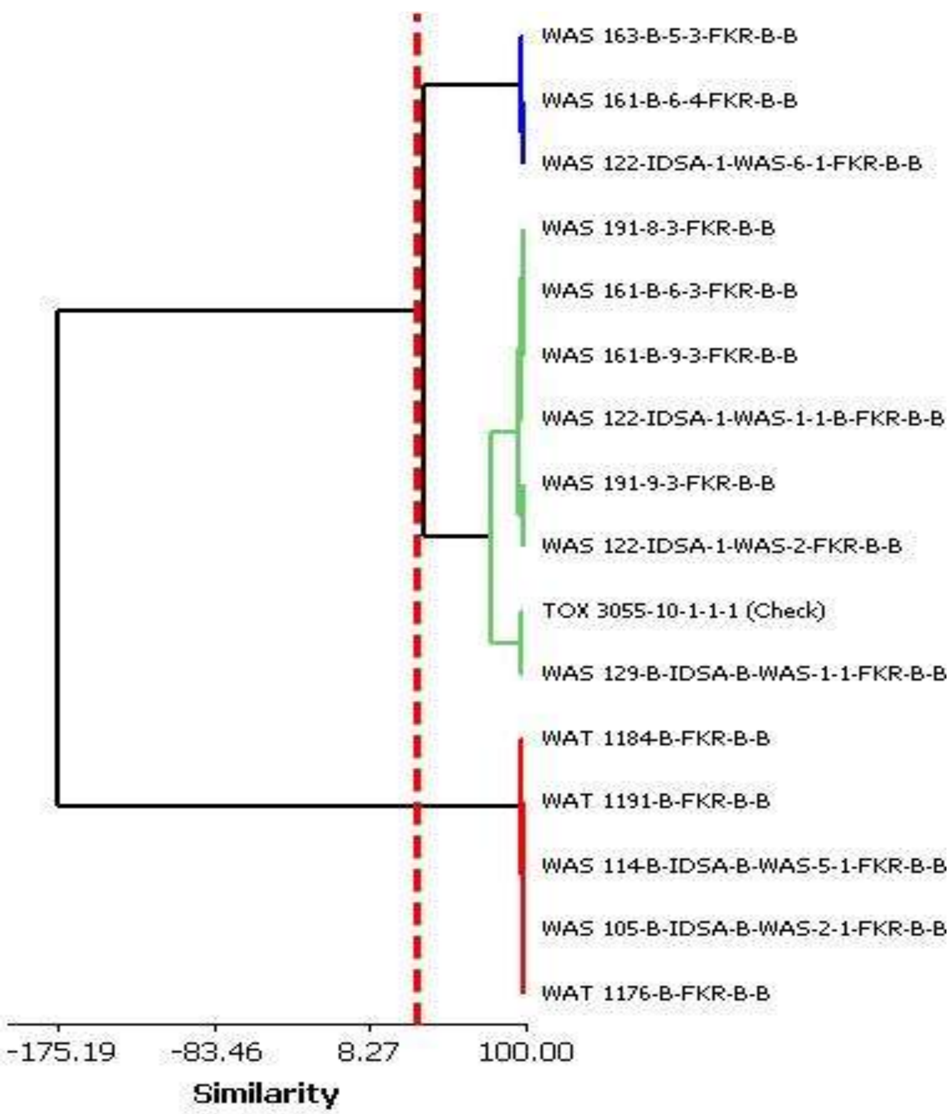

Figure 1. Morphological dendogram showing the minimum distance between cluster groups (2002).

Table 4. Characteristics of morphological groups defined by topology in 2002.

	Group 1		Group 2		Group 3	
Character	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Tiller No. at 60 days	104	173	101	151	124	141
Panicle number (Pan m^{-2})	40	56	32	70	24	57
Plant height (Ht)	88	118	73	97	76	94
Flowering date (FLW)	86	90	80	107	84	89
Sterility	1	3	1	7	1	5
Leaf blast (LB)	1	3	1	9	1	3
Stemborer	0	3	0	1	1	3
AfRGM	13	23	15	22	19	23
Yield (Kg/ha)	2133	2347	1280	1840	933	1093

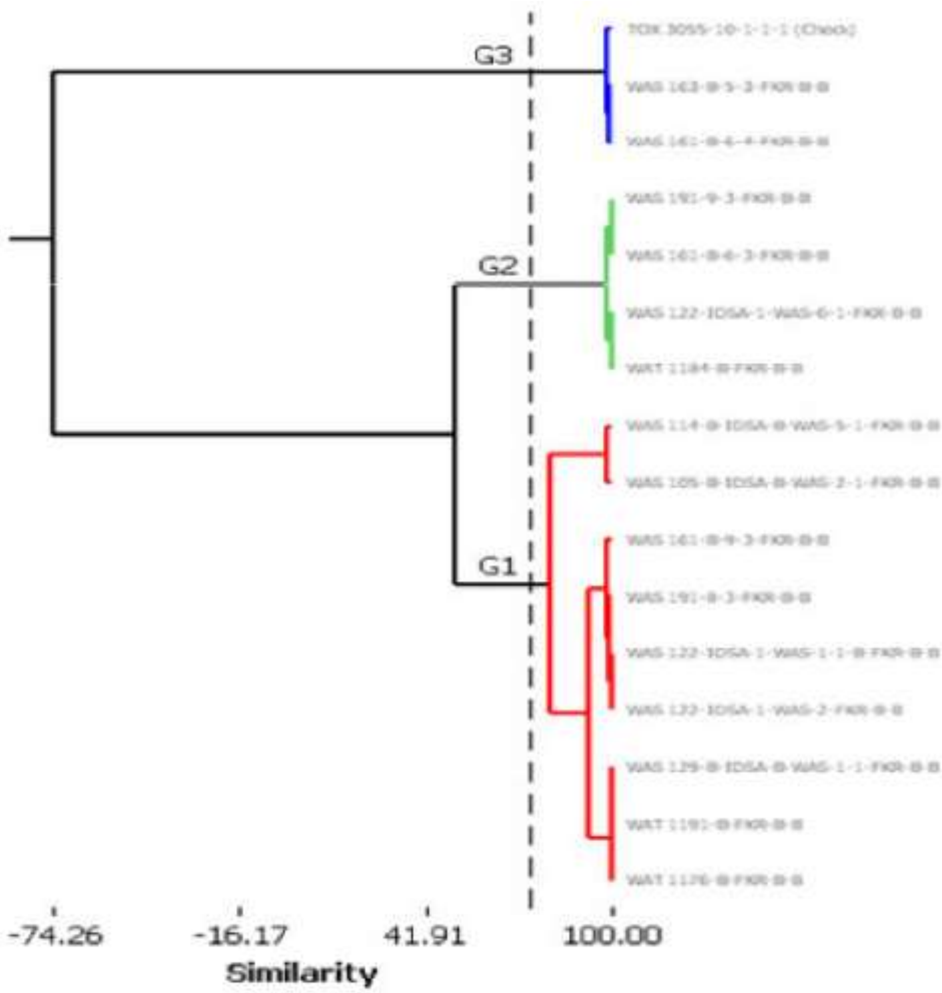

Figure 2. Morphological dendogram showing the minimum distance between cluster groups (2003).

while group 2 and 3 has its own distinct characteristics.

A plot of relationship between the 16 varieties as shown by the first and second principal components axes (Prin 1 and 2) (Figure 3) revealed that all the varieties were ordered into four distinct PCA clusters. Most of the varieties in group 2 were centrally distributed more towards the first principal axis and they have good yield. However, genotypes selected from group 1 were also

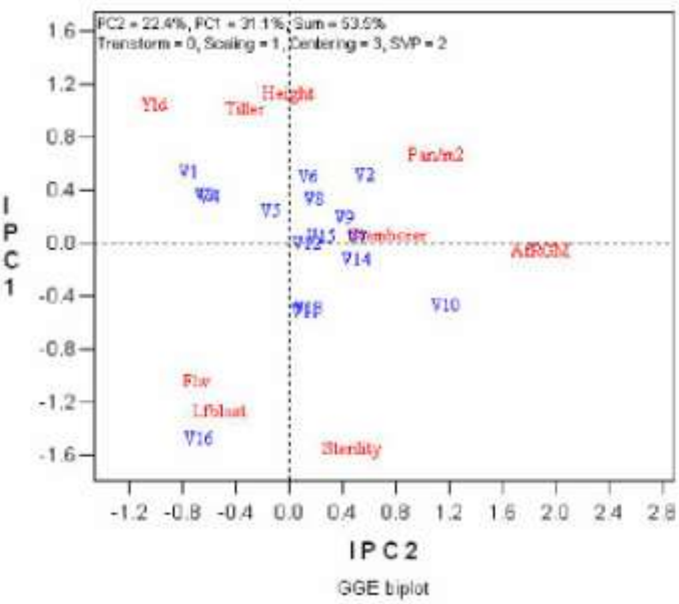

Figure 3. Plot of Prin 1 and Prin 2 showing the relationship between clusters of 16 Varieties in 2002.

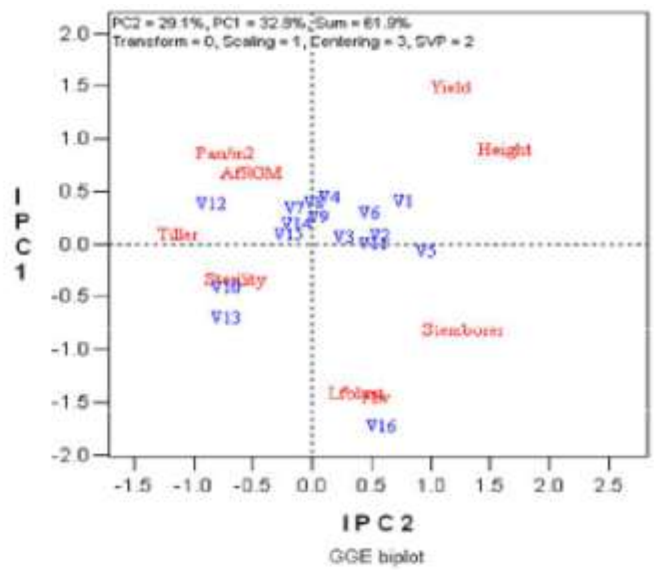

Figure 4. Plot of Prin 1 and Prin 2 showing the relationship between clusters of 16 varieties in 2003.

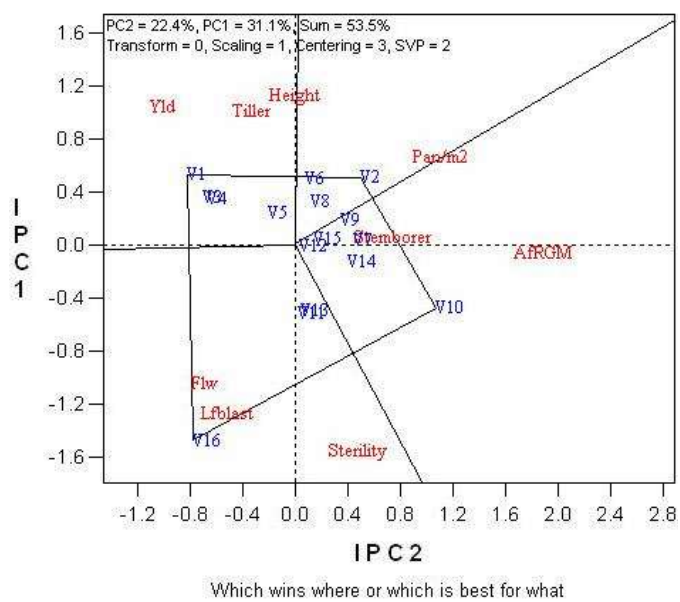

Figure 5. A polygon view of the GGE biplot of genotype x trait, showing which genotype won where or best for which trait (2002).

distributed towards the upper left side of first principal axis and they have good tillering ability and moderate height. Group three were distributed towards the lower right side and they are susceptible to AfRGM.

Figure 5 defined the genotypes that performed best in 2002 (which genotype won in which trait). The polygon is formed through connecting the best genotypes in each trait to other. Starting from the biplot origin, perpendicular lines are drawn to each side of the polygon, which divide the biplot into 4 sectors. The which-won-where pattern is examined as follows. The varietal number at the vertex of polygon in any sector is the genotype that produces the highest value in trait(s) that fall in that sector. Thus, genotypes (1, 3, 4 and 5) had good yield and tiller while genotype (1) produced the highest yields. The genotypes that had highest flowering date and leaf blast was genotype (16). While genotypes (2, 6 and 8) had high value in panicle/m^2.

2003 wet season

Table 5 presents the means of nine characters measured in 16 rice varieties. Analysis of variance showed highly significant differences in plant height, flowering date, sterility and leaf blast. There was no significant difference in panicle number, tillering numbe, yield, stem borer and AfRGM. However, 7 interspecifics had a higher number of tillers than the average (470 tillers). Out of the materials tested, seven varieties had height below an average value (111 cm). Thus, seven varieties were semi-dwarf while genotypes (1, 2 and 11) had medium height. Seven varieties had flowering days below the the average and this indicate that they are medium maturing varieties. Eight varieties had higher panicle number than average (265) . The average yield recorded was 3214 kg/ha and all varieties were moderately resistant an tosterility except WAS 163-B-5-3-FKR-B-B that is genotype (13).

The correlation matrix showed that tiller was positively and significantly associated with Panicle/m^2 but negatively significant to plant height. Flowering date was positively and significantly associated with stem-borer

Table 5. Means of nine characters measured in twenty rice varieties (2003).

S/No	Variety	Tiller	Pan/ m^2	Height (cm)	Flw DAS	Sterility	Leaf blast	Stemborer	AfRGM	Yield (t ha^{-1})
1	WAT 1176-B-FKR-B-B	437	273	139	85	1	2	2	9	3628
2	WAT 1184-B-FKR-B-B	448	253	130	88	1	1	1	4	2961
3	WAT 1191-B-FKR-B-B	471	264	105	88	1	2	2	9	3672
4	WAS 105-B-IDSA-B-WAS-2-1-FKR-B-B	436	295	111	89	2	1	1	10	4123
5	WAS 114-B-IDSA-B-WAS-5-1-FKR-B-B	386	213	115	86	1	4	2	7	3894
6	WAS 129-B-IDSA-B-WAS-1-1-FKR-B-B	427	259	117	85	1	2	1	7	3687
7	WAS 122-IDSA-1-WAS-6-1-FKR-B-B	451	268	111	88	1	0	1	16	2925
8	WAS 122-IDSA-1-WAS-2-FKR-B-B	497	268	113	85	1	0	1	9	3358
9	WAS 122-IDSA-1-WAS-1-1-B-FKR-B-B	533	209	114	87	1	0	1	11	3404
10	WAS 161-B-6-4-FKR-B-B	517	300	94	91	2	5	1	12	2325
11	WAS 161-B-9-3-FKR-B-B	423	200	128	86	2	4	0	7	3251
12	WAS 161-B-6-3-FKR-B-B	540	320	99	82	2	2	0	10	3002
13	WAS 163-B-5-3-FKR-B-B	503	255	96	88	4	6	1	9	2195
14	WAS 191-8-3-FKR-B-B	508	305	99	88	1	1	1	6	3491
15	WAS 191-9-3-FKR-B-B	544	288	102	86	1	1	2	9	3127
16	TOX 3055-10-1-1-1 (Check)	464	212	98	108	1	8	3	5	2070
	Mean	470	265	111	87	1	2	1	9	3214
	Significance	ns	ns	**	**	**	**	ns	ns	ns

*, **; Significant at 5 and 1% probability levels, respectively.

and highly significant to leaf blast. However, flowering date had negative but significant association with yield. While plant height was positively and significantly associated with yield and leaf blast was negatively associated with yield. Sterility was positively and significantly correlated to leaf blast (Table 6).

Table 7 presents the principal components analysis showing the contribution (factor scores) of each character among the 16 varieties. The three principal components accounted for about 73.26% of total variance with the first and second principal component taking 29.79 and 28.52%, respectively. The relative discriminating power of the principal axes as indicated by the eigen values was highest (2.68) for axis 1 and lowest (1.35) for axis 3. The first principal component that accounted for the highest proportion (29.79%) of total variation was mostly correlated with plant height, yield, plant height and tiller. They have medium height and high yield. Characters that were mostly correlated with the second principal component were leaf blast, panicle number, flowering date and AfRGM.

Figure 2 presents the morphological dendrogram showing the minimum distance between cluster groups. Accessions were divided into 3 major groups. Table 8 shows characteristics of morphological groups defined by topology as each of the three groups has its own distinct characteristics. A plot of relationship between the 16 varieties as shown by the first and second principal components axes (Prin 1 and 2) (Figure 4) revealed that all the varieties were ordered into four distinct PCA clusters. Most of the varieties in group 2 were centrally distributed more towards the first principal axis and they have good tiller and panicle number/m^2. However, genotypes selected from group 1 were also distributed towards the upper right side of first principal axis while group three were distributed towards the lower side.

Figure 6 defined the genotypes that performed best in 2003 (which genotype won in which trait). The polygon is formed through connecting the best genotypes in each trait to other. Starting from the biplot origin, perpendicular lines are drawn to each side of the polygon, which divide the biplot into 6 sectors. The which-won-where pattern is examined as follows. The varietal number at the vertex of polygon in any sector is the genotype that produces the highest value in trait(s) that fall in that sector. Thus, genotypes (1, 4, 6, 8 and 9) had good yield and moderately height while genotype (4) produced the highest yields. The genotypes (16) had long cycle and highest

Table 6. Correlation coefficients of nine traits used in characterizing sixteen rice varieties (2003).

Character	Tiller at 60 DAS	Pan m^{-2}	Plant height (cm)	Flw date	Sterility	Leaf blast	Stem-borer	AfRGM	Yield (t ha^{-1})
Tiller at 60 DAS	1.000								
Pan m^{-2}	0.462*	1.000							
Plant height (cm)	-0.605*	-0.363	1.000						
Flowering date	-0.060	-0.324	-0.333	1.000					
Sterility	0.184	0.112	-0.342	-0.070	1.000				
Leaf blast	-0.151	-0.343	-0.332	0.647**	0.453*	1.000			
Stemborer	-0.169	-0.242	-0.084	0.613*	-0.397	0.341	1.000		
AfRGM	0.270	0.303	-0.210	-0.258	0.135	-0.319	-0.239	1.000	
Yield (t ha^{-1})	-0.410	0.053	0.478*	-0.546*	-0.421	-0.619*	-0.082	-0.041	1.000

*, **; Significant at 5 and 1% probability levels, respectively.

Table 7. Principal components analysis showing the contribution (factor scores) of each character among the sixteen rice varieties (2003).

Character	Prin1	Prin2	Prin3
Yld (t ha^{-1})	0.850	-0.195	0.025
Plant height (cm)	0.806	0.196	-0.327
Sterility	-0.596	-0.227	-0.672
Leaf Blast	-0.569	0.685	-0.266
Tiller at 60 DAS	-0.560	-0.552	0.371
Panicle number (Pan m^{-2})	-0.181	-0.722	0.267
Flowering date (FLW)	-0.494	0.687	0.284
AfRGM	-0.130	-0.608	0.087
Stemborer	0.151	0.548	0.647
Eigen value	2.682	2.567	1.345
Variance (%)	29.795	28.518	14.950
Cumulative (%) variance	29.795	58.313	73.263

Table 8. Characteristics of morphological groups defined by topology in 2003.

	Group 1		Group 2		Group 3	
Character	Min.	Max.	Min.	Max.	Min.	Max.
Tiller No. at 60 days	386	533	448	544	464	517
Panicle number (Pan m-^{2})	200	305	253	320	212	300
Plant height (Ht)	99	139	99	130	94	98
Flowering date (FLW)	85	89	82	88	88	108
Sterility	1	3	1	3	1	5
Leaf Blast (LB)	0	5	0	3	5	9
Stemborer	0	3	0	3	1	3
AfRGM	6	11	4	16	5	12
Yield (Kg/ha)	3251	4123	2925	3127	2070	2325

value in leaf blast and stem -borer. Thus, interspecific performed well than the check.

Figure 7 represents the average tester coordination view, showing the performance of the genotypes across the years and their stability under valley fringe condition. Visualization of the mean and stability of genotypes is

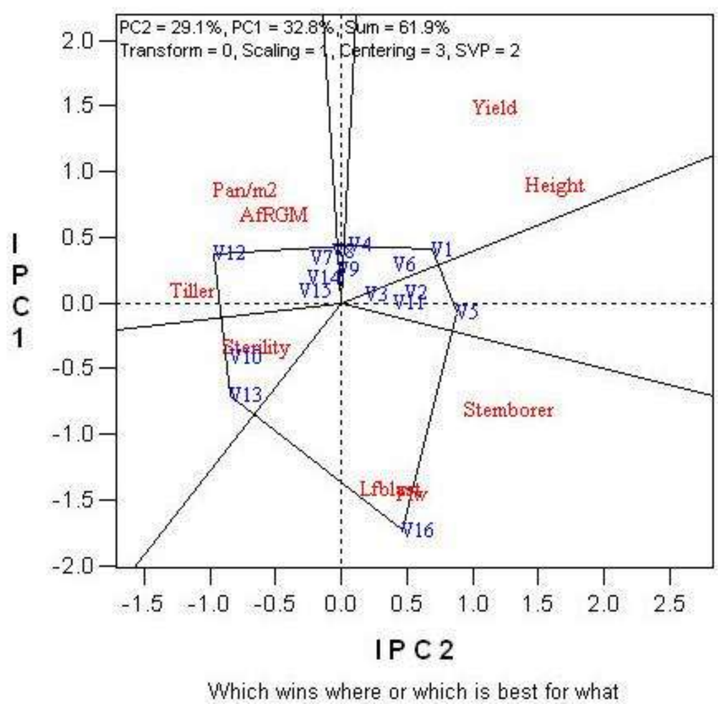

Figure 6. A polygon view of the GGE biplot of genotype x trait, showing which genotype won where or best for which trait (2003).

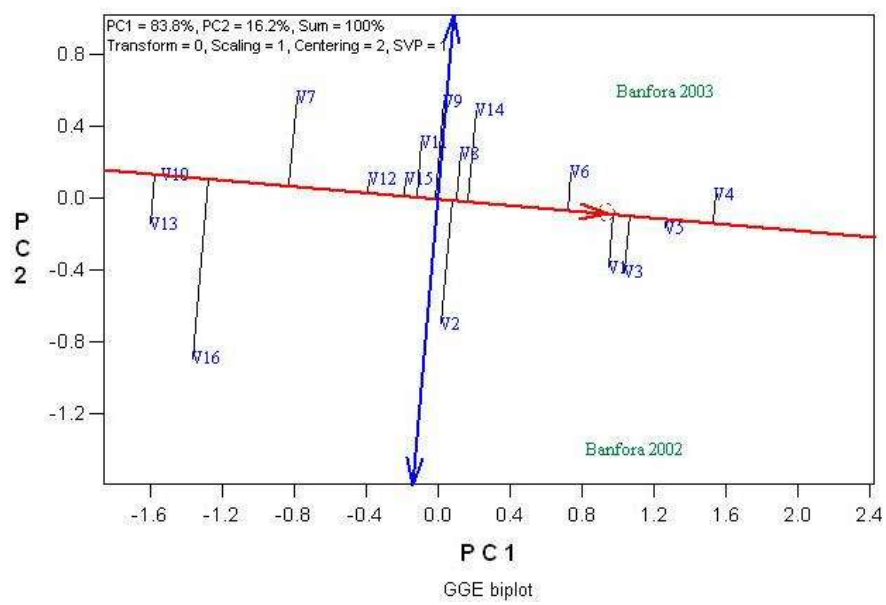

Figure 7. The mean performance vs. stability of the 16 rice varieties across the two seasons under valley fringe lowland condition.

achieved by drawing an average environment coordinate (AEC) on the genotype-focused biplot. First, an average environment, represented by the small circle, is defined by the mean PC1 and PC2 scores of the environments. The small circle near Banfora 2003 location suggests 2003 as the best in term of yield performance. The line connecting the biplot origin and the circle (Banfora) is referred to as the average-tester axis. Based on their mean performance, the genotypes are ranked along the average-tester axis with the arrow pointing towards genotype with greater value. Thus, the genotype is ranked along the AEC abscissa, with the arrow pointing to higher mean performance.

Based on this, Genotype (4) was clearly the highest-yielding, on average, in these environments, followed by (5, 3, 1, and 6) and the least in terms of performance was the genotype (13). The double arrow indicates that a greater projection onto the AEC ordinate, regardless of the direction, means greater instability. The bi-plot confirmed the conclusions drawn from Figures 5 and 6.

Trends in insects and diseases attacks according to varieties and seasons

In 2002, nine varieties including five intra-specifics and four interspecifics had value below means (18) recorded for AfRGM. Three varieties including one intra-specific and two interspecifics showed no stem borer attack (dead heart) compared to the mean obtained in the study. All intra or interspecific varieties rated below or equal to the average of 2 while TOX 3055-10-1-1-1(check) was rated high, thus, susceptible to leaf blast. In 2003, average score recorded for AfRGM was (9) and (1) for stemborer. Five varieties including one intra-specific and four interspecifics had values higher than the average recorded for AfRGM.

DISCUSSION

Variations did exist among the genotypes tested with respect to the traits that were evaluated. Total number of tillers, panicle number and flowering days were observed to greatly influence the yield among the genotypes that were evaluated. The yields recorded in 2003 were all higher than those recorded in 2002 and this was due to the differences observed between the genotypes in panicle numbers and insect attacks. The number of tillers produced which ascertains panicle number is the most important factor in high grain yield. However, this characteristic does not seem to be the causal factor in this study because WAS 191- 9-3-FKR-B-B, that is genotype (15) which had highest number of tiller recorded 3127 kg/ha. Thus, the rate of fertile tillers was a factor that could justify this, because high tillering associated with high sterility rate reduces panicle number; meanwhile high tillering associated with low sterility rate increases panicle number.

Moreover, variations observed in the study may also due to difference in rainfall pattern in 2002 and 2003. The amount of rainfall recorded in 2002 and 2003 were 920.8 and 1226 mm, respectively. Therefore rainfall was an instrumental in the development of agro-morphological characters, and occurrence of insect attacks and diseases. The observation of these agro-morphological characters showed an average of 470 tillers and 265 panicles in 2003, which higher than those recorded in 2002. This potential development was also observed in yields. Regarding insect attacks no significant difference was observed between varieties over both years.

Since the cycle is one of the major concerns of African countries because of irregular rainfall pattern. Therefore, interspecific varieties showed cycles that were generally shorter than intra-specific varieties and check. Height was also an important factor in the lowland, because what was sought was a variety that was not too tall to avoid lodging, but not also too short to bear strong water levels. For this characteristic, genotypes (1, 5, 6, 7, 8, 9, 11, 12 and 14) were below average during the both years and no variety were susceptible to lodging during the both years.

Principal components analysis and hierarchical clustering generated from similarity or genetic distance matrices has provided an overall pattern of variation as well as the degree of relatedness among the genotypes. In addition, the principal component analysis, confirmed the contributions of the three traits to grain yield among the genotypes. The implication is that if selection is to be made between cluster groups for a future breeding exercise, panicle number, total number of tillers, days to heading, should be given high priorities. The GGE bi-plot generated several graphic bi-plots, strong genotype by environment interaction was confirmed. It also revealed the relationship among genotypes in terms of their responses and stability to the environments and traits. The results confirmed that the interspecific genotypes (WAS 122; WAS 161; 163; and 191 series) performed well across the locations and they were very stable. The interspecific varieties formed the most interesting group and have a better capacity for adaptation to the diversity of lowlands. They have acceptable yields, sometimes higher than those of intraspecific varieties and check.

Conclusion

In Burkina Faso the major concern of the national rice breeding and improvement program is to develop short or average height materials (lodging resistance) with short cycle, high yield potential and resistant or tolerant to various biotic and abiotic stresses. The results confirmed that the interspecific genotypes performed well across the seasons. Interestingly, interspecific varieties produced the greatest number of tillers and these observations confirm those made by Jones et al. (1996), who noted that interspecific *O. glaberrima* × *O. sativa* had a very high tillering capacity, which predisposed them to be more competitive with weeds.

In conclusion, the results obtained were quite encouraging and showed that, the varieties possess good agronomic traits that are well adapted to intensified lowland rice farming. The recent naming of some of these interspecific varieties as NERICA-L (New Rice for Africa Lowland) by WARDA has confirmed that they compare well with the traditional varieties. Based on the topology of the varieties, it is concluded that the interspecific crossings *O. glaberrima* × *O. sativa indica* can increase lowland rice biodiversity. Thus from this study, we now have a new set of interspecific lines that are adapted to lowland conditions and which the national research programs in Burkina Faso can use in various tests for satisfying farmers' needs.

REFERENCES

Adeyemi P, Vodouhe SR (1996). Amélioration de la productivité des variétés locales de *Oryza glaberrima* Steud. par des croisements intra et interspécifiques avec *Oryza sativa* Linn *in* Hybridations interspécifiques au Bénin. ADRAO, Bouaké (Côte d'Ivoire) pp. 159 - 175.

Akoroda MO (1983). Principal Components analysis and metroglyph of variation among Nigerian yellow yams. Euphytica 32: 565- 573.

Besançon G (1993). Le riz cultive d'origine africaine*Oryza glaberrima* Steud et les formes sauvages et adventices apparentées: Diversité, relations génétiques et domestication *O. breviliguta* A. Chev, et *O. Stapfii* A. Chev.. PhD Dissertation, University of Paris 11, France. p. 246.

Illy L (1997). La place de la riziculture irriguée dans le système de production agricole et animale au Burkina Faso. In Miézan KM, Wopereis MCS, Dingkuhn M, Deckers J and Randolph TF (eds.) Irrigated rice in the Sahel: Prospects for sustainable development. West Africa Rice Dev. Assoc. (WARDA), Bouaké, Ivory Coast pp. 131-135.

IRRI (1996). Standard Evaluation Systems for Rice. Manila Philippines p. 52.

Jones MP, Audebert A, Mande S, Aluko K (1996). Characterization and utilization of oryza glaberrima Steud. In upland rice breeding. In Proceedings Workshop Africa-Asia Joint Research on Interspecific Hybridisation between the African and Asian Rice Species *O.glaberrima* and *O.sativa,* WARDA, Bouaké, Côte d'Ivoire pp. 43-59.

Jones MP, Mande S, Aluko K (1997c). Diversity and potential of *Oryza glaberrima* Steud in upland rice breeding. Breed. Sci. 47: 395-398.

Jones MP, Dingkuhn M, Aluko GK, Semon M (1997a). Interspecific *Orza sativa* x *O.glaberrima* Steud. Progenies 92: 237-246

Jones MP, Dingkuhn M, Johnson DE, Fagade SO (1997b). Interspecific hybridization: progress and prospect, Bouaké, Côte d'Ivoire, WARDA. pp. 21-29.

Ogunbayo SA, Ojo DK, Guei RG, Oyelakin O, Sanni KA (2005). Phylogenetic diversity and relationship among forty rice accessions using Morphological and RAPDs techniques. Afr. J. Biotechnol. 4:1234 -1244.

Ogunbayo SA, Ojo DK, Popoola AR, Ariyo OJ, Sié M, Sanni KA, Nwilene FE, Somado EA, Guei RG, Tia DD, Oyelakin OO, Shittu A (2007). Genetic comparisons of landrace rice accessions by morphological and RAPDs techniques. Asian J. Plant Sci. 6(4): 653-666.

Pham JL (1992). Evaluation des ressources génétiques des riz cultivés en Afrique par hybridation intra et interspécifique. Thèse Docteur es sciences , Université de Paris XI ORSAY (France) p. 236.

Randolph TF (1997). Rice demand in the Sahel. In K.M. Miézan, M.C.S. p. 71-88.

SAS Institute Inc. SAS/STAT (1999). Guide for personal computer, version 8 edition, Cary, NC, SAS institute Inc. p. 1028.

Segdaa Z, Haefeleb SM, Wopereisc MCS, Sedogoa MP, Guinkod S (2005). Integrated soil, water and nutrient management for sustainable irrigated rice systems in Burkina Faso. In Synthesis of soil, water and nutrient management research in the Volta Basin Pp. 159-188.

Sie M (1999). Caractérisation des hybrides interspécifiques *(O. glaberrima* x O. sativa) pour leur adaptabilité à la riziculture de bas-fond. Formulaire de requête d'un financement spécial pour un projet d'un groupe d'action. p. 6.

Sneath PHA, Sokal RR (1973). The Principle and Practice of Numerical Classification. In: Kennedy D, Park RB (Eds.), Numerical Taxonomy. Freeman, San Francisco. p. 537.

Swofford DL, Olsen GJ, Waddell PJ, Hillis DM (1990). Phylogenetic Reconstruction. In: Molecular systematics. Hillis, D.M. and Moritz C. (Eds). Sinauer Associates, Sunderland, pp: 411-501.

WARDA (1996). Rice trends in sub-Saharan Africa. A synthesis of statistics on rice production, trade and consumption. WARDA, Bouaké, Ivory Coast. p. 8.

WARDA (2006). Annual Report for 2005. West Africa Rice Development Association. pp. 8-25.

Wopereis MCS, Donovan C, Nebié B, Guindo D, Ndiaye MK (1999). Soil fertility management in irrigated rice systems in the Sahel and Savanna regions of West Africa: Part I. Agronomic analysis. Field Crops Res. 61(2):125-145.

Yan W, Hunt LA, Sheng Q, Szlavnics Z (2000). Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci. 40: 597-605.

Yan W (2001). GGE biplot—a Windows application for graphical analysis of multienvironment trial data and other types of two-way data. Agron. J. 93: 1111-1118.

Yan W (2002). Singular value partitioning in biplot analysis of multienvironment trial data. Agron. J. 94: 990-996.

Yan W, Rajcan I (2002). Biplot evaluation of test sites and trait relations of soybean in Ontario. Crop Sci. 42: 11-20.

Yan W, Kang MS (2003). GGE biplot analysis: A graphical tool for breeders, geneticists, and agronomists. CRC Press LLC. Boca Roton, Florida. p. 271.