



## GGE Bi-Plot Analysis of Genotype by Environment Interaction in Medium Maturing Upland Rice Genotypes in Ethiopia

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**Abstract:** The experiment was conducted in Woreta, Pawe, Metema, Assosa, Mytsebri, Bako, Bonga and Jimma from 2012-2014 main cropping seasons with the major objectives of medium maturing, high yielding and pest resistance rice varieties for the upland rice production system in Ethiopia. A total of 20 upland genotypes including one check were used in the study. The trial was laid out in randomized complete block design with three replications with plot size of 6.0 m<sup>2</sup>. The combined analysis of variance revealed significant difference on days to maturity, panicle length, plant height, fertile tiller per plant and grain yield ( $P \leq 0.01$ ). G7 (IR 83384-B-B-102-3) was the highest yielding genotype followed by G3 (IR 78937-B-20-B-B-4) and G5 (IR 83750-B-B-131-1) with grain yield of 4223.4, 3849.7 and 3776.3 kg ha<sup>-1</sup>, respectively. The GGE bi-plot graphic analysis revealed that the two principal components explained 76.42 % of the total GEI variance. GGE bi-plot analysis showed that G7 performed best in almost all environments except in E3 and E11. Grain yield performance and stability analysis revealed that G7 was the highest yielding and relatively stable. Therefore G7 was identified as candidate variety and it was verified along with the check on farmer's field and on station.

**Keywords:** GE interaction, GGE, medium maturing, Stability, Grain yield

### 1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population, mostly in developing countries in Asia, Africa and Latin America [1, 2], and is thus of significant importance to food security [3]. On a global scale, in the year 2011, 720 million tons of paddy rice was produced, of which more than 90% was produced in Asia. Rice means life for millions of people and it is planted in many regions of the world. It primarily grows in the major river deltas of Asia and Southeast Asia, such as the Mekong Delta, known as the Rice Bowl of Vietnam, the second-largest rice-producing nation on Earth [4]. In addition, rice is the most rapidly growing source of food in Africa. Rice is therefore of significant importance to food security in an increasing number of low-income food-deficit countries.

Much of the future expansion of the world's rice land will probably be in upland rice because most of the land suited to irrigated paddy culture is already planted in lowland rice [5]. Such expansion is more feasible in some parts of Africa, and in the "cerrado savanna" area in Central West Brazil and the Amazon basin area of South America, than anywhere in Asia. About 75 percent of Africa's total rice is upland, planted in the humid regions of West Africa.

Upland or dry land rice is found in rain fed mountains or plateaus. The rice is dry-seeded, due to the lack of humidity, mostly poor soils, and the absence of surface water accumulation [6]. Yields are often low compared to rain fed lowland and irrigated rice. Upland rice farming can be found in Brazil, Madagascar, India, Southeast Asia and Africa. The amount of produced upland rice represents approximately 13% of the rice-planted area in the world and 4% of the global rice production [4].

Rice was introduced to Ethiopia in 1960s, however the production and productivity was stagnant until 2005. Since 2016, rice production and productivity is constantly increasing [7]. Ethiopia has a huge potential, estimated to 30 million hectares, for further rice production and expansion. Currently rice is

cultivating in Amhara, Benishangule Gumze, South NNPR, Gambella, Tigray and Oromia regions of Ethiopia [8](MoA, 2010). Rice is increasingly important in Ethiopia which could be evidenced by consistent increments of domestic production and imports [9]. Rice research and development is constrained by shortage of high yielding varieties, lack of improved agronomic packages, low input utilization, terminal drought, low temperature effect, soil fertility decline and pre and post-harvest management problems [8]. In Ethiopia, rice breeding research is 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  $G \times E$  interaction complicates the selection of a rice variety with superior performance and adaptability to diverse environments. The  $G \times E$  interaction may arise when specified genotypes are grown in diverse environments [10]. 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 [11]. Although productivity of rice in the country is increasing with consistent deployment of new improved varieties into production [12], but still the productivity levels attained in both research managed fields as well as farmer's fields is low compared to both elsewhere in the world and the biological potential of rice. Therefore the major objective of this study was to identify and promote high yielding; stable, medium maturing and pest resistant rice varieties for rain fed upland rice productions systems of Ethiopia.

## 2. MATERIALS AND METHODS

The experiment was conducted from 2012-2014 in eight locations; Woreta, Pawe, Metema, Assosa, Mytsebri, Bako, Bonga and Jimma. The locations are where the trials conducted. A total of 20 genotypes including one check used (Table 1). The trial was laid out in randomized complete block design with three replications with a plot size of 6 m<sup>2</sup> (Six rows with 5 m long with 0.20 m row spacing). Seed rate of 60 kg/ha was used and direct seeding methods in a row was applied. Fertilizer (UREA and DAP) were applied based on each location recommendation. All DAP was applied at the time of sowing. For UREA, split application was applied; 1/3 at sowing, 1/3 at active tillering and the remaining 1/3 during panicle initiations. Other agronomic practices were applied according to each location recommendations.

**Table1.** List of genotypes used for the study

S/N	Genotypes	Code	Source
1	IR 82635-B-B-25-4	G1	International Rice Research Institute
2	IR 82635-B-B-145-1	G2	International Rice Research Institute
3	IR 78937-B-20-B-B-4	G3	International Rice Research Institute
4	WAB880SG14	G4	Africa rice
5	IR 83750-B-B-131-1	G5	International Rice Research Institute
6	IR 82635-B-B-82-2	G6	International Rice Research Institute
7	IR 83384-B-B-102-3	G7	International Rice Research Institute
8	IR 82616-B-B-64-3	G8	International Rice Research Institute
9	IR 82635-B-B-47-2	G9	International Rice Research Institute
10	IR 82635-B-B-59-2	G10	International Rice Research Institute
11	ARCCU16Bar-15-5-1-26-B-1	G11	Africa rice
12	ARCCU16Bar-12-13-26-4-B-1	G12	Africa rice
13	ARCCU16Bar0-12-22-4-1-B-1	G13	Africa rice
14	ARCCU16Bar-11-8-5-2-B-1	G14	Africa rice
15	ARCCU16Bar-29-13-3-B-1	G15	Africa rice
16	ARCCU16Bar-12-12-33-3-B-1	G16	Africa rice
17	ARCCU16Bar-9-4-17-3-B-1	G17	Africa rice
18	ARCCU16Bar9-26-29-1-B-1	G18	Africa rice
19	ARCCU16Bar-13-2-16-2-1-1	G19	Africa rice
20	AD01(check)	G20	Fogera National Rice Research and Training Center

### 2.1. Data Collection and Statistical Analysis

Data were collected for days to heading, days to maturity, panicle length, plant height, filled grains/panicle, fertile tillers/plant, leaf blast, panicle blast, brown spot and grain yield. Grain yield (kg

## GGE Bi-Plot Analysis of Genotype by Environment Interaction in Medium Maturing Upland Rice Genotypes in Ethiopia

ha<sup>-1</sup>) was estimated based on adjustment at 14% moisture level on the basis of four central harvestable rows. The grain yield and other agronomic parameters were subjected to analysis of variance using the SAS version 8.1 software. The grain yield data were also subjected to GGE-bi-plot analysis for ranking of genotypes based on grain yield performance and stability and also for detecting wider and/or specifically adapted genotype(s).

### 3. RESULT AND DISCUSSION

#### 3.1. Combined Analysis of Variance

The combined analysis of variance revealed the main effects of genotypes and environments has significant different ( $P \leq 0.01$ ) for days to maturity, panicle length, plant height, filled grains/panicle, fertile tillers/plant and grain yield. Genotype by environment interaction was significantly different for all characters except fertile tillers per plant (Table 2). The combined grain yield ranged from 2646.4 kg ha<sup>-1</sup> to 4223.4 kg ha<sup>-1</sup> with mean grain yield of 3304.6 kg ha<sup>-1</sup>. Genotypes, G7 (IR 83384-B-B-102-3), G3 (IR 78937-B-20-B-B-4) and G5 (IR 83750-B-B-131-1) were the highest yielding genotypes with grain yield of 4223.4, 3849.7 and 3776.3 kg ha<sup>-1</sup> and yield advantage of 40.4 %, 27.9 % and 25.5 % over the check, respectively. The significant interaction difference of the two way interaction of genotype x environment revealed that the possibility of getting genotypes which can be adapted widely/or specifically.

**Table 2.** Over all combined mean grain yield and other yield parameters of 20 upland medium maturing type rice genotypes

Genotypes	Code	DTM	PL	PH	FTP	FGP	Gy	PB	LB	BS
IR 82635-B-B-25-4	G1	131.4	23.4	76.9	5	102.5	3561.0	2.2	1.3	1
IR 82635-B-B-145-1	G2	132.4	24.6	74.8	5.4	102.7	3725.1	2.5	1.4	1.2
IR 78937-B-20-B-B-4	G3	131	24.8	73	6.1	103.1	3849.7	2.7	1.4	0.8
WAB880SG14	G4	121.3	24.2	83.8	5.1	91	3452.0	2.8	1.6	1
IR 83750-B-B-131-1	G5	131.5	24.4	66.8	5.9	95.8	3776.3	2.6	1.5	1.8
IR 82635-B-B-82-2	G6	130.8	24.2	71	5.3	99.6	3478.5	2.6	1.2	1.4
IR 83384-B-B-102-3	G7	129.5	24.2	83.6	5.4	88.6	4223.4	1.8	1.0	1.1
IR 82616-B-B-64-3	G8	127.1	25.2	84.8	4.9	102.3	3673.8	2.8	1.5	1.8
IR 82635-B-B-47-2	G9	128.3	24.6	77	5.2	99	3220.3	2.2	1.4	1.1
IR 82635-B-B-59-2	G10	131.7	23.2	74	5.4	102	3549.5	2.7	1.5	1.7
ARCCU16Bar-15-5-1-26-B-1	G11	118.8	22.6	80.3	4.7	93.5	3014.6	2.3	1.8	1.6
ARCCU16Bar-12-13-26-4-B-1	G12	120	23.6	82.4	4.6	103	2713.6	2.3	1.8	0.7
ARCCU16Bar0-12-22-4-1-B-1	G13	121.1	23.1	76.4	5.5	90.6	2773.5	2.4	2.3	1.1
ARCCU16Bar-11-8-5-2-B-1	G14	121.9	22.8	82.4	4.9	97.6	3115.2	2.1	2.2	1
ARCCU16Bar-29-13-3-B-1	G15	123.5	24.8	83.4	4.8	102	3272.1	1.5	1.6	1.4
ARCCU16Bar-12-12-33-3-B-1	G16	118.1	22.4	74.4	5	92.3	2646.4	2.3	2.3	0.8
ARCCU16Bar-9-4-17-3-B-1	G17	118.5	24.1	83.6	5.1	90.5	2878.6	2.4	1.6	1
ARCCU16Bar9-26-29-1-B-1	G18	119.7	23.3	81.3	5.1	92.3	3291.0	2.6	1.8	1.1
ARCCU16Bar-13-2-16-2-1-1	G19	121.6	24.2	86.9	5.3	92.6	2868.3	2.3	1.7	1
AD01 (check)	G20	119.7	23.4	78.4	4.7	89.6	3008.1	2.2	1.8	1.1
Mean		124.9	23.8	78.8	5.2	96.5	3304.6			
CV (%)		4.29	10.48	7.24	21.83	17.84	24.53			
LSD (5%)		2.48	1.16	2.64	0.52	7.98	375.42			
Genotype (G)		***	***	***	***	***	***			

## GGE Bi-Plot Analysis of Genotype by Environment Interaction in Medium Maturing Upland Rice Genotypes in Ethiopia

Environment(E)		***	***	***	***	***	***			
G x E		***	**	***	NS	**	***			

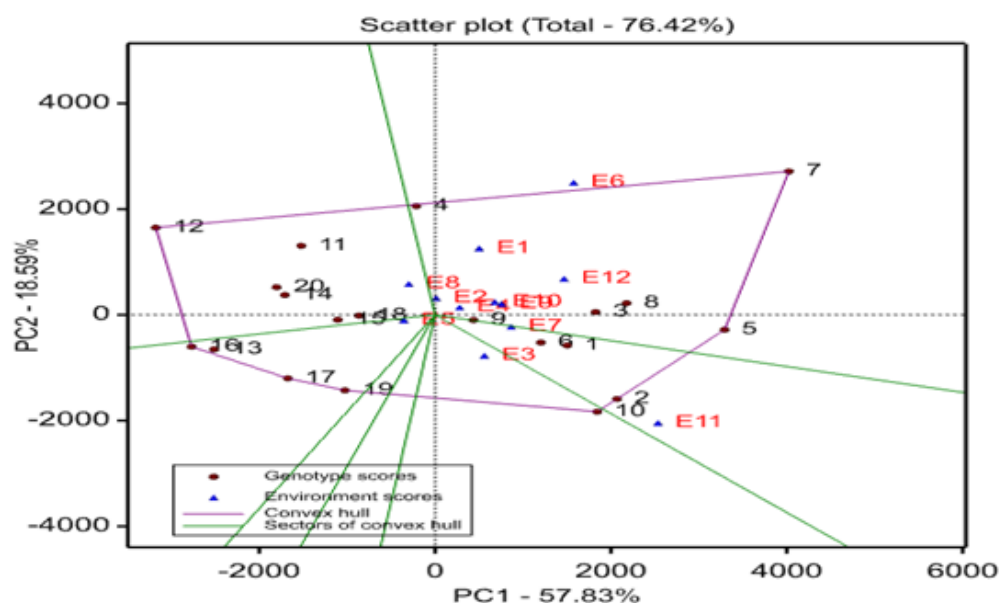
**Note:** \*, \*\*, \*\*\* significant at 5%, 1% and 0.1% respectively, NS= not significant, DTH= days to 50% heading, DTM= days to 85% heading, PL= panicle length (cm), PH= plant height (cm), FTP = number of fertile tillers per plant , FGP= number of filled grains per panicle, PFG= percent of filled grains per panicle, , Gy= grain yield (kg/ha), LB=leaf blast, PB= panicle blast, and BS= brown spot.

### 3.2. Which- Won- Where Pattern of Genotypes and Environments

GGE bi-plot analysis is a multivariate analytical technique that graphically displays a two table and allows visualizing the relation among genotypes, environments and their interaction [13]. In the present study, the GGE bi-plot graphic analysis of twenty upland medium maturing rice genotypes revealed that the two principal components explained 76.42 % of the total GEI variance (Fig.). The polygon view of the GGE bi-plot clearly displays the which-won- where pattern[14]. Hence some of the genotypes were on the vertexes while others within the polygon. Genotypes within the polygon were less responsive to location than the vertex genotypes[14]. Genotype 7, 5, 10, 16 and 12 are the vertex genotypes and they are the most responsive genotypes since they are placed far away from the bi-plot origin when compared with other genotypes that are located within the polygon. GGE bi-plot analysis showed that genotype (G7) performed best in almost all environments except in E3 and E11 (Figure 1). If no environment is present in a sector, then vertex genotype of that sector is considered to be a poor performer in all test environments [15].

Accordingly there is no any environment which felled inside the sectors of the vertex genotypes G12 and G16 which indicated those vertex genotypes were not the best in any of the environments.

According to[15]report, responsive genotypes were those having either best or the poorest performance in one or all environments. Accordingly, among the vertex genotypes G5 and G7 were identified as the high yielding genotypes while G12 and G16 were the low yielding genotypes across the testing environments (Fig. 1).

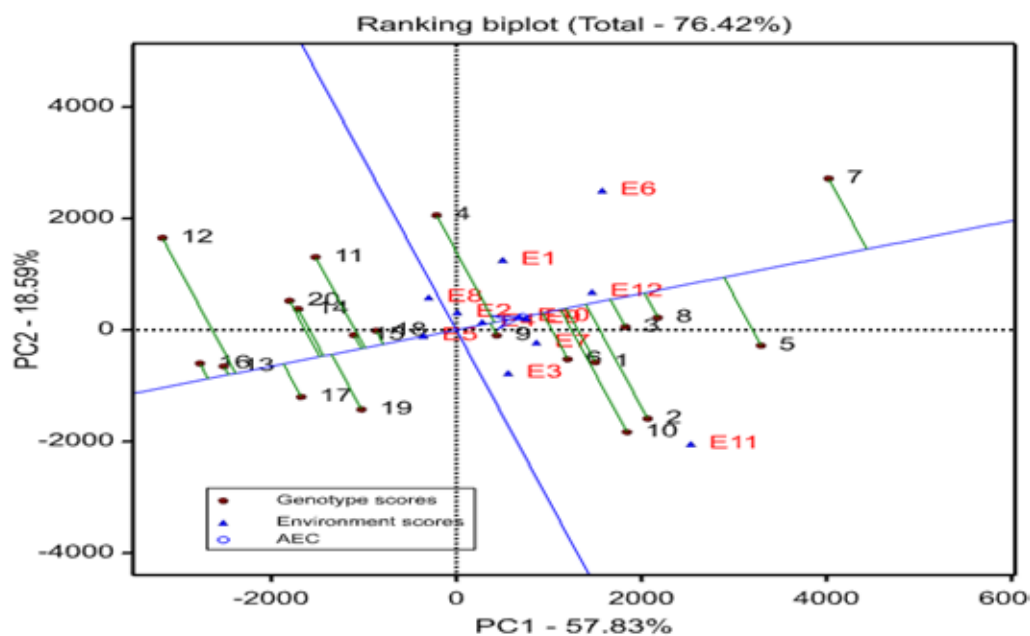


**Figure1.** The polygon view of (which- won-where) 20 upland rice genotypes and environments for grain yield

### 3.3. Ranking of Genotypes based on Mean and Stability Performance

In this study, the stability and grain performance of twenty upland rice genotypes were visualized graphically through the GGE bi-plot (Fig. 2). This can be evaluated by average environment coordination (AEC) method [13, 15]. In Fig.2 the line with single arrow head is the AEC abscissa. AEC abscissa passes through the bi-plot origin and marker for average environment and points towards higher mean values. The average environment has average PC1 and PC2 scores across environments [13]. The perpendicular line to AEC passing through the bi-plot origin area referred to

as AEC ordinate. The greater the absolute length of the projection of genotype indicates more instability. Furthermore, the average yield of genotypes is approximately by the projections of their markers to the AEC abscissa [11]. According to Fig. 2, genotypes with above average means were from G7, G5, G8, G3, G1, G6, G2, G10, G4 and G9, while genotypes below average means were from G12, G16, G13, G17, G19, G20, G14, G11, G15 and G18. However, the length of the average environment vector was sufficient to select genotypes based on yield mean performances. Genotypes with above average means (G7, G5, G8, G3, G1, G6, G2, G10, G4 and G9) could be selected, whereas the rest were discarded. A longer projection to the AEC ordinate, regardless of the direction, represents a greater tendency of the GE interaction of a genotype, which means it is more variable and less stable across environments and vice versa[16]. Accordingly, Genotype G9 was most stable but low yielding than those genotypes which were above average means. Genotype G8 was stable and relatively high yielding followed by genotype G3, G1 and G6. Grain yield performance and stability analysis (Fig.2) clearly showed that G7 was the highest yielding and also relatively stable though less stable than G8, G3, G5, G9, G6 and G1. Genotype G16 was stable but low yielding. Following performance of the genotypes across locations and over years, G7 was identified as candidate variety and it was verified along with the check on farmer's field and on station. It showed best performance and the variety was evaluated by National Variety Release Technical Committee. However the National Variety Release Technical Committee found that the candidate variety (G7) was found good in most of the characters like high yield and biomass, long panicle, moderate disease resistance/tolerance and other desirable merits. However the candidate was selected from the medium maturing set and it was found 20 days late in terms of maturity as compared to the other candidates and standard check. Therefore, considering some of its merits the technical committee recommended the variety to be included as candidate in the upcoming medium maturing set.



E1= Woreta2012, E2= Maitsebri2012, E3=Pawe 2012, E4=Woreta2013, E5= Bako2013, E6=Metema2013, E7= Pawe2013, E8=Assosa2013, E9= Woreta2014, E10=Maitsebri2014, E11=Pawe2014, E12=Metema2014

**Figure2.** Ranking of 20 upland medium type rice genotypes based on mean yield performance and stability evaluated across diverse environments.

#### 4. CONCLUSION AND RECOMMENDATIONS

The present study revealed that significant differences among genotypes and environments for grain yield and related agronomic traits suggesting differential response of genotypes to varied environments. Mean grain yield and stability performance over environments of each genotype is explored by using AEC methods. These methods showed that G7 (IR 83384-B-B-102-3) has high mean grain yield and relatively stable out of the twenty tested genotypes. This genotypewas proposed for national variety release. The experiment revealed the importance of medium maturing, high yield and diseases resistance in the evaluation of genotypes.



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