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Character association and path coefficient analysis for improving grain yield in sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract
The experiment was carried out with 40 sorghum genotypes during *kharif*, 2021 at College Farm, Navsari Agricultural University, Navsari, and Gujarat. The correlation studies indicated that grain yield per plant was significant and positively correlated with plant height, panicle length, primary branches per panicle, 100 seed weight, protein content and harvest index, which suggested that these characteristics can be improved simultaneously with grain yield per plant by direct selection. Path analysis revealed that the highest positive direct effects on grain yield per plant were exhibited by harvest index followed by straw yield per plant, 100 seed weight, days to maturity, panicle length and plant height. Therefore, selection and improvement for such traits are easy in sorghum. From the results obtained, it would be reasonable to suggest the breeder who is involved in increasing the seed yield to concentrate more on plant height, panicle length, and 100 seed weight and harvest index.

Keywords: Character association, path analysis, sorghum

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench] is a member of the Andropogoneae tribe of subgroup Panicoideae in the grass family, Poaceae (Harlan and de Wet, 1972). The word sorghum is derived from the word “sorgo” which means “rising above”. Sorghum is often cross pollinated and exhibits about 6% outcrossing having 2n=2x=20 chromosomes. The height of cultivated varieties varies from 0.5 m to 6.0 m. According to the inflorescence (panicle), which varies from very open or loose to very compact, cultivated sorghum has been classified into 5 races *viz*., *bicolor*, *guinea*, *caudatum*, *durra* and *kafir* and ten intermediate races corresponding to the pairwise combination of major races. They are identified according to the morphological traits, panicle, grain and glume traits (Harlan and de Wet, 1972).
It is considered to be of Ethiopian origin (Vavilov, 1935) [13]. Its origin and domestication can be traced back to about 5000-8000 years ago. The second origin is the subcontinent of India. During the first millennium B.C., it is likely to have been brought to India from Eastern Africa. It was known to exist there perhaps as far back as 1000 B.C. (Wendorf *et al*., 1992) [14]. The cultivated sorghum has evolved from wild sorghum *i.e. S. arundinaecea*, *S. verticelliflorum*, *S. sudanense* and *S. aethiopicum*. It is known by diverse names *viz*., *Jowar*, *Jaur*, *Cholam* or *Jola* in India, *Kofir corn* and *Dhuma* in Africa, *Kaoling* in China and *Milo maize* in America.
The crop is widely grown in the semi-arid tropics (SAT) of Asia, Africa, America and Australia. Across the globe, sorghum is ranked fifth, after wheat, maize, rice and barley, both in terms of area and production. The world's largest producers of sorghum are the United States, Nigeria, Ethiopia, Sudan, Mexico and India. In India's major cereal crops, it ranks third after wheat and rice.
An assessment of the amount of genetic variation available for all yield attributes, the correlation coefficient between seed yield and its contributing traits, as well as a relationship between seed yield and other traits will greatly assist plant breeders in formulating effective selection strategies. An evaluation of the correlation coefficient measures the mutual relation between various plant characteristics and defines the feature characteristics upon which selection can be based to improve yield. However, it does not offer a complete picture of how these components influence grain yield. For this reason, the correlation must be partitioned into direct and indirect effects *via* path analysis to obtain information on the actual contribution of each character to the yield. Therefore, by combining correlation with path Analysis, we could identify suitable selection criteria to improve yields.

Materials and Methods

The experiment was conducted to evaluate 40 genotypes, in randomized block design with three replications at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat). The entire experimental material was divided into three replications, in which each plot consisted of 1 row of 4.8 meter long rows. Each row comprised of 32 plants of single genotype with 45 cm and 15 cm row to row and plant to plant spacing, respectively. All the recommended practices along with necessary plant protection measures were followed timely to avoid damage through insect pests and diseases and for the healthy and good raising of the crop. The other agronomical practices were followed as per recommended practices.

The observations were recorded on 10 randomly selected plants from each genotype in each replication, excluding border rows to minimize border effects. Data for all the characters were collected from the arbitrarily selected 10 plants on an individual plant basis for different characters, except for days to 50% flowering and their averages were computed and subjected to the statistical analysis. Observations for days to 50% flowering and days to maturity were recorded on plot basis. All the weights were recorded in gram with the help of a physical balance. The observation was recorded for days to 50% flowering, days to maturity, plant height, panicle length and primary branches per panicle, 100 seed weight, and grain yield per plant, straw yield per plant, harvest index, protein content, Fe content, Zn content.

The analysis of variance for Randomized Block Design (RBD) was done for each character with the method suggested by Panse and Sukhatme (1985) [9]. Genotypic (r_g) and phenotypic (r_p) correlation coefficients were calculated by adopting the method explained by Miller *et al.* (1958) [8]. Path analysis suggested by Wright (1921) [15] and Dewey and Lu (1959) [2] was adopted for partitioning the genotypic correlation between variables with grain yield into direct and indirect effects of those variables on the yield.

Results and Discussion

Yield is a complex and polygenic ally inherited character resulting from multiplicative interaction of its component traits. The cumulative effect of such traits determines the yield. The change in one character brings about a series of changes in the other characters, since they are interrelated. Therefore, correlation studies and the knowledge of the magnitude of genetic association between yield and its component characters are of considerable importance in any selection programmer as they provide degree and direction of a relationship between two or more component traits. Usually, plant breeders are interested in selecting two or more characters at a time. Selection for specific character may result in correlated response of other character. Improvement in grain yield is one of the major focuses of plant breeder; this is achieved by indirect selection for other easily observable character.

This needs a good understanding of association between such economic traits and its component characters. Simple correlation study is insufficient to compute the association because different genotypes are prone to environmental effects various degrees. Hence estimation of correlation at genotypic and phenotypic levels gives way to understanding environmental influence on heredity expression. Therefore, the correlation coefficients between yield and its components and among the components were estimated at genotypic and phenotypic levels. The genotypic (r_g) and phenotypic (r_p) correlation coefficients for 12 characters are presented in Table 1.

The magnitude of genotypic correlations was recorded higher as compared to corresponding phenotypic correlations for majority of the traits under study indicated that there was an inherent association between those characters at genotypic level. Grain yield per plant exhibited highly significant and positive correlation with plant height, panicle length, primary branches per panicle, 100 seed weight and harvest index at both phenotypic and genotypic levels. Straw yield per plant exhibited significant and positive correlation with grain yield per plant at genotypic level. Protein content showed highly significant and positive correlation at genotypic level, while significant and positive correlation at phenotypic level. Since, these characters association were in the desirable direction, thus selection practiced for the improvement in one character will automatically results in the improvement of other correlated trait, hence due weightage should be given to these characters during selection for grain yield improvement.

Similar findings were obtained by Prasad and Sridhar (2019) for plant height; Girish *et al*. (2016) [3] and Kathalkar (2017) [5] for panicle length; Chittapur *et al*. (2013) [1] for primary branches per panicle; Kavipriya *et al*. (2020) [6] and Kumar *et al*. (2021) [7] for 100 seed weight; Kumar *et al*. (2021) [7] for harvest index; Kathalkar (2017) [5] for days to 50% flowering; Subalakhshmi *et al*. (2019) [12] for days to maturity; Patil *et al*. (2022) [10] for straw yield per plant.

In this study, it has been found that the amount of genotypic correlation was higher as compared to their corresponding phenotypic correlations for majority of the characters, which reflects the less environmental influence and existence of inherent relation among the characters under study. Genotypic correlation coefficients were higher than phenotypic correlation coefficients, which might be due to the masking effect of environment in the total expression of the genotypes, which results in reduced phenotypic association. The significant and desired directional inherent and observable correlation was registered between grain yield and all characters under investigation except Fe content and Zn content. This showed that above traits having inherent relationship with grain yield, which also depicted their importance in the grain yield enhancement and can be done by improving those characters.

Yield being a complex character, is composed of several components some of them is classified as main component and has direct influence on yield, while others have indirect influence by changing the behavior and growth of different traits. Correlation studies provide information only on the magnitude and direction of association of yield with its components and also among various components. But to know the direct effects of each independent variable on yield and indirect effects through other characters, path coefficient analysis has to be performed.

Path coefficient analysis indicated that highest positive direct effect on grain yield per plant was exerted by harvest index followed by straw yield per plant, 100 seed weight, days to maturity, panicle length and plant height indicated that these characters may provide expected advance during selection for grain yield. Thus, these characters turned out to be the major components of grain yield per plant. Therefore, it revealed that there was true relationship between these characters and grain yield and hence direct selection of these characters could be effective for improving grain yield in sorghum. Path coefficient analysis for 12 characters are presented in Table 2 and Figure 1.

Days to maturity exhibited positive direct effect with grain yield per plant but on parallel side it recorded negative correlation at both genotypic and phenotypic levels. Hence, it would be better to avoid direct selection of this character when grain yield is to be improved. Highest negative direct effect on grain yield per plant was recorded by days to 50% flowering, primary branches per panicle, protein content, Zn content and Fe content. Negative direct effects of above characters might be due to their negative indirect effects via another trait on them.

The enhancement of economically important character like grain yield per plant includes taking into account of all yield contributing characters, which were having both direct and indirect effects. The outcome of path analysis suggests that selection advantage should be given to harvest index followed by straw yield per plant, 100 seed weight, and days to maturity and panicle length.

Table 1: Genotypic and phenotypic correlation coefficients of grain yield per plant with other characters in sorghum

Characters		DF	DM	PH	PL	PB/P	HSW	SY/P	HI	PR	Fe	Zn
DF	r_g	1.000**										
	r_p	1.000**										
DM	r_g	0.862**	1.000**									
	r_p	0.721**	1.000**									
PH	r_g	-0.132	-0.102	1.000**								
	r_p	-0.094	-0.111	1.000**								
PL	r_g	-0.206*	-0.153	0.460**	1.000**							
	r_p	-0.217*	-0.133	0.367**	1.000**							
PB/P	r_g	-0.149	-0.153	0.224*	0.539**	1.000**						
	r_p	-0.090	-0.056	0.206*	0.430**	1.000**						
HSW	r_g	-0.082	-0.230*	0.475**	0.355**	0.546**	1.000**					
	r_p	-0.067	-0.127	0.344**	0.273**	0.384**	1.000**					
SY/P	r_g	-0.035	-0.0002	0.275**	0.144	0.053	0.369**	1.000**				
	r_p	-0.040	-0.018	0.212*	0.110	0.054	0.266**	1.000**				
HI	r_g	-0.176	-0.203*	0.063	0.471**	0.277**	-0.041	-0.560**	1.000**			
	r_p	-0.141	-0.105	0.057	0.408**	0.225*	-0.029	-0.578**	1.000**			
PR	r_g	-0.063	-0.043	0.187*	0.105	0.258**	0.574**	-0.102	0.247**	1.000**		
	r_p	-0.032	-0.028	0.167	0.118	0.206*	0.431**	-0.098	0.233*	1.000**		
Fe	r_g	-0.233*	-0.313**	-0.046	0.075	-0.164	0.092	0.056	-0.119	0.120	1.000**	
	r_p	-0.205*	-0.232*	-0.045	0.066	-0.139	0.074	0.053	-0.105	0.108	1.000**	
Zn	r_g	-0.235**	-0.216*	0.039	0.082	0.243**	0.343**	0.184*	-0.085	0.254**	-0.032	1.000**
	r_p	-0.185*	-0.134	0.033	0.072	0.209*	0.279**	0.146	-0.058	0.238**	-0.029	1.000**
GY/P	r_g	-0.275**	-0.261**	0.410**	0.766**	0.416**	0.380**	0.194*	0.683**	0.254**	-0.057	0.054
	r_p	-0.242**	-0.177	0.337**	0.636**	0.362**	0.255**	0.148	0.688**	0.231*	-0.049	0.049

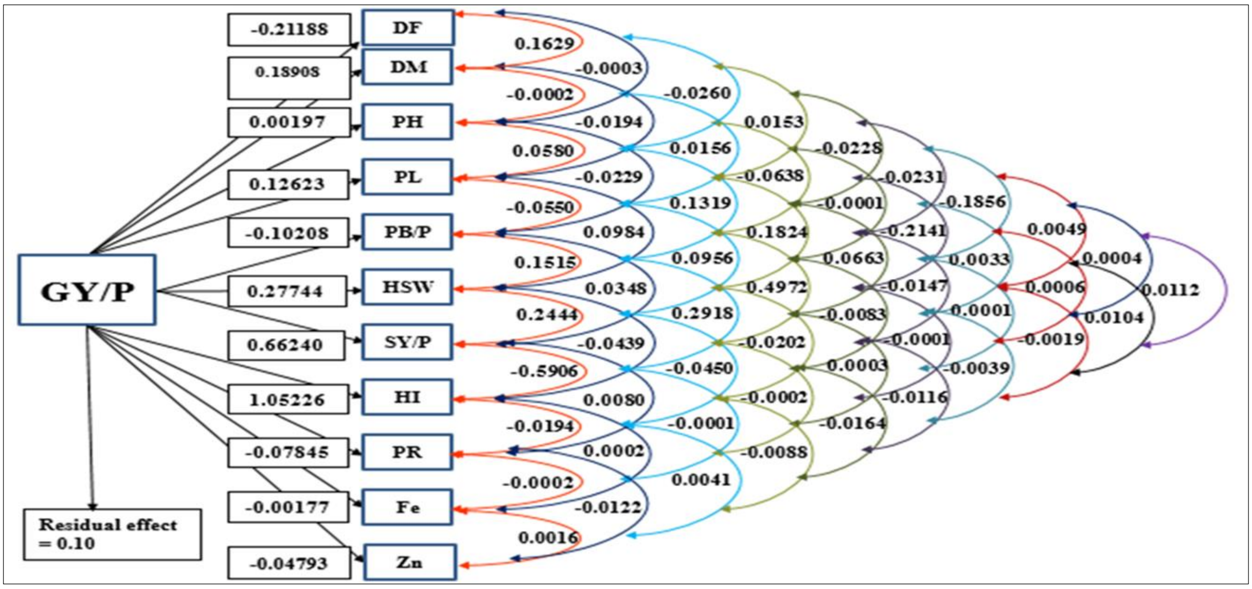
** significant at 1% level of probability, * significant at 5% level of probability, DF = days to 50% flowering, DM = days to maturity, PH = plant height (cm), PL = panicle length (cm), PB/P = primary branches per panicle, HSW = 100 seed weight (g), GY/P = grain yield per plant (g), SY/P = straw yield per plant (g), HI = harvest index, PR = protein content (%), Fe = Fe content (ppm), Zn = Zn content (ppm)

Table 2: Direct and indirect effects (path matrix) of 11 causal variables on grain yield per plant in sorghum

Characters	DF	DM	PH	PL	PB/P	HSW	SY/P	HI	PR	Fe	Zn	Genotypic correlation coefficients with GY/P
DF	-0.21188	0.16294	-0.00026	-0.02600	0.01525	-0.02283	-0.02314	-0.18564	0.00493	0.00041	0.01124	-0.275**
DM	-0.18259	0.18908	-0.0002	-0.01936	0.01559	-0.06376	-0.00011	-0.21411	0.00334	0.00055	0.01035	-0.261**
PH	0.02803	-0.0193	0.00197	0.05802	-0.02288	0.13188	0.18238	0.06630	-0.01468	0.00008	-0.00185	0.410**
PL	0.04363	-0.02899	0.00091	0.12623	-0.05499	0.09838	0.09562	0.49719	-0.00825	-0.00013	-0.00391	0.766**
PB/P	0.03165	-0.02888	0.00044	0.06800	-0.10208	0.15152	0.03484	0.29175	-0.02021	0.00029	-0.01163	0.416**
HSW	0.01744	-0.04345	0.00094	0.04476	-0.05575	0.27744	0.24437	-0.04388	-0.04502	-0.00016	-0.01643	0.380**
SY/P	0.00740	0.00003	0.00054	0.01822	-0.00537	0.10235	0.66240	-0.59058	0.00799	-0.00010	-0.00881	0.194*
HI	0.03738	-0.03847	0.00012	0.05964	-0.02830	-0.01157	-0.37177	1.05226	-0.01938	0.00021	0.00408	0.683**
PR	0.01331	-0.00804	0.00037	0.01327	-0.02630	0.15921	-0.06749	0.25997	-0.07845	-0.00021	-0.01215	0.254**
Fe	0.04928	-0.05926	-0.00009	0.00945	0.01670	0.02551	0.03699	-0.12581	-0.00938	-0.00177	0.00155	-0.0568
Zn	0.04970	-0.04083	0.00008	0.01029	-0.02477	0.09510	0.12170	-0.08953	-0.01989	0.00006	-0.04793	0.0540

Residual Effect = 0.10

*, ** significant at 5% and 1% levels of significance, respectively, DF = days to 50% flowering, DM = days to maturity, PH = plant height (cm), PL = panicle length (cm), PB/P = primary branches per panicle, HSW = 100 seed weight (g), GY/P = grain yield per plant (g), SY/P = straw yield per plant (g), HI = harvest index, PR = protein content (%), Fe = Fe content (ppm), Zn = Zn content (ppm)



DF = days to 50% flowering, DM = days to maturity, PH = plant height (cm), PL = panicle length (cm), PB/P = primary branches per panicle, HSW = 100 seed weight (g), GY/P = grain yield per plant (g), SY/P = straw yield per plant (g), HI = harvest index, PR = protein content (%), Fe = Fe content (ppm), Zn = Zn content (ppm)

Fig 1: Genotypic path diagram for grain yield imparted by the component characters

Conclusion

The conclusion that can be obtained from the correlations and path coefficient analysis study is that plant height and straw yield per plant are the important developmental characters. Among the yield contributing traits, panicle length, primary branches per panicle and 100 seed weight are the key yield component characters, hence these traits should be considered as a selection criteria for improving grain yield in sorghum. Protein content, Fe content and Zn content are important qualitative traits. From the results obtained, it would be reasonable to suggest the breeder who involved in increasing the seed yield to concentrate more on plant height, panicle length and 100 seed weight and harvest index.

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