International Journal of Research and Review
www.ijrrjournal.com E-ISSN: 2349-9788; P-ISSN: 2454-2237

Original Research Article

Assessment of Phenotypic Stability and Agronomic Performance in Some Upland and Lowland Rain Fed Rice Genotypes in Diverse Agro-Ecologies of Northwest Ethiopia

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Received: 02/03/2016 *Revised: 23/04/2016* *Accepted: 23/04/2016*

ABSTRACT

Two different sets of field experiments were conducted at Woreta, Metema, Pawe, Addis Zemen and Assosa in Ethiopia during 2008/09 to 2011/12 main cropping seasons with the objective of identifying high yielding, stable, early maturing and disease resistance rice varieties for upland and lowland production systems. In experiment- I, 13 upland rice genotypes (NERICA and some non-NERICA) including one check were evaluated at Woreta, Metema and Pawe. In experiment-II, 20 lowland rice genotypes including one check were evaluated at Woreta, Addis Zemen, Pawe and Assosa. In both sets of experiments, the trials were laid out in a randomized complete block design of three replications. The combined analysis of variance in experiment-I revealed significant genotypic, environmental and genotype x environment interaction effect for grain yield. The highest yielding genotype in Experiment-I was G2, followed by G3 with mean grain yield of 3840.3 and 3656.8 kg ha^{-1}, respectively. Genotype, G2 was also the most stable and diseases resistance. Similarly, in experimental-II, the highest mean grain of 4583.8 kg ha^{-}1, 4243.2 kg ha$^{-1,}$ and 3825 kg ha^{-1} were recorded by G4, G17 and G9, respectively. Of the three genotypes, G9 with grain yield of 3825kg ha^{-1} was highly preferred by farmers in terms earliness and diseases resistance. Hence, based on high mean grain yield, diseases resistance and better stability, G 2 (NERICA-12) as NERICA-12 and G9 (IRGA370-38-1-1F-B1-1) as 'Hibbire', both in 2013, were recommended and released following national variety release committee evaluation and farmers fed back. Therefore, these varieties should be promoted and popularized in large scale to make use of their merits.

Key words: upland rice, lowland rice, GGE, stability.

INTRODUCTION

Rice is a universal food, feeding more than half of the world's population every day. It provides 20% of the world's dietary energy supply, while wheat supplies 19% and maize 5% (FAO, 2004). Rice is a traditional staple food in West Africa and Madagascar and it is also important food crop in East, Central, and Southern Africa (Balasubramanian *et al*., 2007).

In Ethiopia, production of rice started recently and is expected to increase rapidly in most parts of the country. Rice is currently considered as a strategic food security crop and its use as food crop, income source, employment opportunity, animal feed has been well recognized in Ethiopia (Teshome and Dawit, 2011). Rian fed rice, both upland and lowland, is cultivated in Amhara, Tigray, Oromia, South NNPR, Gambella and Benshangule

Gumize regions of Ethiopia (MoA, 2010). Rice production and productivity is linearly rising especially after 2005 (CSA, 2005-2013). Ethiopia has a huge potential, estimated to 30 million hectors, for further rice production and expansion. However, rice research and development is constrained by, among other things, shortage of high yielding varieties, luck of improved agronomic packages, low input utilization, terminal drought, low temperature effect, soil fertility decline and, pre and post harvest management problems (MoA, 2010).

In Ethiopia, rice breeding research has entirely relied on introduction of rice germplasms from exotic sources such as Africa Rice and IRRI. The breeding research efforts are made to develop improved and high yielding upland and lowland rice varieties mainly through multi-environment evaluation of rice genotypes. However, the incidence of G × E interaction complicates the selection of a rice variety with superior performance and adaptability to diverse environments. The G x E interaction may arise when specified genotypes are grown in diverse environments (Zobel, 1990). It is important for breeders to identify specific genotypes adapted or stable to different environment(s), thereby achieving quick genetic gain through screening of genotypes for high adaptation and stability under varying environmental conditions prior to their release as cultivars Yan and Kang (2003). In the current studies, therefore, three different sets of breeding researches activities were conducted aiming at the development and promotion of high yielding, stable, early maturing and disease resistant rice varieties for rain fed upland and lowland rice productions systems of Ethiopia.

MATERIALS AND METHODS

Two sets of experiments were conducted at five different locations; in Amhara region (Woreta, Metema and Addis zemen) and in Benshangul Gumize region (Pawe and Assosa) from 2008 to 2011 main cropping seasons. The first experiment was for upland rice while the third was for lowland rice production system. Experiment-I was carried out in seven environments (Woreta2008=E1, Pawe2008 =E2, Woreta2010 =E3, Pawe2010= E4, Woreta2011= E5, Pawe2011=E6 and Metema2011= E7) with 13 genotypes (12 introduced from Africa Rice) and one standard check. It was conducted over three years (2008-2011). The experiment was laid out with RCBD of three replications. Experiment-II was also carried out in ten environments (Woreta2008= E1, Adiszemen 2008=E2, Pawe2008=E3, Woreta2009=E4, Assosa 2009=E5 Pawe2010=E6, Woreta 2011=E7, Adis Zemen 2011= E8, Pawe 2011=E9 and Assosa2011=E10) with 20 lowland rice genotypes (19 introduced from IRRI and Africa Rice) and one standard check. The experiment was laid out with a randomized complete block design (RCBD) of three replications from 2008 to 2011 cropping seasons. Detail descriptions of experimental sites are indicated at Tables 1 and 2. For all experiments, plot size was 6 m2 (six rows of 5 m long and 20-cm row spacing) with seeding rate of 60 kg/ha bases. Fertilizer rate, time of application and crop management activities were employed as per recommendations.

Table 1. Descriptions of sites for Experiment-I

Location	Latitude	Longitude	Altitude (m)	Annual rainfall (mm)	Mean temperature (^{o}C)		Soil type
					Min.	Max.	
Woreta	11° 58′ N	37° 41′ E	1810	1300	11.5	27.9	Vertisol
Metema	12° 54′ N	36° 15′ E	750	1100	22	29	Vertisol
Pawe	11° 9′ N	36°3′E	1050	1457	17.17	32.75	Cambisol

Data collection and statistical analysis

Data on days to 50% heading, days to 85% physiological maturity, panicle length(cm), plant height(cm), fertile tillers per plant, filled grains per panicle, grain yield(g/plot) and 1000 seed weight(g) were collected from the middle four rows. Grain yield obtained on plot bases was converted into kg ha^{-1} and adjusted at 14% grain moisture content. Disease data were collected based on 0-9 scale following IRRI standard evaluation system (IRRI, 1996); where 0 stands for immune, 1 for highly resistant, 2 for resistant, 3 and 4 for moderately resistant, 5 and 6 for moderately susceptible, 7 for susceptible, and 8 and 9 highly susceptible.

The grain yield and other agronomic parameters were subjected to analysis of variance using the SAS version 8.1software. The yield data were also subjected to the Additive Main Effect and Multiplicative Interaction (AMMI) analysis using gene stat version 13. The GGE biplot analysis was also used for detecting wider and /or specifically adapted genotype(s).

Table 2. Descriptions of sites for Experiment-II

Agro-ecological character	Locations			
	Woreta	Addis Zemen	Pawe	Assosa
Latitude	11^0 58'N	11^0 92 'N	11^0 9'N	10^0 03'N
Longitude	37 ^{0} 41' E	37 ^{0} 7' E	36 ^{0} 3' E	34^{0}59'E
Altitude (masl)	1810	1780	1050	1590
Annual rainfall(mm)	1300	1032	1457	1050
Mean maximum temp.(^{0}C)	27.9	29.36	32.75	29
Mean minimum temp(^{0}C)	11.5	11.31	17.17	14
Soil type	Vertisol	Fluvisol	Cambisol	Nitosol

RESULTS AND DISCUSSION

Experiment I: The combined analysis of variance indicated highly significant (*P*<0.01) genotypic, environmental and G×E interaction effects for grain yield while G x E was not significant for other parameters (Table 3). The significance of genotypic effect is an indication of performance difference among genotypes. For instance, genotypes G2 was the highest yielding of the tested genotypes with 3840.3kg ha^{-1}, while G12 was the lowest yielding with 1953 kg ha^{-1}. Genotype G3 was also the second high yielding genotype with mean grain yield of 3656.8 kg ha^{-1} (Table 3). The two genotypes G2 and G3 showed better resistance to blast diseases and gave grain yield advantage of 4.9% and 7.9%, respectively. Since G×E interaction was significant, it is difficult to recommend genotypes based on mean yield *per se*; rather it is important to examine stability of performance of genotypes over environments.

In GGE analysis, the first principal component (PC1) accounted 69.74% of the interaction while PC2 accounted 19.59% (Figs. 1and 2) and together accounted for 89.31% of the interaction. Based on GGE analysis, genotypes G2, G11, G4 and G12 contributed little to the interaction; of these only G2 was one of the highest yielding genotypes. Genotype, G3 was also relatively stable and the second hight yielding genotype (3740.3 kg ha^{-1}). Of the tested genotypes, G2 was the most stable and the first high yielding genotype with 3840.3 kg ha^{-1}(Figs.1and 2).

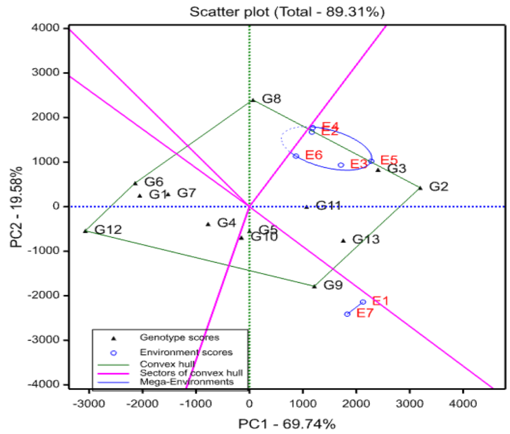

Fig1. GGE biplot of 13 upland rice genotypes for grain yield based on which won where pattern.

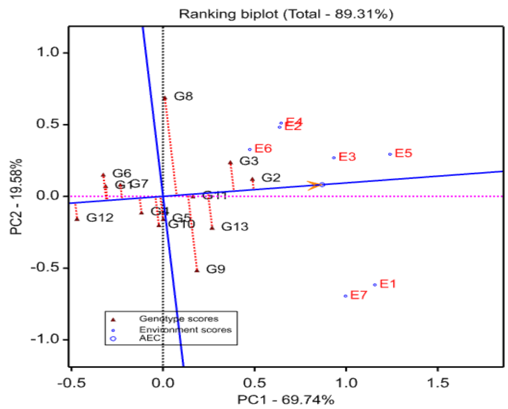

Fig2. GGE biplot for ranking of 13 rice genotypes based mean yield performance and stability.

Table 3. Combined mean yield and yield related parameters of 13 upland rice genotypes tested at seven environments.

Genotype	Code	Days to maturity	Filed Grains/panicle	1000 seed wt(g)	Grain yield (kg/ha)	Leaf blast	Panicle blast
NERICA-11	G1	119.1bc	121.3	26.3	2507.5f	2.3	2.0
NERICA-12	G2	124.3a	132.8	29.6	3840.3a	1.0	1.0
NERICA-13	G3	122.4ab	112.6	29.9	3656.8a	1.2	1.5
NERICA-14	G4	117.5bc	117.9	25.8	2845.8def	2.6	2.3
NERICA-15	G5	116.8c	119.1	26.1	3080.7cde	2.0	2.3
NERICA-16	G6	116.2c	117.3	24.7	2436.9f	2.3	2.6
NERICA-17	G7	116.9c	119.6	25.7	2661.4ef	2.0	2.6
NERICA-18	G8	116.1c	132.4	28.3	3685.6a	1.6	1.8
FOFIFA-4129	G9	119.4abc	121.4	30.5	3202.6bcd	2.3	2.3
FOFIFA-3737	G10	119.6abc	126.4	29.8	3119.bcd	2.3	2.0
FOFIFA-3730	G11	122.3ab	119.3	30	3506.6ab	2.6	2.0
NERICA-10	G12	118.9bc	118.9	23.9	1953g	3.0	2.6
NERICA-4(check)	G13	118.3bc	130.5	25.8	3485.1abc	2.3	2.3
Mean		119.1	122.3	27.4	3067.8	2.1	2.1
CV(%)		6.9	24.5	13	22		
Genotype(G)		*	NS	**	**		
Environment(E)		**	**	NS	**		
G × E		NS	NS	NS	**		

Note: *, **, and ***, significant at 5%, 1% and 0.1%, respectively. NS-non-significant.

The present result suggested that two genotypes, G2 and G3 could be recommended for wider adaptation as both genotypes performed well and showed better yield stability. Following evaluation by national variety release committee and comments from the farmers, G2 (NERICA-12) was released as an upland rice variety in 2013 for Fogera and other areas of similar conditions. Hence, this variety must be popularized and pre-scale up in large scale to make use of its merits.

Experimental II: The results of combined analysis of variance showed that all sources of variations (genotypes, environments and GE interaction) differed significantly at 1% probability level for days to maturity, 1000 seed weight and grain yield (Table 4). The significance of genotypic effect is an indication of performance difference among genotypes across diverse locations which need further analysis to identify specific or widely adapted genotypes. Genotypes, G4, G17 and G9 were with the highest mean yields of 4583.8, 4243.2 kg ha^{-1} and 3825 kg ha^{-1}, respectively. These three genotypes revealed grain yield advantage of 44.7%, 34.0% and 12.1% in that order. However, unlike the other two top high yielding genotypes, G9 was early maturing and showed complete diseases resistance which attracted most farmers during participatory variety selection (PVS) (Table 4).

In the AMMI analysis, differences between the environments accounted for more than half (55.23%) of the treatment sum of squares while genotypes and G × E interaction accounted significantly for 11.01% and 33.74%, respectively of the treatment SS. The first four interaction PCAs were also highly significant, together capturing 84.84% of the total variation in the G × E interaction SS (Table 5).

The polygon view of the GGE bi-plot (Fig 3) indicates the best genotype(s) in each environment and groups of environments (Yan and Hunt, 2002). The vertex genotypes are among the most responsive genotypes; all others are less responsive in their respective direction. The vertex genotypes for each sector are the ones that gave the highest yield for the environments that fall within that sector. The genotype with the highest mean yield in E1, E4, and E7 is G4, followed by G11, G14 and G8. In the E5, E8 and E10 the best genotypes is G17. Genotypes G2, G9 and G12 were the highest yielding genotypes in E2, E3, E6 and E9. The other vertex genotypes (G3, G5, G6, G8, G10 and G13 are poorest in all environments because there is no environment in their sectors.

Table 4. Combined mean yield and yield related parameters of 20 lowland rice genotypes tested at ten environments.

Genotype	Code	Days to maturity	Filled grains/ Panicle	1000 seed wt. (g)	Grain yield (kg/ha)	Leaf blast	Panicle blast
FKRS	G1	137.6ef	110.9cdef	34.3a	2948.1efghi	1.0	0.0
IR75502-5-1-1-B	G2	142.9ab	123.9ab	24.9fg	3310.2de	1.0	1.0
IR72022-7-6-3-2-3	G3	140.8cd	105.2ef	21.3jk	2661.3hij	1.0	0.3
ROJOMENA271/10	G4	139.1de	123.1abc	25.5f	4583.8a	3.0	2.0
IR75517-23-1-1-B	G5	135.5g	106.7def	29.7cde	2779.1ghij	1.6	1.3
IR71730-51-2	G6	139.de	101.4ef	24.3gh	2371.4j	1.3	0.3
WAB272-B-B-5-H4	G7	131.8h	107.6def	31.9b	2981.8efgh	0.6	0.0
WAB95-B-B-40-HB	G8	135.4g	107.7def	30.0cde	3265.6def	3.3	1.6
IRGA370-38-1-1F-B1-1	G9	130.6h	100.5f	30.5c	3825.8bc	0.0	0.0
IR76999-52-1-3-2	G10	142.8abc	107.9def	24.1gh	3010.7efgh	1.0	3.6
WAB502-8-5-1	G11	136.1fg	118.2bcd	29.9cde	3646.0cd	2.3	1.0
WAB368-B-HI-HB	G12	136.7fg	117.8bcd	30.6bc	3087.1efgh	3.3	2.3
IR74052-184-3-3	G13	143.0ab	117.9bcd	22.5ij	2509.8ij	1.0	1.0
WABC165 (IAC165)	G14	135.0g	113.6bcde	30.4cd	3131.8efg	1.3	1.0
PSBRC44	G15	144.6a	112.9bcde	23.1hi	2955.7efghi	2.3	2.6
PSBRC46	G16	142.3bc	118.9abcd	21.7j	2829.1fghi	2.6	1.6
PSBRC92	G17	137.8ef	130.8a	20.3k	4243.2ab	2.3	2.5
WAB376-B-10-H3	G18	136.6fg	113.6bcde	29.1e	2998.2efgh	2.6	10.6
PSBRC50	G19	143.8ab	108def	24.2gh	2981.5efgh	1.6	1.0
GUMARA(Check)	G20	135.4g	110.9cdef	29.2de	3166.1efg	1.3	0.6
Mean		138.4	112.9	26.9	3164.3	1.7	1.7
CV(%)		3.0	22.3	9.3	29		
Genotype (G)		**	**	**	**		
Environment(E)		**	**	**	**		
G × E		**	NS	**	**		

Note: *, **, and ***, significant at 5%, 1% and 0.1%, respectively. NS-non-significant.

Table 5. AMMI analysis of variance for grain yield of 20 lowland rice genotypes tested at 10 environments.

Source of variation	D.f	S.S	M.S	F-ratio	F pr	%variation explained
Treatments	199	1059200308	5322615	7.33	<0.001	
Genotypes	19	116744586	6144452	8.46	<0.001	11.01
Environments	9	585022140	65002460	24.11	<0.001	55.23
Interactions	171	357433583	2090255	2.88	<0.001	33.74
IPCA 1	27	141540396	5242237	7.22	<0.001	39.60
IPCA 2	25	70147707	2805908	3.86	<0.001	19.62
IPCA 3	23	47764344	2076711	2.86	<0.001	13.40
IPCA 4	21	43687048	2080336	2.86	<0.001	12.22
IPCA 5	19	20432679	1075404	1.48	0.0887	
Residuals	11	3311709	301064	0.41	0.9496	
Error	380	276046385	726438			

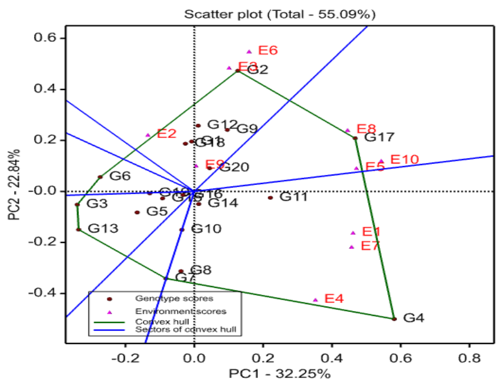

Figure 3. GGE biplot of 20 rice genotypes for grain yield based on which won where pattern.

Of the tested genotypes, G9 performed relatively better in E2, E3, E6 and E9. This genotype was also free from major diseases. Following PVS and evaluation by national variety release committee, G9 was released in 2013 for lowland rice production systems of Fogera and similar areas by the vernacular name 'Hibbire'. Farmers preferred the variety due to its earliness, diseases resistance and white caryopsis color. Currently, the variety is under promotion and popularization. The other two high yielding genotypes, G4 and G17, could be used in further crossing program in the development of high yielding varieties.

CONCLUSION AND RECOMMENDATION

The present study revealed significant differences among the genotypes and environments for grain yield and related traits suggesting differential response of genotypes to varied environments. In the first set of experiment, G2 (NERICA-12) was released as upland NERICA variety. In the second set of experiment in lowland rice, G9 (IRGA370-38-1-1F-B1-1) was released as 'Hibbire' for its earliness, good yield performance, stable, and diseases resistant. The studies revealed the importance of earliness, high yield and diseases resistance in the evaluation of genotypes. Early maturing varieties allow rice producers to use the land for double cropping and also enable escape unpredicted terminal drought. The released varieties are crucial to boost production and productivity in the rainfed upland and lowland rice production system of Ethiopia. Hence, these varieties should be popularized and pre-scale up in large scale to reach significant number of rice farmers and to make use of varieties potential merits.

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How to cite this article: Lakew T, Tariku S, Belay B et al. Assessment of phenotypic stability and agronomic performance in some upland and lowland rain fed rice genotypes in diverse agro-ecologies of northwest Ethiopia. Int J Res Rev. 2016; 3(4):1-6.

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