

Evaluation of Yield and Yield Components of Lowland Rice (*Oryza sativa* L.) Varieties in the Rainfed-Lowland Rice Producing Areas of Ethiopia

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Abstract

A field experiment was conducted to evaluate the performance of rice varieties for grain yield and other agronomic traits in the rainfed lowland rice producing areas of Ethiopia; Assosa, Bako, Pawe and Tepi during 2017 and 2018 cropping season. Six lowland rice varieties were included for evaluation and laid out in Randomized Complete Block Design with four replications. The combined analysis across years and locations revealed significant variations ($p \leq 0.001$) among the tested varieties for days to heading, days to maturity, plant height, grain yield and thousand seed weight while non-significant difference was observed for number of filled grains per panicle and panicle length. Both location and year effects were highly significant for all measured traits. Variety by location and variety by year were highly significant ($p \leq 0.001$) for days to heading, days to maturity, plant height, number of filled grains per panicle, and grain yield though variety by year was not significant for thousand seed weight. Variety by location and variety by year were non-significant for panicle length. Based on the performance of the variety in each test location and year, variety Ediget is recommended for Assosa (2.93 tha^{-1}) and Bako (3.39 tha^{-1}) areas with days to heading and maturity (85 and 145 days) among the tested varieties, and variety Fogera-2 (5.19 tha^{-1}) for Pawe areas with maturity date (121 days) while, in Tepi area variety Hibir followed by Gumara are recommended for better productivity (4.83 tha^{-1} and 4.68 tha^{-1}) respectively. However, based on average grain yield over four locations and two years variety Ediget (3.22 tha^{-1}) followed by Fogera-2 (3.07 tha^{-1}) performed better than others and they are recommended for production.

Keywords: Lowland rice, Adaptation, Variety, Yield

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Introduction

Rice production is a recent phenomenon in Ethiopia, as compared to other cereals crops. It had been introduced by in 1960s at Fogera and Gambela areas through North Korean and Dutch people respectively (CSA, 2011; Gebey *et al.*, 2012).

The country has a huge potential of land for rice production in three ecosystems, upland (5.6 million ha), irrigated (3.7 million ha) and rain fed lowland. Now, a days the production and productivity of rice have been expanding throughout the country (MoARD, 2010). The production has been increased from 11,244.3 tons in 2007 to 126,806.4 tons in 2016. Even though there is an increment in the production, the imports are also increasing from year to year. From 2008 to 2016 the imported rice had increased from 225,000 quintal to 3,118,270 quintal and causes more than 170 US dollars. This indicates the increasing demand of rice from year to year in the country. Rice is not only food securing crop but also a source of employment and income source for youths in most rice producing areas of the country (Dawit *et al.*, 2018).

Even though there is huge potential and increasing demand of the crop, lack of high yielding varieties, terminal moisture stress and low soil fertility, disease and cold effect are the constraints that hinders the expansion and productivity of the crop (Abewaw, 2018). One of the major constraints in rice producing areas is lack of adaptable and high yielding improved rice varieties. So far eleven improved lowland rice varieties had been released in Ethiopia. However, cultivation of improved lowland varieties in most rice growing is limited, due to unavailability of adaptable rice varieties. Farmers grow old rice varieties venerable to disease and ends with low productivity. Therefore, this study was designed to select adapted and high yielding lowland rice varieties in the testing rice producing areas.

Material and Methods

The experiment was conducted at Assosa, Pawe, Bako and Tepi Research Centers during 2017 and 2018 cropping seasons in the rainfed lowland condition. The description of the trail site is indicated in Table 1. Five lowland rice varieties released from national and regional research centers and one widely produced rice varieties, but not yet registered (Table 2) were evaluated in a randomized complete block design replicated four times, on a plot size of 5 long \times 1.5 width. A spacing of 25 cm, 50 and 1.5 m cm were used between rows, between plots and between blocks respectively.

Data were recorded on 5 randomly selected plants from the middle four rows for panicle length, plant height,

number of filled grains per panicle, and on plot bases for days for heading, days for maturity. Grain yield and thousand seed weight were taken on plot basis from the four harvestable rows. Fertilizer application and weeding were carried out following the recommended packages. Data were subjected to analysis of variance (ANOVA) using GenStat version 12 edition software package (Payne *et al.*, 2009).

Table 1. Description of experimental locations

Location	Elevation (m)	Latitude	Longitude	Annual rain fall (mm)	Mean temperature (°C)		Soil type
					Min	Max	
Assosa	1580	10° 03' N	34° 59' E	1,275	14°C	39°C	Nitosols
Bako	1590	9° 06' N	37° 09' E	1,245	9°C	34.4°C	Nitosol
Pawe	1120	11°19'N	36°24'E	1587	16.3°C	32.6°C	Vertisols
Tepi	1200	7° 3' N	35°18' E	1522.1	15°C	30°C	Nitosols

Sources (Tefera *et al.*, 2017, Hailemariam *et al.*, 2017)

Table 2. Description of experimental materials used for the study

Varieties	Released Center	Region	Year of released	Altitude (m.a.s.l)	Rain fall (mm)	Productivity (kg ha ⁻¹)	
						On-farm	On-station
Ediget	Adet RC	Amhara	2011	1150-1850	800-1400	32	52
Hiber	Adet RC	Amhara	2013	1150-1850	1000-1400	26-36	34-47
Gumera	Adet RC	Amhara	1999	1740-1900	1520	30	38
Fogera-2	FNRRTC	Amhara	2016	500-1590	1000-1450	37-49	42-61
Demoze*							
X-Jigna*							

*Demoze and X-jigna have not yet registered, but they are under production in lowland rice producing areas.

Result and Discussion

The analysis of variance over years at Assosa showed highly significant difference ($p \leq 0.01$) among varieties for days to maturity, plant height, number of filled grains per panicle, grain yield and thousand seed weight but not on panicle length (Table 3). The effect of year was highly significant ($p \leq 0.01$) on days to maturity, number of filled grains per panicle and thousand seed weight and significantly for panicle length at ($p \leq 0.01$), and it was non-significant on plant height and grain. The interaction effect of year by variety showed highly significant difference ($p \leq 0.01$) for number of filled grains per panicle, grain yield and thousand seed weight and days to maturity ($p \leq 0.05$); while it was non-significant for panicle length and plant height. A similar finding was also reported by Hailemariam *et al.* 2017.

The average days to maturity ranged from 93 to 115 days; the variety Ediget matured earlier than the others while Fogera-2 was matured latter than the others. The varieties had minimum mean differences for panicle length. The average plant height was ranged from 80.6 cm to 98.6 cm; Fogera-2 has the shortest plant height and Demoze has longest height among the tested varieties. A maximum filled grain was recorded on X-jigna (105.6), and small amount of filled grain was obtained on Gumara (80.9). The average grain yield was ranged from 2933 kg ha⁻¹ for Ediget to 2065 kg ha⁻¹ for X-Jigna. The highest thousand seed weight was obtained for Hibir (38.7 g) followed by Gumara (37.0 g). The results revealed that Ediget (2933 kg ha⁻¹) and Demoze (2933 kg ha⁻¹) are the high yielder and well adapted varieties in the rainfed lowland rice producing areas of Assosa. The variety Ediget was the highest yielder followed by Demoze for Assosa areas and could be recommended for production. Hailemariam *et al.* 2017 had also reported the same result which confirmed that variety Ediget is the less responsive across different years and stable genotype in the area.

Table 3. Mean performance of grain yield and yield related traits of six lowland rice varieties evaluated in 2017 & 2018 cropping season at Assosa, Ethiopia.

Variety	DM	PL	PH	FGPP	GY	TSW
Ediget	93	20.0	95.1	89.9	2933.0	36.6
Hiber	95	19.7	89.5	82.7	2124.0	38.7
Demoze	97	20.0	98.6	101.3	2457.0	31.2
Gumera	98	21.2	96.0	80.9	2162.0	37.0
X-Jigna	99	20.6	95.4	105.6	2065.0	31.2
Fogera-2	115	19.9	80.6	101.3	2069.0	23.9
Mean	100	20.2	92.5	93.6	2301.6	33.1
CV (%)	2.2	9.4	9.3	17.1	21.8	7.1
LSD (5 %)	3.163	2.8	12.3	23.1	722.4	3.4
Variety (V)	***	NS	***	***	***	***
Year (Y)	***	**	NS	***	NS	***
VxY	*	NS	NS	***	***	***

DM=Days to maturity, PL=Panicle length (cm), PH=Plant height (cm) FGPP= Number of filled grains per panicle, GY=, Grain yield (kg ha⁻¹), TSW=Thousand seed weight (g), * **, ***, and NS denotes significance difference at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ and non-significant difference respectively

The combined analysis of variance across years at Bako (Table 4) showed highly significant difference ($p \leq 0.01$) among the tested varieties for days to maturity, days to heading, panicle length, plant height, number of filled grains per panicle, grain yield and thousand seed weight. The effect of year was highly significant ($p \leq 0.01$) for days to maturity, days to heading, plant height, number of filled grains per panicle, grain yield, while it was non-significant on panicle length and thousand seed weight. The interaction effect of variety by year showed highly significant difference ($p \leq 0.01$) for all measured traits (days to maturity, days to heading, panicle length, plant height, number of filled grains per panicle, grain yield) except for thousand seed weight.

Days to heading was ranged from 84 to 101 days; Ediget gave head earlier than the others, whereas Fogera-1 was the late heading variety. Ediget was the earliest maturing (145 days) and Fogera-2 (153 days) was the late maturing among the tested varieties. The average panicle length was ranged from 19.7 cm to 22.4 cm, shortest panicle length recorded for Demoze and longest was for Gumera. The highest plant height was recorded for Demoze (127.9 cm) followed by X-jigna (125.4) whereas the shortest plant height was obtained for Fogera-2 (104.2). The number of filled grains per panicle ranged from 30.5 (Fogera-2) to 55.1 (Ediget). Thousand seed weight was highest for variety Ediget (30.4) and Hiber (30.4), while the small grain weight was obtained for Fogera-2 (18.9). Regarding the grain yield, Ediget was the higher yielder followed by Hiber and the two varieties could be recommended for production in Bako areas.

Table 4. Mean performance of grain yield and yield related traits of six lowland rice varieties evaluated in 2017 & 2018 cropping season at Bako, Ethiopia

Variety	DH	DM	PL	PH	FGPP	GY	TSW
Ediget	85	145	20.3	114.1	55.1	3398.0	30.4
Hiber	84	146	20.1	107.1	54.0	2820.0	30.3
Demoze	88	145	19.7	127.9	44.2	2637.0	26.3
Gumera	94	145	22.4	122.8	33.1	1847.0	26.9
X-Jigna	89	146	20.6	125.4	35.8	1440.0	26.6
Fogera-2	101	153	19.8	104.2	30.5	1419.0	18.9
Mean	90	147	20.5	116.9	42.0	2260.1	26.6
CV (%)	2.6	1.1	4.7	3	25.4	36.9	11.6
LSD (5 %)	2	2	1.0	3.6	10.9	847.4	3.1
Variety (V)	***	***	***	***	***	***	***
Year (Y)	***	***	NS	***	***	***	NS
VxY	***	***	***	***	***	***	NS

DH= Days to heading, DM=Days to maturity, PL=Panicle length (cm), PH=Plant height (cm) FGPP= Number of filled grains per panicle, GY=, Grain yield (kg ha⁻¹), TSW=Thousand seed weight (g), *** denotes significance difference at $p \leq 0.001$, NS=Non-significant difference

The combined analysis of variance across years at Pawe (Table 5) showed highly significant difference ($p \leq 0.01$) for days to heading, days to maturity, plant height, number of filled grains per panicle, grain weight and thousand seed weight; and significant difference ($p \leq 0.05$) was observed for panicle length among the tested varieties. The effect of year was also highly significant on all measured traits ($p \leq 0.01$) except panicle length. The interaction of variety and year revealed a highly significant difference ($p \leq 0.01$) for days to heading, days to maturity, plant height, whereas number of filled grains per panicle, grain yield and thousand seed weight didn't show significant difference. There was highly significant difference among varieties. The non-significant effect of

year by variety indicates that the varieties are stable across years for the testing locations.

Variety Demoze (70 days) followed by Ediget (72 days) were the early variety for heading while Fogera-2 (121 days) was the late heading variety. Panicle length is one of the major yield contributing traits. The longest panicle was recorded on variety Gumara followed by Fogera-2 while shortest panicle length was recorded on Hiber. The average plant height ranged from 85.6 (Hiber) to 107.2 (Gumara). The tallest variety were Gumara followed by Demoze and x-jigna, while the shortest height was recorded on Hiber and Fogera-2. Filled grain is one of the yields contributing factor and the highest filled grain and grain yield were recorded on the same variety Fogera-2 which were 117.6 and 5188 kg ha⁻¹ and followed by Gumara 99.2 and 3619 kg ha⁻¹ respectively. However, the small number of filled grains was recorded on variety Hiber whereas Demoze was the lowest yielder variety. Thousand seed weight was higher for variety Hiber followed by Gumara while the smaller was recorded on Fogera-2.

Table 5. Mean performance of grain yield and yield related traits of six lowland rice varieties evaluated in 2017 & 2018 cropping season at Pawe, Ethiopia

Variety	DH	DM	PL	PH	FGPP	GY	TSW
Ediget	72	106	18.2	89.2	95.6	2860.0	32.0
Hiber	68	102	17.7	85.6	81.7	2702.0	30.8
Demoze	70	106	18.1	95.4	83.0	2168.0	24.3
Gumera	79	115	19.8	107.2	99.2	3619.0	29.1
X-Jigna	69	104	18.8	95.8	89.2	2218.0	25.7
Fogera-2	85	121	19.7	87.1	117.6	5188.0	20.9
Mean	74	109	18.7	93.4	94.4	3125.6	27.1
CV (%)	2.5	2.1	6.8	7.1	10.8	14.1	3.9
LSD (5 %)	2	2	1.3	6.7	10.4	447.5	1.1
Variety (V)	***	***	**	***	***	***	***
Year (Y)	***	***	NS	***	***	***	***
VxY	***	***	NS	***	NS	NS	NS

DH= Days to heading, DM=Days to maturity, PL=Panicle length (cm), PH=Plant height (cm) FGPP= Number of filled grains per panicle, GY=, Grain yield (kg ha⁻¹), TSW=Thousand seed weight (g), ** and *** denotes significance difference at $p \leq 0.01$ and $p \leq 0.001$ respectively, NS=Non-significant difference

The analysis of variance at Tepi revealed that the varieties were highly significant different ($p \leq 0.01$) for days to heading days to maturity, plant height, number of filled grains per panicle, grain yield and thousand seed weight while panicle length didn't show significant difference in 2017 cropping season (Table 6). A similar result was also previously reported by Tefera *et al.*, 2017. The average days to heading for the varieties in this cropping season was 92 days. The variety which took long days to head was Fogera-2 (108 days), while variety Ediget and Demoze (87 days) followed by Hiber (88 days) are earlier to head. Days to maturity ranged from 118 to 137 days, the early maturing variety was Ediget while Fogera-2 (137 days) was the late maturing variety in the area. The longest panicle length and tallest plant height was recorded on Gumara 19.7 cm and 111.1 cm respectively. Gumara was also the best yielding variety (4680 kg ha⁻¹) followed by Hiber (4830 kg ha⁻¹) whereas Demoze (2398 kg ha⁻¹) and X-jigna was the lower yielder varieties in the area. The higher thousand seed weight were also obtained on those high yielding varieties, Hiber (35.8 g) and Gumara 35.8 g). As a result, Hiber followed by Gumara were the best variety in grain yield, filed grain and also thousand seed weight in the cropping season and area.

Table 6. Mean performance of grain yield and yield related traits of six lowland rice varieties evaluated in 2017 cropping season at Tepi, Ethiopia

Variety	DH	DM	PL	PH	FGPP	GY	TSW
Ediget	87	118	18.6	108.3	77.1	4173.0	34.8
Hiber	88	128	18.4	99.5	78.1	4830.0	35.8
Demoze	87	129	18.8	99.6	55.7	2398.0	28.3
Gumera	93	130	19.7	111.1	75.4	4680.0	35.8
X-Jigna	91	131	19.1	101.9	67.4	2784.0	29.2
Fogera-2	108	137	19.1	79.6	66.3	4163.0	20.2
Mean	92	129	18.9	100.0	70.0	3837.9	30.6
CV (%)	4.3	1.8	5.9	6.7	14.5	22.8	12.2
LSD (5 %)	5.9	3.5	1.7	10.0	15.3	1316.9	5.6
Variety (V)	***	***	NS	***	***	***	***

DH= Days to heading, DM=Days to maturity, PL=Panicle length (cm), PH=Plant height (cm) FGPP= Number of filled grains per panicle, GY=, Grain yield (kg ha⁻¹), TSW=Thousand seed weight (g), *** and NS denotes significance difference at $p \leq 0.001$ and non-significant difference respectively

Combined analysis of variance was performed to assess the performance of varieties with the test locations and years. Significant variation ($p \leq 0.001$) was observed among the tested varieties for days to heading, days to

maturity, panicle length, plant height, grain yield and thousand seed weight while non-significant difference was observed for number of filled grains per panicle (Table 7). Both location and year effects were highly significant for all measured traits indicating the test locations and years differed. Variety by location and variety by year were highly significant ($p \leq 0.001$) for days to heading, days to maturity, plant height, number of filled grains per panicle, and grain yield indicating that varieties performed differently in each location and year. Though variety by year was not significant for thousand seed weight. Variety by location and variety by year were non-significant for panicle length and suggesting that the stability of the varieties across locations and years. The interaction of variety by location by year was highly significant for days of heading, days of maturity, plant height, grain yield and thousand seed weight while panicle length and number of filled grains per panicle were not significant for this interaction.

Grain yield is the most important economic trait in most crop improvement programs. The highest grain yield was recorded for Ediget (3222 kg ha⁻¹) and Fogera-2 (3073 kg ha⁻¹) while the low grain yield was recorded on X-Jigna. This is due to the long age of the variety under production. The average maturity days for the variety was 88 days; Fogera-2 and Gumara were the late maturing varieties and Hiber and Ediget were early maturing. Variety Fogera-2 had high number of filled grains per panicle and grain yield. However, variety Ediget was the best variety across locations and year in terms of number of filled grains per panicle and grain yield per ha (3222 kg ha⁻¹) with high thousand seed weight.

Table 7. Combined analysis of mean performance of grain yield and yield related traits of six lowland rice varieties over locations and years

Variety	DH	DM	PL	PH	FGPP	GY	TSW
Ediget	84	131	19.4	100.8	83.1	3222.0	33.2
Hiber	83	133	19.0	94.8	73.5	2875.0	33.7
Demoze	86	134	19.2	106.2	74.0	2417.0	27.4
Gumera	91	136	20.9	109.0	75.9	2848.0	31.7
X-Jigna	86	133	19.9	105.0	76.5	2033.0	28.0
Fogera-2	101	143	19.7	89.1	81.6	3073.0	21.1
Mean	88	135	19.7	100.8	77.4	2744.6	29.2
CV (%)	2.9	1.5	7.2	6.5	26.7	25.8	8.8
Variety (V)	***	***	***	***	NS	***	***
Location	***	***	***	***	***	***	***
Year	***	***	***	***	**	***	***
VxL	***	***	NS	***	**	***	**
VxY	***	***	NS	***	**	***	NS
LxY	***	***	*	***	**	***	***
VxLxY	***	***	NS	***	NS	***	***

DH= Days to heading, DM=Days to maturity, PL=Panicle length (cm), PH=Plant height (cm) FGPP= Number of filled grains per panicle, GY=, Grain yield (kg ha⁻¹), TSW=Thousand seed weight (g), *, **, *** and NS denotes significance difference at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$ and non-significant difference respectively

An “ideal” genotype is one that has both high mean yield capacity and high stability. The center of concentric circles (Figure 1) represents the position of an “ideal” genotype, which is defined by a projection onto the mean-environment axis that equals the longest vector of the genotypes that had above-average mean yields and by a zero projection onto the perpendicular line (zero variability across all environments). The closer a genotype to the ideal one is the more valuable it is.

Although such an “ideal” genotype may not exist in reality, it can be used as a reference for genotype evaluation (Yan, Tinker, 2006). The ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important. Thus variety-1 (Ediget), variety-2 (Hiber) are located near to the concentric circle are also regarded as valuable genotypes in terms of yield capacity and stability.

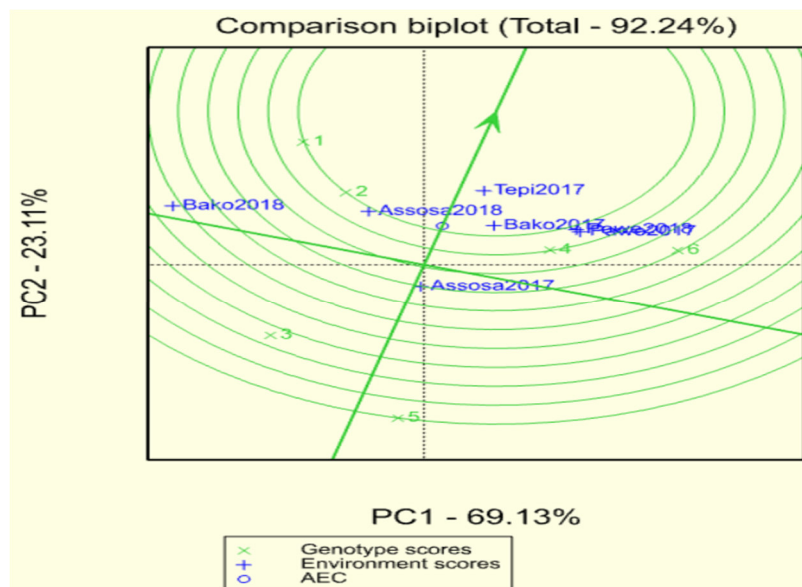


Figure 1. The average-environment coordination (AEC) view of ranking rice lowland rice varieties relative to an ideal genotype (center of the concentric circle).

Conclusion and Recommendation

The combined analysis of variance over years and locations showed that there were high interactions of variety by location, variety by year and variety by location by year. This indicated that varieties performance varies in each location and year. Therefore, the variety Ediget had best performance in Bako and Assosa and it is recommended for production in the areas. While Fogera-2 had better performance in Pawe and is recommended for production in the area. In Tepi area variety Hibir and Gumara followed by Ediget had better performance and they are recommended for production. However, the combined the combined analysis over years and locations indicated that variety Ediget had better performance and it is recommended for early maturity and good yield followed by Fogera-2 for good yield and late maturity.

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