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Lokesh Kumar Verma
Ph.D. Scholar, University of Agriculture Sciences, Dharwad, Karnataka, India

BD Biradar
Professor, Department of Genetics and Plant Breeding, University of Agriculture Sciences, Dharwad, Karnataka, India

Corresponding Author:
Lokesh Kumar Verma
Ph.D. Scholar, University of Agriculture Sciences, Dharwad, Karnataka, India

Correlation and path analysis for grain yield and yield attributes in *rabi* sorghum [*Sorghum bicolor* (L.) Monech]

Lokesh Kumar Verma and BD Biradar

Abstract
The characters association and their direct and indirect effects were studied in 68 germplasm lines which are part of minicore. The association study revealed the positive and significant association of days to 50 *per cent* flowering (0.514**), panicle girth (0.516**), nodes per plant (0.278*), stem girth (0.445**), panicle weight (0.979**), 1000 grain weight (0.768**), seeds per panicle (0.741**), volume (0.714**), grain length (0.353**), grain width (0.639**) and seed thickness (0.643**) with grain yield per plant. The partition of yield and yield attributes into direct and indirect effects revealed that the characters *viz.*, panicle length (0.026), whorls per panicle (0.010), nodes per plant (0.104), plant height (0.021), panicle weight (0.367), 1000 grain weight (0.282), grains per panicle (0.424), volume (0.158), grain density (0.044) and grain thickness (0.033) showed a positive direct effect on grain yield per plant. On grain yield indicating the importance of these characters hence, these characters should be considered while planning a breeding strategy by utilizing *rabi* sorghum.

Keywords: character association, Minicore, path analysis, sorghum bicolor, rabi

Introduction
Sorghum (*Sorghum bicolor* (L.) Moench) is one of the major cereal crops of the semi-arid tropics. It is the fifth most important cereal crop following rice, wheat and maize and barley staple food in the semi-arid parts of the world. India is the major sorghum growing country in the world, ranks third in the area with 4.66m ha and second in production with 4.63 million tons next to United States of America in 2019-20 (Foreign Agricultural Service/USDA, 2020).
Sorghum has been classified under family Graminae, subfamily Poaceae, tribe Andropogonae, genus Sorghum, Species sorghum bicolor. Yield is a complex character, which depends upon many independent contributing characters. Knowledge of the magnitude and type of association between yield and its attributes helps in evaluating the contribution of different components towards yield. Yield being a polygenic character is highly influenced by the fluctuations in the environment. Hence, the selection of plants based directly on yield would not be very reliable.
Improvement in sorghum yield depends on the nature and extent of genetic variability, heritability and genetic advance in the base population. Besides, the information on the nature of the association between yield and its components helps in simultaneous selection for many characters associated with yield improvements (Mahajan *et al.*, 2011) [6].
The estimates of correlations alone may be often misleading due to the mutual cancellation of component traits. So, it becomes necessary to study path coefficient analysis, which takes into account the casual relationship in addition to the degree of relationship. The path coefficient analysis initially suggested by Wright (1921) [14] and described by Dewey and Lu (1959) [3] allows partitioning of correlation coefficient into direct and indirect contributions (effects) of various traits towards dependent variable and thus helps in assessing the cause and effect relationship as well as effective selection. Hence, this study was aimed to analyze and determine the traits having greater interrelationship with grain yield utilizing the correlation and path analysis.

Materials and Methods
The experimental material consisted of 68 germplasm lines which are part of minicore. The experiment was conducted in Complete Randomized Block Design with two replications. Each genotype was sown in two rows of 3 m at Botany garden, Department of Genetics and Plant

Breeding, University of Agricultural Sciences, Dharwad in *rabi* 2017. All recommended agronomic packages of practices were followed to raise a good crop expression. Observations were recorded on the following characters viz., Days to 50% flowering, peduncle length, Panicle length, panicle breadth, primaries per panicle, whorls per panicle, panicle weight, grain yield per plant, 1000 grain weight, grain width, grain length, grain thickness, 1000 grain volume, grain density, number of grains per panicle, nodes per plant, leaves per plant, stem girth and plant height and subjected to statistical analysis. The correlation coefficients were calculated to determine the degree of association which indicates the extent and direction of the association. The correlation co-efficient provides a reliable measure of association among the characters and helps to differentiate vital associations useful in breeding from those of the non-vital ones (Falconer, 1981) [4]. Data for all these attributes were subjected to window stat software. Path coefficient is a standardized partial regression coefficient and as such, it is a measure of the direct and indirect effect of set variables as a dependent variable such as grain yield. This is done as suggested by Wright (1921) [14] and elaborated by Dewey and Lu (1959) [3]. Knowledge of the relationship among yield components is essential for the formulation of breeding programs aimed at achieving the desired combinations of various components of yield. The estimates of correlation coefficients among the different characters.

Result and Discussion

Correlation

Correlation coefficient is a statistical measure, which measures the degree and magnitude of association between any two casually related variables. This association is may be due to pleiotropic gene action or linkage or more likely both. In plant breeding, correlation coefficient analysis measures the mutual relationship between two characters and it determines character association for improving yield and other economic characters. Since the association pattern among yield components help to select the superior genotypes from divergent population based on more than one interrelated characters. Thus information on the degree and magnitude of association between the characters is of prime importance for the breeder to initiate any selection.

In the present investigation, the phenotypic correlation was studied and furnished in Table 1. Correlation studies revealed that almost all the studied characters except peduncle length, panicle length, plant height, exhibited a positive correlation with grain yield per plant and among them, days to 50 *per cent* flowering (0.514**), panicle width (0.516**), nodes per plant (0.278*), stem girth (0.445**), panicle weight (0.979**), 1000 grain weight (0.768**), seeds per panicle (0.741**), volume (0.714**), grain length (0.353**), grain width (0.639**) and grainthickness (0.643**) exhibited significant association with grain yield. These results indicate that the genotypes with higher panicle girth, panicle weight and grains per panicle along with grainrelated traits produce a higher yield. Hence, these traits are most important for yield *per se*and should be selected for the study. The results are in concordance with Patel *et al.* (1980) and Rizwan Haris (2001) [8, 10] for days to 50 *per cent* flowering, Umakanth *et al.*(2005) [11] for 1000 grain weight, Warkad *et al*. (2010) [13] for days to 50 *per cent* flowering, panicle width, 1000 grain weight and stem girth. However, in contrast to this, Prabhakar *et al*. (2001), Muhammad *et al*. (2000) [9, 7] observed a significant negative correlation between days to 50*per cent* flowering and grain yield.

Path analysis

Path analysis partitions the total correlation coefficient into direct and indirect effects and measures the relative importance of the causal factor individually. In the present experiment, panicle length (0.026), whorls per panicle (0.010), nodes per plant (0.104), plant height (0.021), panicle weight (0.367), 1000 grain weight (0.282), grains per panicle (0.424), volume (0.158), grain density (0.044) and grain thickness (0.033) exhibited positive direct effect on grain yield per plant. These results are in agreement with the findings of Iyanar *et al*. (2001) [5] for panicle length and 1000 grain weight, Warkad *et al*. (2010) [13] and Mahajan *et al.* (2011) [6] for panicle length. Hence, panicle length is directly contributing to grain yield and it indicates that selection can be performed for this trait to increase grain yield. Selection can also be performed for 1000 grain weight in order to increase grain yield. The direct and indirect effect is presented in Table 2. The characters *viz.*, days to 50 *per cent* flowering, panicle width, primaries per panicle, leaves per plant, stem girth, grain length and grain width exhibited a negative direct effect on grain yield. These results are in line with Warkad *et al*. (2010) [13] for stem girth, Vijaya kumar *et al*. (2012) [12] for days to 50% flowering and Arun kumar (2013) [2] for days to 50% flowering and stem girth. Either too early or too late to flowering may decrease the yield levels of sorghum. Hence breeder has to decide the optimum time of flowering which is commensurate with sorghum grain yield. However, panicle width and stem girth may not be important criteria for selection to improve crop yield. The characters, panicle width showed a positive indirect effect on grain yield through peduncle length (0.034), whorls per panicle (0.003), nodes per plant (0.055), plant height (0.002), panicle weight (0.201), 1000 grain weight (0.137), grains per panicle (0.152), volume (0.078) and grain thickness (0.016). The character *viz.*, primaries per panicle exhibited positive indirect effects via peduncle length (0.017), whorls per panicle (0.005), nodes per plant (0.040), plant height (0.004), panicle weight (0.035), 1000 grain weight (0.074), volume (0.040), seed density (0.0004) and seed thickness (0.011). Grain length showed indirect positive effects via peduncle length (0.008), panicle length (0.007), whorls per panicle (0.003), leaves per plant (0.021), panicle weight (0.014), 1000 grain weight, grains per panicle, volume and grain thickness. Grain width exhibitedan indirect positive effect through peduncle length, whorls per panicle, nodes per plant, panicle weight, 1000 grain weight, grains per panicle, volume and grain thickness. Hence these characters may contribute indirectly to grain yield and also be considered in breeding programs.

Table 1: Phenotypic correlation coefficient among 19 characters in 68 genotypes of rabi sorghum

Correlations	D 50% flowering	peduncle length (cm)	Panicle length (cm)	panicle girth (mm)	primaries per panicle	whorls per panicle	leaves per plant	nodes per plant	plant height (cm)	stem girth (mm)	Panicle weight (g)	test weight (g)	Seeds/ panicle	Volume (cc)	Seeds density	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	GRAIN YIELD (g)
Days 50% flowering	1	-.677**	-.333**	.370**	.094	.208	.404**	.408**	-.187	.439**	.504**	.461**	.327**	.445**	-.006	.174	.447**	.509**	.514**
peduncle length (cm)		1	.594**	-.577**	-.295*	-.117	-.456**	-.452**	.252*	-.311**	-.441**	-.369**	-.306*	-.331**	-.030	-.140	-.435**	-.373**	-.436**
Panicle length (cm)			1	-.574**	-.191	-.064	-.357**	-.375**	.002	-.079	-.221	-.135	-.207	-.093	-.114	.265*	-.309*	-.296*	-.204
panicle width (mm)				1	.459**	.336**	.504**	.524**	.088	.393**	.550**	.484**	.358**	.492**	-.071	.222	.536**	.499**	.516**
primaries per panicle					1	.492**	.355**	.383**	.203	.126	.094	.263*	-.094	.252*	.011	.125	.284*	.322**	.094
whorls per panicle						1	-.095	-.053	-.194	.151	.225	.367**	-.005	.379**	-.031	.305*	.354**	.314**	.232
leaves per plant							1	.974**	.508**	.479**	.249*	.209	.189	.192	.014	-.171	.090	.363**	.235
nodes per plant								1	.553**	.496**	.289*	.234	.223	.199	.048	-.149	.131	.378**	.278*
plant height (cm)									1	-.054	-.140	-.040	-.131	-.023	-.045	-.263*	-.084	.126	-.119
stem girth (mm)										1	.476**	.301*	.435**	.192	.227	.036	.256*	.228	.445**
Panicle weight (g)											1	.766**	.721**	.720**	-.003	.382**	.653**	.640**	.979**
1000 grain weight (g)												1	.170	.916**	.039	.489**	.824**	.828**	.768**
Grains/ panicle													1	.152	.033	.019	.149	.137	.741**
Volume (cc)														1	-.351**	.597**	.802**	.796**	.714**
Grain density															1	-.372**	-.053	-.058	.016
Grain length (mm)																1	.455**	.296*	.353**
Grain width (mm)																	1	.663**	.639**
Grain thickness (mm)																		1	.643**
Grain yield (g)																			1

*, ** significant at 5% and 1% level, respectively.

Table 2: Phenotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on grain yield per plant

Path matrix	D 50% flowering	peduncle length (cm)	Panicle length (cm)	panicle girth (mm)	primaries per pani	whorls per panicle	leaves per plant	nodes per plant	plant height (cm)	stem girth (mm)	Panicle weight (g)	test weight (g)	Seeds/ panicle	Volume (cc)	Seeds density	Seed length (mm)	Seed width (mm)	Seed thickness (mm
Days 50% flowering	-0.007	0.005	0.002	-0.003	-0.001	-0.001	-0.003	-0.003	0.001	-0.003	-0.004	-0.003	-0.002	-0.003	0.000	-0.001	-0.003	-0.004
Peduncle length (c	0.040	-0.059	-0.035	0.034	0.017	0.007	0.027	0.027	-0.015	0.018	0.026	0.022	0.018	0.020	0.002	0.008	0.026	0.022
Panicle length (cm	-0.009	0.015	0.026	-0.015	-0.005	-0.002	-0.009	-0.010	0.000	-0.002	-0.006	-0.004	-0.005	-0.002	-0.003	0.007	-0.008	-0.008
panicle width (mm)	-0.020	0.031	0.030	-0.053	-0.024	-0.018	-0.027	-0.028	-0.005	-0.021	-0.029	-0.026	-0.019	-0.026	0.004	-0.012	-0.028	-0.027
primaries per pani	-0.001	0.002	0.002	-0.004	-0.008	-0.004	-0.003	-0.003	-0.002	-0.001	-0.001	-0.002	0.001	-0.002	0.000	-0.001	-0.002	-0.003
Whorls per panicle	0.002	-0.001	-0.001	0.003	0.005	0.010	-0.001	-0.001	-0.002	0.001	0.002	0.004	0.000	0.004	0.000	0.003	0.003	0.003
Leaves per plant	-0.050	0.057	0.044	-0.063	-0.044	0.012	-0.124	-0.121	-0.063	-0.059	-0.031	-0.026	-0.024	-0.024	-0.002	0.021	-0.011	-0.045
Nodes per plant	0.042	-0.047	-0.039	0.055	0.040	-0.006	0.101	0.104	0.057	0.052	0.030	0.024	0.023	0.021	0.005	-0.016	0.014	0.039
plant height (cm)	-0.004	0.005	0.000	0.002	0.004	-0.004	0.011	0.012	0.021	-0.001	-0.003	-0.001	-0.003	-0.001	-0.001	-0.006	-0.002	0.003
Stem girth (mm)	-0.011	0.008	0.002	-0.010	-0.003	-0.004	-0.012	-0.012	0.001	-0.025	-0.012	-0.008	-0.011	-0.005	-0.006	-0.001	-0.006	-0.006
Panicle weight (g)	0.185	-0.161	-0.081	0.201	0.035	0.082	0.091	0.106	-0.051	0.174	0.366	0.281	0.264	0.264	-0.002	0.140	0.239	0.234
1000 grain weight (g)	0.130	-0.104	-0.038	0.137	0.074	0.104	0.059	0.066	-0.011	0.085	0.216	0.282	0.048	0.259	0.011	0.138	0.233	0.234
Grains/ panicle	0.139	-0.130	-0.088	0.152	-0.040	-0.002	0.080	0.094	-0.056	0.184	0.306	0.072	0.424	0.065	0.013	0.008	0.063	0.058
Volume (cc)	0.070	-0.052	-0.015	0.078	0.040	0.060	0.030	0.032	-0.004	0.030	0.114	0.145	0.024	0.158	-0.056	0.095	0.127	0.126
Grain density	0.000	-0.001	-0.005	-0.003	0.000	-0.001	0.001	0.002	-0.002	0.010	0.000	0.002	0.001	-0.015	0.044	-0.016	-0.002	-0.003
Grain length (mm)	-0.003	0.002	-0.005	-0.004	-0.002	-0.005	0.003	0.003	0.004	-0.001	-0.007	-0.008	0.000	-0.010	0.006	-0.017	-0.008	-0.005
Grain width (mm)	-0.007	0.007	0.005	-0.009	-0.005	-0.006	-0.001	-0.002	0.001	-0.004	-0.010	-0.013	-0.002	-0.013	0.001	-0.007	-0.016	-0.011
Grain thickness (mm	0.017	-0.012	-0.010	0.016	0.011	0.010	0.012	0.012	0.004	0.008	0.021	0.027	0.004	0.026	-0.002	0.010	0.022	0.033

Conclusion

From the results of this study, it could be concluded that there were most of the traits evaluated were positively associated among themselves and could be improved simultaneously. It further concluded that characters such as whorls per panicle (0.010), nodes per plant (0.104), panicle weight (0.367), 1000 grain weight (0.282), seeds per panicle (0.424), volume (0.158), grain density (0.044) and grain thickness (0.033) showed higher correlation and positive direct effect on grain yield per plant. Therefore, due consideration should be given to these characters, while planning a breeding strategy for increased yield per plant.

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