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Phenotypic and Genotypic Correlation and Path Coefficients in Rainfed Upland Rice (Oryza sativa L.) Genotypes at Guraferda, Southwest Ethiopia

Abayneh Kacharo Kampe* Addis Alemayehu Tassew Altaye Tiruneh Gezmu
South Agricultural Research Institute, Bonga Agricultural Research Center
Bonga

Abstract
A field experiment was conducted with the objective of determining the magnitude of association between yield and yield component characters. Fifteen rainfed upland rice genotypes were evaluated in randomized complete block design in three replications for two consecutive years (2014 and 2015) in southwest Ethiopia. Correlation coefficient analysis of grain yield showed positive and significant association with days to 85% maturity and number of fertile tillers per plant at both phenotypic and genotypic levels. At phenotypic level, thousand seed weight displayed positive and significant correlation with grain yield, while at genotypic level, panicle length and plant height exhibited positive and significant relationships. Thus, these traits could play pivotal role in the development of high yielding rainfed upland rice genotypes. Separation of correlation coefficients into direct and indirect effects of component traits on grain yield revealed that days to 85% maturity and number of fertile tillers per plant exerted the maximum positive direct effect on grain yield at both genotypic and phenotypic levels. The direct contribution of days to 85% maturity supported indirectly by panicle length and thousand seed weight at phenotypic level. At genotypic level, panicle length assisted the direct contribution of days to 85% maturity to the grain yield. Therefore, while making selection these characters would be reliable criteria for improving grain yield of upland rice genotypes at southwestern Ethiopia.
Keywords: Direct and Indirect effect, Positive and negative correlation, Yield component traits

INTRODUCTION

Rice (*Oryza sativa* L.and *Oryza glaberrima* Steud) belongs to the family Poaceae, is the most significant food crops of the world and assists as a chief food basis for more than 50% of the world population (Wang *et al.,* 2014). It offers a wealth of material for genetic studies because of its wide ecological distribution and enormous variation encountered for various qualitative and quantitative characters. It is predominantly a self-pollinated crop, but up to 3% natural out crossing may occur depending on the cultivar and the environment (Poehlman and Sleper, 1995).

In Ethiopia, the cultivation of rice is of a recent history, however, its use as a food crop, income source, employment opportunity and animal feed have been well recognized (Teshome and Dawit, 2011). In the past few years it was considered as a strategic food security crop that have received due emphasis in promotion of agricultural production and as such it is considered as the “millennium crop” expected to contribute in ensuring food security in Ethiopia. Volume of rice production in Ethiopia is also on move with national average productivity rise of 1.8 ton per hectare (CSA, 2006) to 2.8 ton per hectare (CSA, 2014) at on-farm level. According to Seck *et al.* 2013;the number of participant farmers and the demand for improved rice technologies is also highly increasing from time to time from different stakeholders and the country planned to meet the projected average productivity increase of 5.1tons/ha in 2019.

In Ethiopia rainfed rice is cultivated in Amhara, Tigray, Oromia, South Nation Nationalities and Peoples Region (SNNPR), Gambella and Benshangul Gumuz Regions (MoA, 2010). The total cultivated area at national level has increased from 33,819.65 in 2013/2014 to 45, 454.2 hectares in 2015/2016. The cultivated area has increased in 2015/16 as compared to 2013/2014 by about 37.33% nationally with considerable difference across regions. Accordingly, rice production has increased from a total of 92,362.7 tons, in 2013/14 to 1,268,064.47 tons in 2015/16. Similarly, productivity has also increased from 2.7 in 2013/14 to 2.8tons per hectare in 2015/16.

Despite the country’s immense potential for growing this crop, production, productivity and expansion of the rice has been challenged by lack of improved varieties, lack of recommended crop management practices for different rice ecosystems, lack of pre and post-harvest management technologies and lack of awareness on its utilization (Tesfaye *et al.,* 2005; MoA, 2010; Mulugeta *et al.,* 2012; Taddesse *et al.*, 2014). As a result, rice yield remains progressively low with average national productivity of 2.8 tons/ha (CSA, 2016), which is very much lower than the average yield of rice in the world that accounts 4.54 tons per hectare (FAOSTAT, 2016). Among the determining factors for the reduced productivity of rice in Ethiopia, lack of improved high yielding varieties takes the lion share (Atilaw, 2010; Sewagegne, 2011).

Recognizing the stated importance and existing potentials to boost rice production and productivity to cope up with fastest growing demand, understanding of the interaction of characters among themselves had been of great use for selection to improve productivity of rainfed upland rice. Character association and path coefficients are pre-requisites for improvement of any crop including rice for selection of superior genotypes and improvement of any trait. Knowledge of correlation between yield and its contributing characters are basic and foremost endeavor to find out guidelines for plant selection.

Character association studies have been done in upland rice genotypes in different parts of the country, however there has been no studies done by using currently used upland rice genotypes in southwest Ethiopia. The present study was conducted in order to determine the magnitude of association among component traits among themselves and with grain yield. In the view of above situations, correlation and path coefficient analysis of fifteen rainfed upland rice genotypes were studied for seven characters to evaluate the contribution of each trait towards grain yield.

MATERIALS AND METHODS

Description of the Experimental Site, Materials and Procedures:

The experiment was conducted at Guraferda in Bonga Agricultural Research Center experimental station for two consecutive years (2014 and 2015). The site is located at an altitude of 1235 meters above sea level, 7° 26’ N and 36° 22’ E latitude and longitude, respectively. It receives an annual rainfall of 1710mm and mean monthly minimum and maximum temperature of 16.70C and 24.00C, respectively (Mebratu et al., 2015). The experimental materials consisted of 15 rainfed upland rice genotypes (Advanced lines) obtained from Fogera National Rice Research and Training Center (FNRRTC) and Bonga Agricultural Research Center: Hidassie (WAB515-B-16A1-2), Getachew (AD01), Andassa (AD012), Tana (AD048), NERICA-3(WAB-450-IB-P-28-HB), SUPERICA-1(WAB-4507), Kokit (IRAT-209), NERICA-12, NERICA-13, NERICA-14, NERICA-15, NERICA-18, FOFIFA-4129, FOFIFA-3737, FOFIFA-3730 were used as experimental materials. The experiment was laid out in randomized complete block design in three replications. The spacing between replications, plots and rows was 1, 0.3 and 0.2m, respectively. Seeds were drilled in rows with a rate of 60kg per hectare. The gross and net harvestable plot size of the experiment were 6m2 (six rows of 5m of long and 1.2m wide) and 4m2 (four rows of 5m long and 0.8m wide), respectively, and four inner most central rows were used for data collection. Fertilizer was applied at a rate of 100kg DAP and 100kg Urea ha^{-1}. All DAP was applied during sowing where as urea was applied in three equal splits at sowing, tillering and at panicle initiation stages. Weeding was done three times manually during the whole experimental period as required.

Data Collection and Analysis:

Standard evaluation system developed by IRRI, (2013) was followed in order to collect yield and yield componenet data. Days to 50% heading and days to 85% maturity were computed on plot basis. Five representative plants for each genotype in each replication were randomly taken to record observations on plant height (cm), panicle length (cm), fertile or productive tillers per plant. Grain yield obtained on plot bases was converted into Kg ha^{-1} and adjusted to 14% grain moisture content.

Phenotypic and genotypic correction coefficient analysis:

Phenotypic and genotypic correlation coefficients were computed from variance and covariance components based on the method described by Singh and Chaudhury, (1996). The Pearson correlation test was applied for phenotypic and genotypic correlation coefficients respectively using SAS statistical package (SAS Institute, 2002).

Phenotypic and Genotypic Path Coefficient Analysis:

The direct and indirect effect of component traits on yield and among themselves were estimated following the method suggested by Dewey and Lu, (1959) given as follows.

$r_{ij} = P_{ij} + \Sigma r_{ik} p_{kj}$

Where: - rij = Mutual association between the independent trait (i) and dependent trait (j) as measured by the correlation coefficient.

Pij = Component of direct effects of the independent trait (i) on the dependent variable (j) as measured by the path coefficient and, Σrikpkj = Summation of components of indirect effect of a given independent trait (i) on the given dependent trait (j) via all other independent traits (k).

Residual effect estimated by the formula

$\sqrt{1 - R^2}$; Where: - $R^2 = \Sigma p_{ij}\, r_{ij}$

Where, R^2 is the residual factor, P_{ij} is the direct effect of yield by i^{th} trait, and r_{ij} is the correlation of yield with the i^{th} trait.

RESULT AND DISCUSSION

Correlation Analysis:

Association of Grain Yield and yield related traits at Phenotypic and Genotypic Levels:

Genotypic and phenotypic correlations coefficients analysis result of grain yield and yield related component traits showed both positive and negative associations (Table 1). Positive correlated result indicated that increase of one trait will result in increase of the correlated trait and negative association of traits indicated that increase of one character will decrease the negatively correlated character.

At phenotypic level, days to 85% maturity (r = 0.23**), thousand seed weight (r = 0.31**) and number of fertile tillers per plant (0.22*) displayed positive and significant association with grain yield ha^{-1}, directing that grain yield of upland rice genotypes could be improved by selecting genotypes having higher performance for these traits. The detected positive and significant correlation of grain yield ha^{-1} with these traits indicated that as days to 85% maturity, thousand seed weight and number of fertile tillers per plant simultaneously increased, grain yield ha^{-1} will also increase. Similar results have been earlier reported by Mulugeta *et al.* (2016) in rainfed upland rice genotypes. Pant height exhibited negative and significant association with grain yield ha^{-1}. This result indicated that any increase in plant height could result in decrease in grain yield ha^{-1}that could be related with tallness in rice reduces the grain yield due to high accumulation of photosynthates on elongation of vegetative parts rather than reproductive parts .Therefore, selection is devised on semi dwarf genotypes would result in increased grain yield. Satheeshkumar and Saravanan, (2012) and Ukaoma *et al.* (2013) found negative association of plant height with grain yield. On the contrary, Mulugeta *et al.* (2016) detected significant and positive association of plant height and non-significant association of days to 50% heading with grain yield.

At genotypic level, plant height (r = 0.07*), panicle length (r = 0.19**), number of fertile tillers per plant (r = 0.67**) and days to 85% maturity showed significant and positive association with grain yield ha^{-1}. Days to 50% heading (r = -0.07*) displayed negative and significant correlation with grain yield ha^{-1} (Table 1).This result indicated that any increase in days to 50% heading could result in decrease in grain yield ha^{-1}. Presence of early heading genotypes is important for climate mitigation as drought escape mechanism for areas with marginal rainfall. However, under a favorable growing condition too early heading does not permit production of sufficient assimilates for grain filling and finally ends up with low grain yield (Shavrukov *et al*., 2017; Yoshida,1981). Therefore, selection for early to medium heading upland rice genotypes could be effective in increasing grain yield in the study area.

Table 1. Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients of six yield and yield component traits on 15 rainfed upland rice genotypes.

Traits	DH	DM	PL	PH	NFTP	TSW	GY
DH		0.77**	0.19	0.40**	-0.25	0.05	0.014
DM	0.90**		0.26	0.47**	-0.31 *	0.15	0.23**
PL	0.23	0.32		0.65**	-0.04	-0.05	0.01
PH	0.47	0.63**	0.68**		0.04	0.02	-0.32**
NFTP	-0.45	-0.48	-0.33	-0.26		-0.11	0.22*
TSW	0.02	0.05	-0.11	-0.02	0.03		0.31**
GY	-0.07 *	0.11*	0.19**	0.07*	0.67**	-0.20	

* = Significant at P<0.05; ** = significant at P<0.01; ns = non-significant., DH = Days to 50% Heading DM = Days to 85% Maturity, PL = Panicle Length, PH=Plant Height, NFTP = Number of Fertile Tillers per Plant, TSW = Thousand Seed Weight and GY = Grain Yield (kg/ha)

Correlation among Yield Related Traits at Phenotypic and Genotypic Levels:

Remarkable associations were observed among yield related traits at both phenotypic and genotypic levels (Table 1). Days to 50% heading showed positive and significant association with days to 85% maturity (0.77**) and plant height (0.40**), but with all other yield related traits it showed non-significant correlation. Days to 85% maturity displayed positive and significant correlation with plant height (0.47**) and negative and significant association with number of fertile tillers per plant. Similarly, panicle length also registered positive and significant association plant height at phenotypic level. This result suggested that as plant height increases, panicle length, also ultimately increases. Similar result was reported by Singh *et al.* (2014) for the association between plant height and panicle length. Moosavi *et al.* (2015); Mishu *et al.* (2016) also reported positive significant association of plant height with panicle length at phenotypic level.

At genotypic level traits like, days to 50% heading, days to 85% maturity and panicle length, exhibited significant association with other component traits. Days to 50% heading exhibited strong positive and significant correlation with days to 85% maturity (r=0.91**). This characteristic indicates that increasing of days to 50% heading would lead to increase in the days to 85% maturity which might be attributed due to pleiotropic gene effects and linkage between genes for these traits. Association between days to 85% maturity showed strongly positive and significant with plant height The trend of relationship between panicle length with plant height was significantly positive with value of (r=0.68**) at genotypic level.

Path Coefficient Analysis

Path Coefficient Analysis at Phenotypic Level:

Grain yield per hectare of rice was taken as dependent variable and direct and indirect effects of the other independent variables were computed and have been showed in Table 2. Direct positive effect on grain yield of some characters indicated that selection of these traits is directly helpful for the improvement of yield. Negative indirect effects of some characters on grain yield showed that effects of such traits are indirectly affecting the grain yield in the negative direction.

The path coefficient analysis result revealed that, at phenotypic level, days to 85% maturity (0.87) exerted the highest positive direct effect on grain yield ha^{-1}followed by number of fertile tillers per plant (0.53), panicle length (0.51), and thousand seed weight (0.30). Positive direct effect of these traits on grain yield indicates a hand to hand relationship between each other and should be watched closely while practicing selection aimed at the improvement of grain yield. This result was in harmony with the findings of Karim *et al.* (2014) and Hossian *et al.* (2015) but, in contrary to the finding of Moosavi *et al.* (2015). The indirect exertion of days to 85% maturity on grain yield through all the other characters considered were negative, except for panicle length and thousand seed weight. Therefore, along with days to 85% maturity, the causal factors which had positive indirect effects on grain yield ha^{-1} might be considered simultaneously during the process of selection for grain yield improvement program in rainfed upland rice. The indirect influences of number of fertile tillers per plant on grain yield through days to 85% maturity, panicle length, plant height and thousand seed weight were also found to be negative and it showed positive indirect effect via days to heading. Similarly, positive direct effect of panicle length and thousand seed weight on grain yield was attributed to days to 85% maturity and lowered by days to 50 % heading, panicle length, plant height and fertile tillers number per plant.

Days to 50% heading (-0.24) and plant height (-0.99) exerted negative direct effect on grain yield ha^{-1}. In such situations direct selection for genotypes that took long time to head and, highest plant height might be ineffective for the improvement of grain yield in upland rice. The negative direct exertion of days to 50% heading on grain yield was nullified indirectly by days to 85% maturity, panicle length and thousand seed weight. Similarly, the direct negative influence of plant height with grain yield counterbalanced by the positive indirect effects of days to 85% maturity, panicle length, fertile tillers number per plant and thousand seed weight. The current findings suggest that improvement of grain yield of rainfed upland rice genotypes through selection could be achieved through direct selection via positively contributed component traits to grain yield and positively exerted indirect effects to nullify or counterbalance the negative direct effects of component traits. The residual effect was (0.52), indicating that 48% of the variability in grain yield was contributed by traits considered in the path analysis. This result gives an impression that some other major characters than those involved in the present study might also contribute to grain yield.

Path coefficient analysis at genotypic level:

Genotypic path coefficient analysis result (Table 3) revealed that days to 85% maturity had positive and maximum direct effects on grain yield, followed by number of fertile tillers per plant and panicle length. Positive and direct effect of days to 85% maturity with grain yield was lessened by negative and indirect effect of days to 50% heading, plant height, fertile tillers number per plant and thousand seed weight while it was supported indirectly through panicle length. Significant and positive direct effect of number of fertile tillers per plant on grain yield was attributed to days to 50% heading and plant height and but reduced by negative indirect influences of days to 85% maturity panicle length and thousand seed weight. Similarly, the positive and direct effect of panicle length (0.77) on grain yield was lowered by its indirect effect of days to 50% heading, plant height and number of fertile tillers per plant.

The direct influences of days to 50% heading (-0.98), plant height (-0.86) and thousand seed weight (-0.21) on grain yield were negative. The negative direct effect of days to 50% heading indicated that selection for early heading genotypes will lead to high grain yield in upland rice genotypes that helps in escaping terminal moisture stress. In contrary, Mulugeta *et al.* (2016) found negative direct effect of days to 50% heading on grain yield in rainfed upland rice. The residual effect was (0.42), explaining that the contribution of component traits on grain yield was 58% by the characters evaluated in the path analysis, the rest 42% was the contribution of other factors.

Table 2. Phenotypic direct (bolded) and indirect effects of six component traits on grain yield of 15upland rice genotypes

Traits	DH	DM	PL	PH	NFTP	TSW	r^{ph}
DH	**-0.24**	0.67	0.10	-0.40	-0.13	0.01	0.014
DM	-0.18	**0.87**	0.13	-0.47	-0.16	0.04	0.23**
PL	-0.04	0.23	**0.51**	-0.65	-0.02	-0.01	0.01
PH	-0.09	0.41	0.33	**-0.99**	0.02	0.01	-0.32**
NFTP	0.06	-0.27	-0.02	-0.04	**0.53**	-0.03	0.22*
TSW	-0.01	0.13	-0.03	-0.02	-0.06	**0.30**	0.31**

Residual effect= 0.52, DH = Days to 50% Heading DM = Days to85% Maturity, PL= Panicle Length, PH= Plant Height, NFTP= Number of Fertile Tillers per Plant, TSW= Thousand Seed Weight and r^{ph} = phenotypic correlation coefficient

Table 3. Genotypic direct (bolded) and indirect effects of six component traits on grain yield of 15 upland rice genotypes

Traits	DH	DM	PL	PH	NFTP	TSW	r^g
DH	**-0.98**	1.67	0.18	-0.41	-0.52	-0.01	**-0.07***
DM	-0.88	**1.86**	0.25	-0.54	-0.55	-0.01	0.11*
PL	-0.23	0.59	**0.77**	-0.59	-0.38	0.02	0.19**
PH	-0.46	1.17	0.52	**-0.86**	-0.30	0.00	0.07*
NFTP	0.44	-0.89	-0.25	0.22	**1.15**	-0.01	0.67**
TSW	-0.05	0.09	-0.08	0.02	0.03	**-0.21**	-0.2

Residual effect= 0.42, DH = Days to 50% Heading DM = Days to 85% Maturity, PL= Panicle Length, PH= Plant Height, NFTP= Number of Fertile Tillers per Plant, and TSW= Thousand Seed Weight and r^g = genotypic correlation coefficient

CONCLUSION

It is essential to know the degree of mutual association prevailing between yield and its component traits, which forms the basis for selecting desirable genotypes. A study of correlation and path analysis will thus help in identifying suitable selection criteria for improving yield. Hence the present study was undertaken to determine the extent of correlation and path coefficients in some selected rainfed upland rice genotypes. Based on correlation analysis, days to 85% heading and number of fertile tillers per plant influenced grain yield of upland rice genotypes at both phenotypic and genotypic levels and displayed significant and positive association with grain yield. Hence, in order to increase grain yield of rainfed upland rice genotypes, more emphasis should be placed on increasing the period of days to 85% maturity and number of fertile tillers per plant. Since, simple correlation does not partition correlation coefficients into cause and effect relationships of yield contributing traits on grain yield; path coefficient analysis is employed to predict the exact figure of direct and indirect contribution of component traits on grain yield. Thus, days to 85% maturity and number of fertile tillers per plant exerted maximum positive direct effect on grain yield at both genotypic and phenotypic levels. The direct contribution of days to 85% maturity supported indirectly by panicle length and thousand seed weight at phenotypic level. At genotypic level, panicle length assisted the direct contribution of days to 85% maturity to the grain yield. Therefore, these characters would be reliable criteria for improving grain yield of upland rice at southwestern Ethiopia.

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