Correlation and Path Coefficient Analysis for Agronomical Traits of Lowland Adapted Ethiopian Sorghum Genotypes [Sorghum bicolor (L.) Moench] Genotypes

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Abstract
The association of traits that may exist between or among sorghum characters is essential for breeders. Therefore, the present study is aimed to analyze and determine the traits having greater association with yield utilizing the correlation and path analysis for different traits of early and medium maturing lowland adapted Ethiopian sorghum genotypes. A total of 110 early and medium maturing sorghum genotypes were used in alpha lattice design which is replicated twice at two locations in 2016 cropping season.The results of correlation analysis suggested that the magnitude of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the traits suggesting that there was inherent relationship between these traits. Grain yield showed significant and positive phenotypic correlation with number of heads per plot (r=0.34**), panicle weight (r=0.19**) and hundred grain weight (r=0.21**). The strongest phenotypic association was observed between days to flowering and days to maturity (r= 0.53**) followed by hundred grain weight and plant height (r= 0.47**). In addition path coefficient analysis provides an effective means of finding direct and indirect causes of association.
Keywords: Correlation, Ethiopian, Path coefficient, Sorghum

INTRODUCTION
Sorghum (Sorghum bicolor (L.) Moench) crop is genetically suited to hot and dry agro-ecologies with frequent drought, where it is difficult to grow other crops. In Ethiopian lowland areas sorghum is mainly grown for both food and feed (stover) purposes. Therefore, it can play a vital role for the uplift of socio-economic status of the farmers in the areas through development of high yielding varieties along with reasonable maturation date.

The study of associations among quantitative traits is important for assessing the feasibility of joint selection of two or more traits and hence for evaluating the effect of selection for secondary traits on genetic gain for the primary trait under consideration. A positive genetic correlation between two desirable traits makes the job of the plant breeder easy for improving both traits simultaneously. The path coefficient analysis allows partitioning of correlation coefficient into direct and indirect contributions (effects) of various traits towards dependent variable and thus helps in evaluating the cause-effect relationship as well as effective selection. Therefore, the present study is aimed to analyze and determine the traits having greater association with yield utilizing the correlation and path analysis for different traits in sorghum.

MATERIALS AND METHODS
One-hundred ten early and medium maturing lowland adapted sorghum genotypes were used for the experiment. The trial was grown in alpha lattice design with two replications at two locations i.e. Meiso and Sheraro research sub-stations. Mieso is located 9°14′N, 40°45′E, and 1394 m.a.s.l. whereas Sheraro lies in 14.4N, 37.9 E, 1179 m.a.s.l. Both the areas are among the potential sorghum producing dry lowlands in the northern and eastern part of country.

Data to be collected
All agronomic data were collected on plot and plant bases using sorghum descriptors (IBPGR/ICRISAT, 1993). In each plot, randomly selected five plants were used to measure the following plant based characters.

Data analysis
Phenotypic (r_p) and genotypic (r_g) correlation coefficient
The correlation was estimated using the formula suggested by Miller *et al.* (1958):

$$r_p = \frac{P_{\text{cov } xy}}{\sqrt{(\delta^2 p_x * p_y)}}$$

Where, r_p = Phenotypic correlation coefficient

$P_{cov\,xy}$ = Phenotypic covariance between character x and y

$$r_g = \frac{g_{cov\,xy}}{\sqrt{(\delta^2 g_x * g_y)}}$$

Where, g_{coxy} = genotypic covariance between character x and y,

r_g = genotypic correlation coefficient,

$\delta^2 gx$ = Genotypic variance of x character

$\delta^2 gy$ = Genotypic variance of y character

$\delta^2 px$ = Phenotypic variance of x character

$\delta^2 py$ = Phenotypic variance of y character

Path coefficient analysis
The path coefficient analysis initially suggested by Wright (1921) and described by Dewey and Lu (1959) allows partitioning of correlation coefficient into direct and indirect contributions (effects) of various traits towards dependent variable and thus helps in assessing the cause-effect relationship as well as effective selection. Genetic correlations were further partitioned into direct and indirect effects using the path coefficient analyses following the method of Dewey and Lu (1959).

$$r_{ij} = P_{ij} + \sum r_{ik} P_{kj}$$

Where, r_{ij} = mutual association between the independent character i (yield related trait) and dependent character, j (yield) as measured by the genotypic correlation coefficient; P_{ij} is components of direct effect of the independent character (i) on the dependent character (j) as measured by the genotypic path coefficients; and $\sum r_{ik} p_{kj}$ = summation of components of indirect effects of a given independent characters (i) on the given dependent character (j) via all other independent characters (k). Whereas the contribution of the remaining unknown characters are measured as the residual which is calculated as:

$$R_R = \sqrt{\left(1 - \sum P_{IJ} - RIJ\right)}$$

RESULTS AND DISCUSSION
Estimation of correlation coefficient of yield and yield related traits
The existence of variation alone in the population is not sufficient for improving desirable characters and hence, estimation of the extent and pattern of genetic variability existing in the available germplasm is essential to breeders. Breeders are also interested in the association that may exist between or among sorghum characters.

The phenotypic and genotypic correlation coefficients computed among yield and yield related traits are presented in Table 1. Yield is a complex character which depends upon several component characters. Therefore, direct selection for yield is often not effective. Thus, it is essential to study the association of yield components with yield which is less influenced by environmental factors. Grain yield showed significant and positive phenotypic correlation with number of heads per plot (r=0.34**), panicle weight (r=0.19**) and hundred grain weight (r=0.21**). The strongest phenotypic association was observed between days to flowering and days to maturity (r= 0.53**) followed by hundred grain weight and plant height (r= 0.47**). On the other hand characters days to flowering, days to maturity and disease score showed negative and significant association with grain yield with the value (r= 0.18**), (r= -0.17**) and (r= -0.11*) respectively.

At genotypic level grain yield showed positive and highly significant correlations with number of heads per plot (r=0.42**) and panicle weight (r=0.31**) (Table 1). The strongest genotypic association was observed between days to flowering and days to maturity (r= 0.71**) followed by plant height and hundred grain weight (r= 0.56**) and plant height and panicle length (r=0.42**). Generally, the values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the traits

suggesting that there was inherent relationship between these traits. This is in accordance with the findings of Mahajan *et al.* (2011), Ezeaku and Mohammed (2006) and (Alhassan *et al.,* 2008).

Table 1. Estimates of correlation coefficients at genotypic (above diagonal) and phenotypic (below diagonal) for yield and yield related traits among nine morpho-agronomic traits of sorghum genotypes evaluated at Meiso and Sheraro, 2016

Traits	DTF	DTM	PHT	NPPP	PAL	PAW	HGW	DS	GYD
DTF		0.712***	0.131	-0.394***	0.0012	-0.147	-0.105	-0.164	-0.218*
DTM	0.53***		0.045	-0.379***	-0.055	-0.182	-0.157	-0.183	-0.114
PHT	0.099*	-0.17***		0.021	0.421***	-0.023	0.565**	0.327***	0.027
NPPP	-0.25***	-0.34***	0.17***		-0.064	0.378***	0.190*	0.219*	0.42***
PAL	-0.01657	-0.06112	0.37***	-0.008		-0.234*	-0.029	0.347***	-0.084
PAW	-0.13**	-0.13**	0.02133	0.21***	-0.18***		0.202*	0.021	0.312***
HGW	-0.099*	-0.55***	0.47***	0.2231	0.12**	0.0624		0.052	0.179
DS	-0.0314	-0.19***	0.39***	0.122**	0.27***	0.024	0.16***		-0.098
GYD	-0.18***	-0.17***	0.089	0.34***	-0.051	0.19***	0.21***	-0.105*	

 * P≤ 0.05; ** P≤ 0.01, ***P≤0.001, DTF= days to flowering, DTM=days to maturity, PHT=plant height, NPPP= number of panicles per plot, PAL=panicle length, PAW=panicle weight, HGW=hundred grain weight, DS=disease score, GYD=grain yield,

Path Coefficient Analysis

Path coefficient analysis provides an effective means of finding direct and indirect causes of association (Wright, 1921). In the present investigation, the path coefficient analysis was done with nine characters using estimates of direct and indirect effects of eight characters on grain yield based on phenotypic and genotypic correlation coefficients (Table 2 and 3).

Phenotypic path coefficient analysis

The phenotypic direct and indirect effects of yield-related traits on grain yield of sorghum are presented in Table 2. Thus, days to maturity, plant height, number of heads per plot, panicle weight and hundred grain weight exerted positive phenotypic direct effect on grain yield. Whereas days to flowering, panicle length and disease score exerted negative direct effects on grain yield. However, days to flowering exhibited positive phenotypic correlation with grain yield due to their positive indirect effects through number of heads per plot, panicle weight and hundred grain weight. Similarly disease score exhibited positive phenotypic correlation with grain yield due to their positive indirect effects through days to flowering and days to maturity. The highest and positive phenotypic direct effects on grain yield were exhibited by number of panicles per plot (0.28), followed by hundred grain weight (0.17). Hence, these traits should be considered in further selection procedures for higher grain yield. The highest indirect effect belonged to number of heads per plot via panicle weight and hundred grain weight. Days to maturity had positive direct effect (0.08) on grain yield. However, it affects the yield negatively via plant height, number of heads per plot, panicle weight and hundred grain weight. Although the number of panicles per plot, panicle weight and hundred grain weight has statistically highly significant positive phenotypic direct effect on the yield, but it has negative indirect effect via days to flowering and days to maturity. The positive phenotypic direct effect of plant height and number of panicles per plot on grain yield is in agreement with Mahajan *et al.*, (2011).

Table 2. Estimates of phenotypic path analysis of the direct (bolded diagonal) and indirect (off-diagonal) effects of yield related traits on grain yield of sorghum genotypes evaluated at Meiso and Sheraro, 2016

Traits	DTF	DTM	PHT	HPP	PAL	PAW	GW	DS	r_p
DTF	**-0.13**	0.04	0.01	-0.07	0.00	-0.02	-0.02	0.01	-0.18**
DTM	-0.07	**0.08**	-0.01	-0.10	0.00	-0.02	-0.09	0.04	-0.17**
PHT	-0.01	-0.01	**0.07**	0.04	-0.01	0.00	0.08	-0.07	0.089
HPP	0.03	-0.03	0.01	**0.28**	0.00	0.03	0.04	-0.02	0.34***
PAL	0.00	0.00	0.02	0.00	**-0.02**	-0.02	0.02	-0.05	-0.051
PAW	0.02	-0.01	0.00	0.06	0.00	**0.12**	0.01	0.00	0.19***
GW	0.01	-0.04	0.03	0.06	0.00	0.01	**0.17**	-0.03	0.21***
DS	0.00	-0.02	0.03	0.03	-0.01	0.00	0.03	**-0.18**	-0.105*

DTF= days to flowering, DTM=days to maturity, PHT=plant height, NPPP= number of panicles per plot, PAL=panicle length, PAW=panicle weight, HGW=hundred grain weight, DS=disease score, GYD=grain yield

Genotypic path coefficient analysis

The genotypic direct and indirect effects of yield-related traits on sorghum grain yield are presented in Table 3. Number of panicles per plot exerted positive direct effect and exhibited positive significant genotypic correlation

with grain yield. Days to maturity, plant height, number of panicles per plot, panicle length, panicle weight and hundred grain weight showed positive genotypic direct effect on yield and also had positive correlation with grain yield. These traits could be used as a reliable indicator in indirect selection for higher grain yield since their direct effect and association with grain yield were positive.

The highest genotypic direct effect on grain yield was exerted by number of panicles per plot (0.38) followed by days to maturity (0.18). The positive associations of these traits with grain yield were due to the positive indirect effects through other traits. Negative direct effects on grain yield were found for days to flowering (-0.21) and disease score (-0.23), which is not agree with previously studied by Premlatha *et al.,* (2006) also these traits exhibited negative correlation with grain yield. The positive genotypic direct effect of plant height is in conformity with the results obtained by Mahajan *et al*., (2011) in their study on variability, correlation and path coefficient analysis in sorghum.

Table 3. Estimates of genotypic path analysis of the direct (bolded diagonal) and indirect (off-diagonal) effects of yield related traits on grain yield of sorghum genotypes evaluated at Meiso and Sheraro, 2016

Traits	DTF	DTM	PHT	HPP	PAL	PAW	GW	DS	r_g
DTF	**-0.21**	0.13	0.01	-0.15	0.00	-0.03	-0.01	0.04	-0.218[*]
DTM	-0.15	**0.18**	0.00	-0.14	0.00	-0.03	-0.01	0.04	-0.114
PHT	-0.03	0.01	**0.08**	0.01	0.02	0.00	0.02	-0.08	0.027
HPP	0.08	-0.07	0.00	**0.38**	0.00	0.07	0.01	-0.05	0.419[***]
PAL	0.00	-0.01	0.04	-0.02	**0.04**	-0.04	0.00	-0.08	-0.084
PAW	0.03	-0.03	0.00	0.14	-0.01	**0.17**	0.01	0.00	0.312[***]
GW	0.02	-0.03	0.02	0.07	0.00	0.03	**0.07**	-0.01	0.179
DS	0.04	-0.03	0.03	0.08	0.01	0.00	0.00	**-0.23**	-0.098

DTF= days to flowering, DTM=days to maturity, PHT=plant height, NPPP= number of panicles per plot, PAL=panicle length, PAW=panicle weight, HGW=hundred grain weight, DS=disease score, GYD=grain yield

SUMMARY AND CONCLUSION
The relationship of different agronomic characters with each other and their relationship with yield is important. Grain yield showed significant and positive phenotypic correlation with number of heads per plot (r=0.34**), panicle weight (r=0.19**) and hundred grain weight (r=0.21**). the values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the traits suggesting that there was inherent relationship between these traits. Though, further evaluation of these and other genotypes of sorghum at more locations and over years is advisable to confirm the promising results observed in the present study.

In general, it may be concluded that the information from this study could be valuable for researchers and/or academicians who anticipate to know the direct and indirect effects of yield component traits in different varieties of sorghum.

ACKNOWLEDGMENTS

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