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Evaluation of Improved Upland Rice Varieties for Potential Rice Producing Area Kemashi Zone of Benishangul Gumze of Ethiopia

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Abstract: Upland rice (Oryza sativa L.) is typically grown by small scale farmers for subsistence in Benishangul Gumze region. Benishangul Gumuse is one of the most important potential regions among other rice producing areas in Ethiopia. 13 improved upland rice varieties were evaluated with the objective of selecting adaptable and best performing upland varieties for rice production areas of kemashi zone. The trial was conducted at Jello-Leka Kebele of Kemashi woreda during 2013/2014 cropping seasons using randomized complete block design under rain fed condition. Days to 50% heading, days to maturity, panicle length, plant height, number of fertile tiller per plant, number of filled grain per panicle and grain yield (kg ha^{-1}) ranged from 41.33 to 53.33, 81.00 to 88.33, 20.2 to 23.93, 74.87 to 105.07, 4.60 to 6.73, 84.00 to136.67, 4723.0 to 6492.0, respectively. Grain yield showed positive and significant correlation with number of fertile tillers per plant (r = 0.23^{*}) at phenotypic level and with number of filled grains per panicle (r = 0.61^{**} and 0.84^{*}) both at phenotypic and genotypic level. Days to maturity showed negative and significant correlation (r = -0.34^{*} and-0.46^{*}) with the grain yield at both phenotypic and genotypic level. Number of fertile tillers per plant (0.0492) and number of filled grains per panicle (0.547) had positive high direct effect on grain yield at phenotypic level. Days to maturity (-0.971) and number of fertile tillers per plant (-0.0006) were showed negative direct effect on the grain yield at genotypic level. Generally, this experiment suggests that the varieties NERICA-15 and NERICA-4 were recommended to increase production and productivity of rice in Kemashi district of Kemashi zone. The result from correlation and path coefficient analysis suggest that number of filled grain per panicle was important yield contributing trait and could be considered most important trait for upland rice grain yield improvement.

Keywords: Correlation, Direct and Indirect Effect, Quantitative Traits

1. Introduction

Rice (*Oryza sativa* L.) has two cultivated and more than 30 named wild species with a broad geographic distribution [18]. The cultivated species are *Oryza sativa* L., which has an Asian origin and *Oryza glaberrima* Steud, with an African origin. It is the most rapidly growing food commodity in sub-Saharan Africa (SSA), mainly driven by urbanization. It has become a commodity of strategic significance and the fastest growing food source in Africa, such that its availability and price are now a major determinant of the welfare of the poorest segments of consumers who are the least food-secure consumers in Africa. It is no longer a luxury food but has become the cereal that constitutes a major source of calories for the urban and rural poor [7]. Rice is now grown and consumed in more than 40 African countries, where about 20 million people depend on rice directly for their livelihood. The demand for rice in SSA is expected to grow substantially as the population currently growing at the rate of 3 to 4% per annum and rice consumption is growing faster than that of any major food. However, self-sufficiency in African rice production is declining as demand increases, driving the urgent needs to increase and improve the continents production of rice to satisfy the demand [12]. To attain rice self-sufficiency and meet the future demand resulting from population growth, high yielding varieties with desirable agronomic traits for diverse ecosystems are required to be developed [1, 6, 8].

The importance of rice as a food security crop, source of income and employment opportunity due to its relative high productivity as compared to other cereals is recognized by farmers as well as private investors who frequently request for improved varieties adapted to different ecosystems. The potential rain-fed rice production area in Ethiopia is estimated to be about thirty million hectares based on GIS techniques and rice agro-ecological requirement. Rice is a recent introduction in Ethiopia where its breeding and other research components are found at infant stage. Rice breeding research has been started by adaptive trials of introduced varieties, which resulted in the release of some varieties [4]. It grows on 0.27% (33,819.65 hectares) of production area with a total production of 0.37% (923,627.30 quintals) in different regions of Ethiopia [2]. Even though the development aspect in promoting rice production is limited to certain areas there is an increasing trend in both area and production of the crop since 2006 [4]. Upland rice (*Oryza sativa* L.) is typically grown by small scale farmers for subsistence in Benishangul Gumze region of Ethiopia. Benishangul Gumuse is one of the most important potential regions among other rice producing areas in Ethiopia

Rice production mostly has been focused on optimizing grain yield, reducing production costs, and minimizing pollution risks to the environment. Higher grain yield and increased yield stability across a range of environments are needed for rice farmers, who typically harvest yields of 0.9–2.4 t ha^{-1} in rainfed lowland fields and 0.6–1.5 t ha^{-1} in upland fields [14]. The development of high yielding cultivars with wide adaptability is the ultimate aim of plant breeders. Therefore, by exploiting the good adaptation and stability of yield and its components in rice genotypes, it would be possible to develop/identify high yielding and well adapted varieties [9]. Thus effective yield component breeding to increase grain yield could be achieved, if the components traits are highly heritable and positively correlated with grain yield [17].

Through selection and plant breeding techniques, high yielding and diseases and pest resistant rice varieties have been developed in Ethiopia. However, evaluation of those improved upland rice varieties has not yet been done for potential rice producing area of Kemash district. The goal of increasing productivity and production of upland rice will be realized if and only if the ultimate users, namely farmers, adopt the technologies that are developed by research. It is therefore imperative to introduce and test improved rice varieties and scaling up best adapted varieties to the respective area. Kemashi district of Kemashi Zone is one of the potential upland rice growing areas in Benishangul Gumze region of Ethiopia. However, lack of evaluation of improved varieties and promotion usually constraints its production in the area. Therefore, the major objective of the present study was to identify high yielding upland rice varieties suitable for upland rice producing areas of Kemash zone.

2. Material and Method

2.1. Experimental Location

A field experiment was conducted on a nitosol soil at the Kemash Research sub-center of Assosa Agricultural, Research Center situated at 10.067°N, 34.517°E, Altitude 1000m above sea level and annual temperature ranges between 20-30°C which reaches 28-35°C during the hottest periods. Rainfall of unimodal spread through May to October with annual amounts ranges between 500-1800mm.

2.2. Experimental Design and Crop Management

This experiment was conducted in 2013-2014 using RCBD with three replications. Plot size was 5m × 1.2m, with spacing between row, plots and blocks 20cm, 30cm and 1m, respectively. Thirteen rice cultivars were grown in this experiment (Table 1). Fertilizer was applied at the rate of 160kg ha^{-1} of urea with three applications (first 1/3 at planting, 1/3 at tillering and 1/3 at panicle initiation) and 100kg ha^{-1} of DAP at planting were applied and weeds were removed mechanically at several steps.

2.3. Data Collection

Data were collected on plot and plant basis. On a plot basis, the data were taken from the central four rows. These were phenological data (number of days to heading, and maturity) and grain yield. On the other hand, the number of fertile tillers per plant, number of filled grains per panicle, panicle length and plant height were taken on plant basis.

The number of days to heading was calculated from the date of sowing to the date on which 50% of plants in the plot attained heads. The number of days to maturity was taken from sowing to the date on which 80% of plants in the middle four rows attained maturity. It was judged by field observation and at maturity, the straws and the panicles of the crop changed to yellowish color. The grain yield (g) of each plot was taken after cleaning very well. It was also adjusted to a moisture level of 14% and then converted into kg ha^{-1}.

The number of fertile tillers per plant, the number of filled grains per panicle, panicle length and plant height were taken from five randomly taken plants in each plot and the average value was calculated.

Table 1. *Rice cultivars used in the experiment.*

No	Varieties	No	Varieties
1	Hidassie	8	NERICA-10
2	Getachew (AD01)	9	NERICA-11
3	Andassa (AND012)	10	NERICA-12
4	Tana (AND048)	11	NERICA-13
5	NERICA-4 (49WAB-450-IB-P--9/1)	12	NERICA-14
6	SUPERICA-1 (WAD-4507)	13	NERICA-15
7	KOKIT (IRAT-209)		

2.4. Statistical Analysis

Statistical analysis was performed using SAS 9.2 and EXCEL software and the means were compared using LSD test at 5% probability level.

2.4.1. Correlation Coefficient Analysis

Phenotypic and genotypic correlation coefficients were calculated using phenotypic and genotypic variances and co-variances as below: [5]

$$\text{Genotypic r} = \frac{\mathrm{Cov}_{g12}}{\sqrt{(\sigma^2 g_1).\sigma^2 g_2}}$$

Where, Cov_{g12} is the genotypic covariance between two traits, $\sigma^2 g_1$ is the genotypic variance of the first trait, and $\sigma^2 g_2$ is the genotypic variance of the second trait; and

$$\text{Phenotypic r} = \frac{\mathrm{Cov}_{p12}}{\sqrt{(\sigma^2 p_1).\sigma^2 p_2}}$$

Where, Cov_{p12} is the phenotypic covariance of the progeny means between the two traits, and $\sigma^2 p_1$ and $\sigma^2 p_2$ are the phenotypic variance for each trait.

2.4.2. Path Coefficient Analysis

A measure of direct and indirect effects of each character on grain yield was estimated using a standardized partial regression coefficient known as path coefficient analysis, as suggested by [3]. Thus, correlation coefficient of different characters with grain yield was partitioned into direct and indirect effects adopting the following formula.

$$riy = r1iP1 + r2iP2 + \ldots + rIiPi + \ldots + rniPn$$

Where rij is correlation of ith character with grain yield; $r1iPi$ is indirect effects of ith character on grain yield through first character; rni is correlation between nth character and i^{th} character; n is number of independent variables; Pi is direct effect of i^{th} character on grain yield; Pn is direct effects of nth character on grain yield.

Direct effect of different component characters on grain yield were obtained by solving the following equations:

$$(riy) = (Pi)\,(rij);\text{and } (Pi) = (rij) - 1\,(r1iPi)$$

Where, (Pi) is matrix of direct effect; (rij) is matrix of correlation coefficients among all the nth component characters; (riy) is matrix of correlation of all component characters with grain yield; $(r1iPi)$ is indirect effect of i^{th} character on seed yield through first character.

3. Result and Discussion

Results of analysis of variance of 6 characters for 13 improved upland varieties are presented in (Table 3). Coefficients of variation (CV) were used to compare the precision of the experiment with various means. The means with less than 20% in CV for most of the characters revealed existence of reliability of the data. All the characters except number of fertile tillers per plant and grain yield showed highly significant variation ($p \leq 0.05$) (Table 2). The significance of varieties differences indicates the presence of genetic variability for each of the characters among the tested varieties and possibility of manipulating these variations for improvement. Similar results were reported by [13] and [16].

Days to 50% heading showed significant differences among all varieties ranging from 41.33 to 53.33 days after sowing and for days to maturity which ranged between 81.00 to 87.33 days. Hidassie was the earliest in maturity (81.00 days) while 'Getachew' was late in maturity (87.33). Plant height showed significant difference among all the varieties. It ranged from 74.81 cm (NERICA-11) to 105.07 cm (Getachew). The number of fertile tillers per plant ranged between 4.60 (KOKIT) and 6.73 (NERICA-12). The number of filled grains per panicle was significantly affected by genotypes and the most important components of yield. It differed significantly among all the tested genotypes and varied from 84.00 in 'KOKIT' to 136.67 in 'NERICA-15'. It showed that number of filled grains per panicle is an essential parameter for increasing grain yield performance. The results are in conformity with [16]. The highest number of grains per panicle (136.67) was recorded in 'NERICA-15' followed by 'NERICA-10' (136.67) and 'NERICA-4' (136.27). Grain yield of varieties ranged from 4723 to 6492 kg ha^{-1} with an average value of 5568.12 kg ha^{-1}. Coefficient of variation for the variable was 13.11% (Table 3). The highest grain yield was recorded in NERICA-15 (6492 $kgha^{-1}$) followed by NERICA-4 (6355 kg ha^{-1}). This indicates the potential of the area for upland rice production in general. Further research on rice cultivar development through adaptation and selection are essential to fulfill the requirements of the improved varieties by farmers.

Table 2. *Analysis of variance (mean square) for yield and yield contributing characters.*

S. O. V	DH	DM	PH	PL	FT	FG	GY
Replication	4.85	0.08	16.67	2.59	0.037	84.75	93018.53
Genotype	39.72**	15.75**	387.14**	4.20**	1.10	1005.56**	974326.3
Error	1.90	1.69	50.07	1.23	1.54	303.88	533442.7
CV%	3.06	1.54	8.13	5.07	22.49	14.89	13.11
LSD	2.32	2.18	1.87	11.92	2.0929	29.376	1230.8

Where, DH = days to 50% heading, DM = days to maturity, PL = panicle length, PH = plant height, FT = number of fertile tillers per plant, FG = number of filled grains per panicle, GY = grain yield.

Table 3. *Mean performance of 13 verities for yield and other agronomic characters.*

NO.	VARITIES	DH	DM	PL	PH	FT	FG	GY (kg ha^{-1})
1	Hidassie	43.33	81.00	21.20	75.73	5.80	127.40	5480.00
2	Getachew	47.00	87.33	23.93	105.07	6.13	100.07	4848.00
3	Andassa	53.33	88.33	23.20	102.87	5.60	106.87	5699.00
4	Tana	51.33	88.00	23.20	104.73	5.00	91.40	5179.00
5	NERICA-4	43.67	84.67	21.33	75.80	6.27	136.27	6355.00
6	SUPERICA-1	44.67	83.00	20.80	87.73	5.40	123.33	5790.00
7	KOKIT	43.33	84.67	20.20	78.53	4.60	84.00	4723.00
8	NERICA-10	41.33	83.00	23.07	86.40	5.53	136.67	6045.00
9	NERICA-11	42.00	83.00	20.87	74.87	4.73	124.00	5093.00
10	NERICA-12	43.33	83.00	22.53	89.53	6.73	132.40	6048.00
11	NERICA-13	42.67	83.00	22.00	79.73	5.53	122.20	5600.00
12	NERICA-14	46.33	86.00	20.67	92.80	5.33	100.20	5035.00
13	NERICA-15	42.67	83.00	21.73	77.47	5.13	136.67	6492.00
Means		45.00	84.46	21.90	87.02	5.52	117.04	5568.12
Range		41.33-53.33	81-88.33	20.2-23.93	74.87-105.07	4.60-6.73	84.00-136.67	4723.0-6492.0

Where, DH = days to 50% heading, DM = days to maturity, PL = panicle length, PH = plant height, FT = number of fertile tillers per plant, FG = number of filled grains per panicle, GY = grain yield (kg ha^{-1})

3.1. Correlation Among Yield and Yield Related Traits

The results indicated (Table 4) that at phenotypic level there was positive and significant correlation between number of fertile tillers per plant ($r = 0.23^{*}$) and number of filled grains per panicle ($r = 0.61^{**}$) with grain yield. Similarly, number of fertile tillers per plant (0.84^{*}) was showed significant positive correlation with grain yield at genotypic level. Indicating selecting for those traits showing positive and significant correlation with grain yield there is a possibility to increase grain yield of upland rice at the area. Therefore, selection for the improvement of the grain yield based upon these characters will be effective. Days to maturity showed negative and significant correlation ($r = -0.34^{*}$ and -0.46^{*}) with the grain yield at both phenotypic and genotypic level. The rest of the traits (days to 50% heading, panicle length and plant height) showed no significant correlation with the grain yield both at genotypic and phenotypic level. [11] Reported highest estimates of correlation at both genotypic and phenotypic level between yield and number of effective tillers / plant (r = 0.721; rg = 0.971) and number of fertile grains/panicle (rp = 0.478; rg = 0.461) and non-significant with the rest of the characters. Similarly, the result was inconformity with [1] for the number of tillers per plant ($r = 0.58^{**}$) and the number of grains per panicle ($r = 0.52^{*}$).

Day to heading showed positive and significant correlation with days to maturity, plant height and panicle length only at phenotypic level. Days to heading showed negative significant correlation with number filled grain per panicle at phenotypic level and with panicle length at genotypic level. Days to maturity showed significant positive association with plant height at both genotypic and phenotypic level and also showed significant negative correlation with number filled grain per panicle at phenotypic level. Plant height showed positive and negative significant correlation with panicle length and number filled grain per panicle, respectively, at phenotypic level. In agreement with [11] who reported positive significant correlation of plant height with panicle length.

Table 4. *Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients of the 8 quantitative traits of upland rice verities at Kemash 2014 cropping season.*

Traits	DH	DM	PH	PL	FT	FG	UFG	GY
DH	1	-0.189	-0.1387	-0.99^{*}	0.65465	-0.6809	0.62003	0.95708
DM	0.79^{**}	1	0.99^{*}	0.10337	-0.866	-0.5905	0.65327	-0.46^{*}
PH	0.67^{**}	0.67^{**}	1	0.05251	-0.8394	-0.6309	0.69103	-0.4197
PL	0.35^{*}	0.34^{*}	0.60^{**}	1	-0.5868	0.7417	-0.6855	-0.92
FT	0.07432	0.04911	0.17403	0.26469	1	0.10784	-0.1872	0.84^{*}
FG	-0.37^{*}	-0.43^{**}	-0.36^{*}	0.16281	0.34^{*}	1	-0.99^{*}	0.4395
UFG	-0.0522	-0.1589	0.02286	0.3073	0.07677	0.28932	1	0.36603
GY	-0.1244	-0.34^{*}	-0.1632	0.15	0.23^{*}	0.61^{**}	0.07907	1

Where, DH = days to 50% heading, DM = days to maturity, PL = panicle length, PH = plant height, FT = number of fertile tillers per plant, FG = number of filled grains per panicle, GY = grain yield.

3.2. Phenotypic and Genotypic Direct and Indirect Effects of Various Characters on Grain Yield

As correlation does not allow the partitioning of genotypic correlation coefficients into direct and indirect effects, they are further analyzed by path coefficient analysis [3] by using grain yield as a dependent variable. The phenotypic and genotypic direct and indirect effects of different characters on grain yield are presented in Table 5 and 6.

Number of fertile tillers per plant (0.0492) and number of filled grains per panicle (0.547) had positive high direct effect on grain yield at phenotypic level indicating the relationship between these traits as good contributors to grain yield (Table 5). [11] Reported high significant direct effect of panicle density on the grain yield. This indicates that, if other factors are held constant, an increase in number of filled grains per panicle individually will reflect in an increased yield. Similar results were also reported by [15]. Days to maturity showed negative direct effect on the grain yield indicating direct consideration of days to maturity during selection breeding may not be rewarding for yield improvement. The studied trait showed negligible indirect effect through each other.

Table 5. *Estimate of direct effect (bold face and diagonal) and indirect effects (off diagonal) at phenotypic level in 13 upland rice verities tested at Kamash 2014.*

	DM	FT	FG	rp
DM	-0.107	0.00242	-0.24	-034*
FT	-0.005	0.0492	0.186	0.23*
FG	0.0461	0.01673	0.547	0.61**

Where, DM = days to maturity, FT = number of fertile tillers per plant, FG = number of filled grains per panicle, rp = phenotypic correlation coefficient.

Table 6. *Estimate of direct effect (bold face and diagonal) and indirect effects (off diagonal) at genotypic level in 13 upland rice verities tested at Kamash 2014.*

	MD	FT	rg
MD	-0.971	0.51066	-0.46*
FD	0.8406	-0.0006	0.84*

Where, DM = days to maturity, FT = number of fertile tillers per plant and rg = genotypic correlation coefficient.

Only days to maturity and number of fertile tillers per plant showed significant negative and positive genotypic correlation with grain yield, respectively, (Table 6). Therefore, those two characters were subjected to path analysis. Both days to maturity (-0.971) and number of fertile tillers per plant (-0.0006) showed negative direct effect on the grain yield indicating selection based on these characters would be ineffective for enhancing the grain yield of the verities though selection. The positive direct effect of number of fertile tillers per plant at phenotypic level may be due to environment influence. Both traits had a positive indirect effect via each other. Therefore, indirect consideration of both days to maturity and number of fertile tillers per plant through each other during selection might be rewarding. Generally, the result suggest that number of filled grain per panicle was important yield contributing trait and could be considered as important traits for upland rice grain yield improvement.

4. Conclusion

Application and dissemination of improved agricultural technologies play a great role in increasing production and productivity of the crops. All governmental, non-governmental organizations and private sector actors need to join forces if meaningful development has to be realized in this regard. Higher education and research institutions need to give adequate emphasis to the research on development of adaptive and productive rice cultivars for the country. The country shall pay adequate attention to introduce best practice and experience from successful countries on comprehensive development of potential rice cultivars. In this experiment evaluation of 13 improved upland rice varieties was undertaken at Jello-Leka Kebele of Kemashi district of Kemashi Zone. The significant difference were observed in days to heading, days to maturity, plant height, panicle length and grains filling period suggests that existence of high variability among the varieties studied. The study identifies two upland varieties (NERICA-15 and NERICA-4) with superior performances in grain yield and its components. Based on the result the two varieties NERICA-15 and NERICA-4 were recommended for increasing production and productivity of upland rice in the area. Demonstration and promotion must be undertaken on the use of those improved upland rice varieties. On the contrary, 'KOKIT' exhibited relatively poor performance in grain yield and its components indicating the varieties poor adaptation to the environment.

There was positive and significant correlation between number of fertile tillers per plant ($r = 0.23^{*}$) at phenotypic level and number of filled grains per panicle ($r = 0.61^{**}$ and 0.84^{*}) with grain yield at both phenotypic and genotypic level. Indicating selecting for those traits showing positive and significant correlation with grain yield there is a possibility to increase grain yield of upland rice at the area. Days to maturity showed negative and significant correlation ($r = -0.34^{*}$ and -0.46^{*}) with the grain yield at both phenotypic and genotypic level.

Number of fertile tillers per plant (0.0492) and number of filled grains per panicle (0.547) had positive high direct effect on grain yield at phenotypic level indicating the relationship between these traits as good contributors to grain yield. Days to maturity showed negative direct effect on the grain yield at phenotypic and genotypic level indicating direct consideration of days to maturity during selection breeding may not be rewarding for yield improvement. Number of fertile tillers per plant showed negative direct effect on the grain yield at genotypic level indicating selection based on these characters would be ineffective for enhancing the grain yield of the verities though selection.

The positive direct effect of number of fertile tillers per plant at phenotypic level may be due to environment influence. Generally, consideration of traits with high positive correlation and direct effect on the grain yield will be effective during selection breeding. Therefore, the result suggest that number of filled grain per panicle important yield contributing traits and could be considered as the most important traits for upland rice grain yield improvement.

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