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Traits association and path coefficient analysis of yield and yield attributing traits of upland rice (*Oryza sativa* L.) genotypes at pawe, northwestern Ethiopia

Birtucan Demeke[1*], Tiegist Dejene[2], Desta Abebe[3]

[1&3]Ethiopian Institute of Agricultural Research, Pawe Agricultural Research Center, Pawe, Ethiopia.
[2]Bahir Dar University, Plant Science, Bahir Dar, Ethiopia.

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***Correspondence**
Birtucan Demeke
dbirtucan@gmail.com

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Besides the existence of genetic variation, the relationship between traits determines whether plant breeding is successful. As a result, identifying the influence of yield-related traits on yield is critical. Hence, in 2020/21 cropping season, this study was carried out using 70 upland rice (Oryza sativa L.) genotypes at Pawe, to determine the magnitude of association and the direct and indirect influence of yield component traits on grain yield of rice. Traits such as biomass, days to heading, and days to maturity, productive tiller, panicle length, and field grain per panicle have shown medium to high positive association (0.35-0.85) with grain yield. On the Path analysis except days to heading all traits mentioned above had a positive direct influence on grain yield ranging from 0.05 to 0.62. Traits like days to heading, days to maturity, productive tillers, and grain width had moderate positive indirect effects on grain yield. Therefore, in the process of selecting rice genotypes for further breeding programs of yield improvement characters like biomass yield that had the highest positive association and high direct influence could be primarily used as selection criteria since improvement of these traits leads to grain yield increment.

Key words: correlation coefficient, genotypes, path analysis, rice, grain yield, yield components

INTRODUCTION

About half of the world's population relies on rice as their main source of food, making it the most significant staple crop in the world (Saleh et al., 2020). The consumption and production rates of rice are out of balance in many nations, including Ethiopia, as a result of ongoing population increase, reduction of arable land, and other biotic and abiotic stresses. In Ethiopia, in order to improve crop productivity, the national rice breeding program has partnered with international and regional research organizations try to develop varieties that have a high potential for grain yield. As a result, about 43 improved rice varieties have been released, promoted, and distributed for the primary consumers across the nation (Assaye et al., 2022). However, the released materials did not perform uniformly across different agro-ecologies. The primary cause of this unstable yield potential might be the nature of grain yield by itself. Selecting the finest genotypes solely depending on grain yield is ineffective because grain yield is a complex polygenic character that is influenced by genetic variability, environment, and component interactions (Ratna et al., 2015) such as; productive tillers per unit area, filled grains per panicle, thousand-grain weight, biomass yield, plant height, panicle length, seed length, and the days of flowering, heading, and maturation (Li et al., 2019; Zhao et al., 2020). As a result, in order to increase the efficiency of genetic selection in plant breeding, the main factors influencing the strategies are the degree of correlation between characteristics as well as the amount and type of variation. Hence, the breeders must identify the type and strength of associations between yield and yield-attributing traits as well as the impact of these traits on grain yield when determining superior cross combinations and choosing desired plants with higher yields (Oladosu et al., 2018). The strength of the linear link between two variables is measured by the correlation coefficient (Ratner, 2009). It can be used to plan breeding programs, assess their components, and create selection criteria for the desired character (Usman et al., 2017). In plant breeding efforts, correlation may be a valuable technique to assess the relative importance of each component trait on yield. According to Dewey & Lu (1959) and Immanuel et al. (2011), the path coefficient, on the other hand, describes the actual measure of direct and indirect reasons for association and assesses the importance of each attribute contributing to yield. In order to assess the relative importance of the direct and indirect impacts of each component feature on yield, correlation is a crucial technique in plant breeding programs together with path coefficient analysis (Ratna et al., 2015). Therefore, this research was done to determine the nature and degree of the association between yield and its component traits as well as their direct and indirect influence on the yield of upland rice (*Oryza sativa* L.) genotypes.

MATERIALS AND METHODS

Experimental site description and plant material

The research was carried out to identify and evaluate the association among yield and yield-attributing traits for 68 rice genotypes and two released rice varieties. It was conducted during 2020/21 main cropping season at Pawe Agricultural Research Center (PARC), Pawe, Ethiopia. Pawe Agricultural Research Center lays at 11°18'52.5" N and 36°24'45"E. It has an altitude of 1120 m.a.s.l. The soil type of the experimental site was Vertisols. Annual maximum rainfall is 1587 mm and the temperature ranges from16.3°C to 32.6°C (EIAR, 2021). During the growing season, the temperature was in a range between 17.2°C and 32.2 °C, while the rainfall and humidity were 1238.4mm and 75.3%.

Experimental design and management

The experimental design used was alpha lattice (7 x 10) with two replications. The plot size was 7.5 m^2 with 6 rows. Drilling planting method was used by following the recommended seed rate for the location which is 60kg/ha. UREA and DAP fertilizer were applied based on the recommendation for the location.

Data collected

A total of 15 agronomic traits (Days to 50% heading, Days to 85% maturity, Plant height, Panicle length, Number of productive tillers, Number of nonproductive tillers, Number of filled grains per panicle, Number of unfilled grains per panicle, Biomass yield, Grain yield, Thousand grain weight, Grain length, Grain width, Grain shape and Harvest index were recorded based on rice descriptors of International Rice Research Institute (IRRI, 2013). While, crude Protein was determined according to Kjeldahl digestion method (Thiex et al., 2002) followed by conversion of total nitrogen into crude protein content by using protein correction factor 5.95 (Jones, 1941).

Data analysis

The genotypic correlation (rg) and phenotypic correlation coefficients (rp) between paired traits were calculated from variance and covariance components based on formula suggested by Singh and Chaudhary (1985) to determine the degree of relationship of traits with yield and among themselves. The correlation between traits was classified by the strength of the relationship as low (0 to ± 0.3), moderate (> ± 0.3 to ± 0.7) and high (> ± 0.7 to ± 1.0) (Ratner, 2009). Path coefficient analysis was calculated to determine direct and indirect effect of different variables on yield (Dewey and Lu, 1959) using MS excel 2016.

RESULTS AND DISCUSSION

Correlation of traits

Because the most interesting traits for breeders are complex and are the result of the interaction of many components, complete knowledge of the interrelationships of characters, such as grain yield and other traits, is critical for breeders to improve complex quantitative characters.

Correlation of yield-related traits with yield

As it is presented in Table 1, almost all agronomic traits had genotypic correlation coefficients that were higher than their corresponding phenotypic correlation coefficients. This result implied a strong inherent relationship between yield and the component traits. Days to 50% heading, days to 85% maturity, and biomass yield all had strong positive correlations with grain yield. Additionally, on both genotypic and phenotypic level, there was a moderately positive association between grain yield and productive tillers, panicle length, and filled grain per panicle. These positive correlations imply that when those features value developed, grain yield will increase as well. Genetic linkage or pleiotropy may be the cause of the characteristics' high association with yield. Different researchers reported similar results for the above-mentioned traits (Sarker et al., 2014; Oladosu et al., 2014; Oladosu et al., 2018; Abebe et al., 2019).

On the other hand, there was a strong negative genotypic and phenotypic association between the number of nonproductive tillers and grain yield, followed by a moderate negative correlation of yield with crude protein content, plant height, and thousand-grain weights. The inverse relationship between grain yield and these traits means that, genotypes with higher levels of these traits will have lower grain yield potential (Table 1). A negative association between thousand grain weight and grain yield, which is consistent with this finding was reported by Kafi et al. (2021) for double haploid rice genotypes tested in Nigeria. Similarly, negative association between plant height and grain yield was reported from a research which was performed by Al-Salim et al. (2016) in two location of Iraq by using 10 rice genotypes.

Correlation among yield-related traits

Both at genotypic and phenotypic levels, most yield-related variables were significantly correlated. However, some of these correlations were only at one level, while others were completely uncorrelated. Following the association of days to 50% heading and days to 85% maturity, the largest positive correlation between yield-related features was found between biomass with days to 50% heading and days to 85% maturity. Similar morphological correlations between maturity and heading days were discovered (Akhi et al., 2016). The relationships between grain length and grain shape, biomass and productive tillers, nonproductive tillers and crude protein content, days to heading and productive tillers, days to

Table1. Phenotypic (upper) and genotypic (lower) correlation coefficients among yield and yield related traits of 70 rice genotypes

Variable	DH	DM	PL	PH	PT	NPT	FG	UFG	BOM	TGW	HI	CPC	GL	GW	GS	GY
DH		0.873***	0.423***	-0.37***	0.47***	-0.73***	0.316**	0.148	0.764***	-0.174*	-0.38***	-0.49***	0.003	0.001	0.00	**0.79*** **
DM	0.90***		0.376***	-0.43***	0.40***	-0.7***	0.284***	0.096	0.67***	-0.178*	-0.27***	-0.39***	0.005	-0.041	0.041	**0.76*** **
PL	0.45***	0.41***		-0.037	0.28***	-0.27***	0.385	0.292***	0.41***	-0.160	-0.234**	-0.084	0.040	0.050	-0.016	**0.42*** **
PH	-0.4***	-0.45***	-0.10		-0.52***	0.324***	0.122	-0.103	-0.179*	0.254**	-0.091	0.128	0.023	0.227**	-0.171*	**-0.39*** **
PT	0.48***	0.42***	0.31*	-0.54***		-0.58***	-0.065	0.066	0.521***	-0.3***	-0.116	-0.31***	-0.047	-0.059	0.038	**0.65*** **
NPT	-0.8***	-0.73***	-0.29*	0.34**	-0.60***		-0.196	-0.081	-0.80***	0.201	0.284***	0.462***	0.055	0.009	0.022	**-0.90*** **
FG	0.32**	0.29*	0.40***	0.12	-0.06	-0.20		0.365***	0.283***	-0.4***	-0.063	-0.170*	0.031	-0.026	0.034	**0.34*** **
UFG	0.15	0.11	0.31**	-0.12	0.06	-0.09	0.37**		0.148	-0.12	-0.040	-0.006	-0.011	0.029	-0.025	**0.19* **
BOM	0.79***	0.70***	0.45***	-0.19	0.53***	-0.82***	0.29*	0.15		-0.26**	-0.63***	-0.447	-0.101	0.044	-0.082	**0.84*** **
TGW	-0.18	-0.19	-0.19	0.26*	-0.31**	0.22	-0.38**	-0.13	-0.26*		0.045	0.109	0.119	-0.057	0.096	**-0.34*** **
HI	-0.4***	-0.30*	-0.27*	-0.10	-0.12	0.32**	-0.07	-0.04	-0.65***	0.02		0.203*	0.118	-0.087	0.127	**-0.19* **
CPC	-0.6***	-0.47***	-0.12	0.15	-0.34**	0.53***	-0.20	-0.01	-0.50***	0.11	0.22		-0.011	-0.060	0.039	**-0.47*** **
GL	-0.02	-0.01	0.05	0.07	-0.05	0.14	0.04	-0.02	-0.13	0.17	0.12	-0.01		-0.190*	0.684***	**-0.034**
GW	0.00	-0.05	0.04	0.25*	-0.09	0.00	-0.05	0.03	0.05	-0.08	-0.06	-0.08	-0.08		-0.83***	**-0.02**
GS	-0.01	0.04	0.00	-0.18	0.07	0.07	0.06	-0.03	-0.11	0.14	0.12	0.06	0.62***	-0.8***		**-0.003**
GY	**0.81*** **	**0.79*** **	**0.45*** **	**-0.41*** **	**0.66*** **	**-0.91*** **	**0.35** **	**0.19**	**0.85*** **	**-0.36** **	**-0.23**	**-0.53*** **	**-0.08**	**0.00**	**-0.03**	

*Where *** significant at P<.001, ** significant different at P<0.01, * significant difference at P<0.05, ns= no significant difference, DH= days to 50% heading, DM= days to 85% maturity, PL= panicle length, PH= plant height, PT=productive tiller, NPT=nonproductive tiller, FG= filled grain/panicle, UFG=unfilled grain per panicle, BOM=biomass yield, TGW=thousand grain weight, HI=harvest index, CPC= crude protein content, GL=grain length, GW=grain width, GS=grain shape, and GY= grain-yield.*

50% heading with panicle length, panicle length with biomass, days to 85% maturity with productive tillers, and days to maturity with panicle length, panicle length with filed grain per panicle all showed moderately positive significant correlations. Similarly, high and moderate correlations of the above-mentioned traits were reported (Girma et al., 2018, Alamerew et al., 2019; Saleh et al., 2020). Additionally, a moderate correlation was observed between plant height and nonproductive tillers, filled grains and days to heading, filled grain and unfilled grains, and nonproductive tillers with harvest index (Table 1). The highest negative correlation, on the other hand, was seen between nonproductive tillers and biomass, grain length with grain shape, days to 50% heading with nonproductive tillers, and maturity days with nonproductive tillers. Additionally, traits like biomass with harvest index, productive tiller with nonproductive tiller, crude protein content with days to heading, days to heading with plant height and harvest index, days to maturity with harvest index, protein content, and plant height, as well as productive tillers with plant height, nonproductive tillers, thousand grain weight, and crude protein content, and filled grain per panicle with thousand grain weight showed a moderate negative correlation with each other. In agreement with this finding similar negative associations have been reported among the above-mentioned traits (Hasan et al., 2013; Sarker et al., 2014; Solomon and Wegary, 2016). On the contrary to this result, (Kampe et al., 2018) detected a positive significant correlation of days to 85% maturity with plant height and negative correlation with productive tillers per plant on their study at northwestern Ethiopia. Additionally, negative genotypic relation between thousand grain weight and panicle length, positive genotypic relation between filled grain with maturity and panicle length with days to heading and maturity was reported by Rashid et al. (2014) (Table 1).

Path analysis

To better understand the precise relationship between traits and to provide more reliable information on that relationship, the phenotypic and genotypic correlation coefficient was divided into direct and indirect effects by path coefficient analysis. The genotypic and phenotypic path analysis shown in Table 2 revealed that the direct effect values for biomass yield, harvest index, grain length, days to 85% maturity, productive tillers, panicle length, filled grain, and unfilled grain per panicles was positive and ranged from highest 0.62 to lowest 0.02, respectively. Hence, when performing selection to increase grain output, it is important to give attention to these traits because their positive direct effects on grain yield demonstrated their significance in determining this complex feature. In agreement with the findings of this study, positive direct effects of biomass, harvest index, days to maturity, productive tillers, field grain, panicle length and unfilled grain per panicle were reported by different authors (Yadav et al., 2010; Sarker et al., 2014; Roy et al., 2015; Hossain et al., 2018; Hasan et al., 2019; Abebe et al., 2019; Zhao et al., 2020; Belete et al., 2022). Path coefficient analysis for both genotypic and phenotypic levels revealed that nonproductive tillers, grain shape, grain width, plant height, thousand grain weight, and crude protein content were traits that had a negative direct effect on grain yield. The negative relation of these traits for instance protein content with grain yield might be resulted due to proteolytic enzymatic activity. High grain protein rice varieties have higher proteolytic enzyme activity, which speeds up the senescence process and decreases in leaf nitrogen content at the later growth stage. This decrease in leaf photosynthetic rate at the later growth stage leads to a decline in the ability to produce dry matter and grain yield (Liu et al., 2022). While, days to 50% heading showed a positive and a negative direct effect on phenotypic and genotypic levels, respectively. Similar results for plant height, days to 50% heading, and thousand grain weights were reported by different authors, (Solomon and Wegary, 2016; Alamerew et al., 2019; Kafi et al., 2021; Belete et al., 2022).

Table 2. Genotypic and Phenotypic path coefficient analysis of direct (bold diagonal) and indirect effect of traits on grain yield

Variable	R	DH	DM	PL	PH	PT	NPT	FG	UFG	BOM	TGW	HI	CPC	GL	GW	GS	GY
Days to 50% heading	G	**-0.02**	0.13	0.03	0.02	0.04	0.25	0.02	0.00	0.46	0.01	-0.13	0.01	0.00	0.00	0.00	0.81
	P	**0.01**	0.10	0.02	0.02	0.04	0.23	0.02	0.00	0.47	0.01	-0.13	0.01	0.00	0.00	0.00	0.79
Days to 85% maturity	G	-0.02	**0.14**	0.03	0.02	0.04	0.24	0.02	0.00	0.41	0.01	-0.10	0.01	0.00	0.01	-0.01	0.79
	P	0.01	**0.11**	0.02	0.02	0.03	0.22	0.01	0.00	0.41	0.01	-0.09	0.01	0.00	0.00	-0.01	0.76
Panicle length	G	-0.01	0.06	**0.06**	0.00	0.03	0.09	0.02	0.01	0.26	0.01	-0.09	0.00	0.01	-0.01	0.00	0.45
	P	0.00	0.04	**0.06**	0.00	0.02	0.09	0.02	0.01	0.25	0.01	-0.08	0.00	0.00	-0.01	0.00	0.42
Plant height	G	0.01	-0.06	-0.01	**-0.05**	-0.05	-0.11	0.01	0.00	-0.11	-0.01	-0.03	0.00	0.02	-0.06	0.06	-0.41
	P	0.00	-0.05	0.00	**-0.04**	-0.04	-0.10	0.01	0.00	-0.11	-0.01	-0.03	0.00	0.00	-0.03	0.03	-0.39
Productive tillers	G	-0.01	0.06	0.02	0.03	**0.09**	0.20	0.00	0.00	0.31	0.01	-0.04	0.01	-0.01	0.02	-0.02	0.66
	P	0.01	0.05	0.02	0.02	**0.08**	0.18	0.00	0.00	0.32	0.01	-0.04	0.01	0.00	0.01	-0.01	0.65
Nonproductive tillers	G	0.02	-0.10	-0.02	-0.02	-0.06	**-0.33**	-0.01	0.00	-0.48	-0.01	0.10	-0.01	0.03	0.00	-0.02	-0.91
	P	-0.01	-0.08	-0.02	-0.01	-0.05	**-0.31**	-0.01	0.00	-0.49	-0.01	0.10	-0.01	0.01	0.00	0.00	-0.90
Filled grains/panicle	G	-0.01	0.04	0.03	-0.01	-0.01	0.07	**0.05**	0.01	0.17	0.02	-0.02	0.00	0.01	0.01	-0.02	0.35
	P	0.00	0.03	0.02	-0.01	-0.01	0.06	**0.05**	0.01	0.17	0.02	-0.02	0.00	0.00	0.00	-0.01	0.34
Unfilled grain/panicle	G	0.00	0.02	0.02	0.01	0.01	0.03	0.02	**0.02**	0.09	0.01	-0.01	0.00	0.00	-0.01	0.01	0.19
	P	0.00	0.01	0.02	0.00	0.01	0.03	0.02	**0.02**	0.09	0.00	-0.01	0.00	0.00	0.00	0.00	0.19
Biomass yield	G	-0.02	0.10	0.03	0.01	0.05	0.27	0.02	0.00	**0.59**	0.01	-0.21	0.01	-0.03	-0.01	0.03	0.85
	P	0.01	0.08	0.02	0.01	0.04	0.25	0.01	0.00	**0.62**	0.01	-0.22	0.01	-0.01	-0.01	0.01	0.84
Thousand grain weight	G	0.00	-0.03	-0.01	-0.01	-0.03	-0.07	-0.02	0.00	-0.15	**-0.04**	0.01	0.00	0.04	0.02	-0.05	-0.36
	P	0.00	-0.02	-0.01	-0.01	-0.03	-0.06	-0.02	0.00	-0.16	**-0.04**	0.02	0.00	0.01	0.01	-0.02	-0.34
Harvest index	G	0.01	-0.04	-0.02	0.00	-0.01	-0.11	0.00	0.00	-0.38	0.00	**0.32**	0.00	0.02	0.01	-0.04	-0.23
	P	0.00	-0.03	-0.01	0.00	-0.01	-0.09	0.00	0.00	-0.39	0.00	**0.35**	0.00	0.01	0.01	-0.02	-0.19
Crude protein content	G	0.01	-0.07	-0.01	-0.01	-0.03	-0.17	-0.01	0.00	-0.29	-0.01	0.07	**-0.02**	0.00	0.02	-0.02	-0.53
	P	-0.01	-0.04	0.00	-0.01	-0.03	-0.14	-0.01	0.00	-0.28	0.00	0.07	**-0.02**	0.00	0.01	-0.01	-0.47
Grain length	G	0.00	0.00	0.00	0.00	-0.01	-0.05	0.00	0.00	-0.08	-0.01	0.04	0.00	**0.21**	0.02	-0.20	-0.08
	P	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	-0.06	0.00	0.04	0.00	**0.10**	0.02	-0.11	-0.03
Grain width	G	0.00	-0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	0.03	0.00	-0.02	0.00	-0.02	**-0.24**	0.27	0.00
	P	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.03	0.00	-0.03	0.00	-0.02	**-0.12**	0.14	-0.02
Grain shape	G	0.00	0.01	0.00	0.01	0.01	-0.02	0.00	0.00	-0.06	-0.01	0.04	0.00	0.13	0.20	**-0.33**	-0.03
	P	0.00	0.00	0.00	0.01	0.00	-0.01	0.00	0.00	-0.05	0.00	0.04	0.00	0.07	0.10	**-0.17**	0.00

Unexplained variation= Rg (0.20) and Rp (0.18)

According to the results of the path coefficient analysis, traits that affect grain yield indirectly but positively include days to heading, days to maturity, productive tillers, panicle length, and filled grain through biomass, biomass and productive tillers through nonproductive tillers, grain shape through grain width, and grain width through grain shape. Nonproductive tillers, harvest index, crude protein content, and thousand grains weight all revealed negative indirect effects on grain yield through biomass yield. Additionally, biomass yield and crude protein content indirectly and negatively affected grain yield through harvest index and nonproductive tillers, respectively. For the phenotypic and genotypic path coefficients, the unexplained variance was ($R^2 = 0.20$ and $R^2=0.18$), respectively. This meant that traits included in the path analysis accounted for more than 80% of genotypic variability and 82% of phenotypic variability on grain yield, while traits not included in the path analysis accounted for the remaining 20% and 18% of variability. Generally, based on path analysis result, the selection of biomass yield, harvest index, productive tillers, filled grains, panicle length, and days to maturity are some of the factors that might improve grain yield. As a result, these features should be regarded as vital selection criteria in to improve rice yield, and direct selection for these traits is cost-effective.

CONCLUSION

The yield component traits have a significant impact on grain yield. In this study, biomass yield, days to maturity, productive tiller, panicle length, and filled grain all had favorable associations with and direct positive effects on grain yield. Additionally, even though there was no statistically significant link between the harvest index and grain length, the path analysis result showed that they have a positive direct impact on grain yield. As a result, in rice breeding and yield enhancement programs, selection based on traits like biomass, harvest index, grain length, days to maturity, productive tiller, panicle length and filled grain will be more effective and advantageous for any activity intending to improve grain yield.

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AUTHOR CONTRIBUTIONS

Birtucan Demeke conducted the study, carried out all assessments, analyzed the data, and wrote the report. The manuscript was edited by Tiegist Degene and Desta Abebe. All authors approved the content of this manuscript.

COMPETING INTERESTS

The authors declare that there is no conflict of interest & the manuscript has not been submitted for publication in other journals.

ETHICS APPROVAL

Not applicable

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