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Estimates of Variability, Correlation and Direct-Indirect effects among Yield and its Allied Attributes in Sorghum (*Sorghum bicolor* (L.) Moench)

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ABSTRACT

The present study was aimed to estimate the association and path analysis among 11 morphological and three physiological characters during *kharif* 2022 at Crop Research Centre, Department of Genetics and Plant Breeding, ITM University, Gwalior M.P. India. The study was carried out in Randomized Block Design in 3 replications for 30 sorghum varieties. Analysis revealed maximum positively significant association at phenotypic level between Grain yield per plant and dry fodder yield/plant (0.529) followed by green fodder yield/plant (0.518) respectively. At Genotypic level maximum positive and significant association was observed between Grain yield per plant and dry fodder yield per plant (0.538) followed by green fodder yield per plant (0.520). On the other hand, path analysis showed that at phenotypic level dry fodder yield per plant recorded the maximum direct effect (0.559) followed by panicle length (0.377), green fodder yield/plant (0.306) on grain yield/plant while the negative direct effect was maximum for days to 50% flowering (-0.343) followed by test weight (-0.183) and leaf temperature (-0.103). Similarly at genotypic level days to maturity recorded the maximum direct effect (1.975) followed by dry fodder yield per plant (0.721), number of leaves per plant (0.490), panicle length (0.244), stomatal count/microscopic field (0.139) while days to 50% flowering (-2.572) followed by transpiration rate (-0.171), test weight (-0.164), recorded the negative direct effect.

Key words : *Correlation, Path Analysis, Sorghum, Transpiration rate upper surface (ìgcm^{-1}s^{-1})*

Introduction

Sorghum [*Sorghum Bicolor* (L.) *Moench*; 2n = 2x = 20] is one of the important crops used for human consumption. It also has potential to sequestrate carbon, thereby contributing to reduction of greenhouse gases (Khandelwal *et al.*, 2015). As Erdurmus *et al.* (2021) stated that because of wide adaptation capacities of sorghum there are potentiality develop stable and high-yielding genotypes for different environments. We can evaluate the value of sorghum as a tool to ensure food security in arid and semi-arid regions of the world. Presently when 42% of India's land area is under drought crops like sorghum are natures gift to mankind, which should be enhanced by breeding. Presently India ranks sixth for sorghum production in world with a total production of 4423 thousand tons on 4584 thousand ha of area with a productivity of 1.0 tons/ha (Anonymous, 2022-2023). primary objective of the above study is to assess the variability in sorghum however the existence of variation alone in the population is not sufficient for improving desirable characters, hence, estimation of the extent and pattern of genetic variability existing in the available germplasm is essential to breeders (Amare *et al.*, 2015), therefore it is significant to understand the relationship among various characters under the study and their effects on the yield of the crop. The estimates of correlations alone may be often misleading due to mutual cancellation of component traits. So, it becomes necessary to study path coefficient analysis, which considers the casual relationship in addition to degree of relationship (Mahajan *et al*., 2011 cited by Dhutmal *et al*., 2015). Considering the above facts, the objective of the following research is to estimate the coefficient of variation, heritability coupled with genetic advance, correlation coefficient and path coefficient.

Materials and Methods

The present experiment was conducted in *kharif* season 2022-23 at Crop Research Centre, ITM University, Gwalior, Sithouli campus with 800 – 1000 mm of annual rainfall and red, light shallow soil, the experimental site is located at 26º 08' 22.6" N latitude and 78º 11' 42.9" E longitude at a height of 211.5m above sea level. It has a semi humid and subtropical climate. Sowing was done by dribbling method at a spacing of 45cm X 15cm in an area of 300m^2, the study was conducted in the randomized block design with three replications all the characters were recorded for five plants in each replication and their average was worked out Under the study 30 sorghum genotypes were studied for characters namely Days to 50% flowering, Days to maturity, Leaf area (cm^2), Plant height at maturity (cm), Stomatal count/microscopic field, Transpiration rate upper surface (µgcm^{-1}s^{-1}), Leaf temperature (ºC), Number of leaves/plant, Flag leaf length (cm), Length of panicle at maturity (cm), Test weight(g), Green fodder yield/plant (g), Dry fodder yield/plant(g) and Grain yield/plant(g) and subjected to the statistical analysis. analysis of variance and covariance as described by Panse and sukhatme (1954). phenotypic and GCV in percent were computed by the formulae given by Burton (1952). Heritability in broad sense was estimated by the formula given by Singh and Chaudhary (1977). Genetic advance was expressed as percentage of mean by using the formula suggested by Johnson *et al*. (1955). correlation coefficient between characters was computed as suggested by Miller *et al*. (1958). Proportion of direct and indirect contribution of various characters to the total correlation coefficient was established through path coefficient analysis as suggested by Wright (1921) and well defined by Dewey and Lu (1959). All the statistical analysis were estimated using opensource software R Studio version 4.2.2. package named 'Variability' was used for conducting various statistical analysis.

Results and Discussion

Variability

Analysis of variance for all the characterswere revealed to be significant at 0.1% for all 30 genotypes. Referring to the Table 1, it can be stated thatall characters except transpiration rate and plant height at maturityshowedhigher magnitudes of PCV as compared to the GCV indicating the influence of environment on these characters, however the range of PCV varied from 7.75% for leaf temperature to 79.94% for transpiration rate and similarly GCV ranged from 7.63% for leaf temperature to 79.95% for transpiration rate. showing the wide range of variability was observed for most of the characters, followed by the highest PCV for transpiration rate comes the green fodder yield per plant (41.91%), dry fodder yield per plant (41.12%), leaf area (32.87%), grain yield per plant (24.11%), flag leaf length (22.83%), test weight (22.33%) and panicle length (20.01%) with high estimates of PCV, days to 50% flowering (19.88%), number of leaves per plant (16.93%), days to maturity (14.72%), stomatal count per field (13.55%) and plant height at maturity (13.50%) with moderate estimates of PCV and leaf temperature (7.75%) with low estimates of PCV. Similarly for genotypic coefficient of correlation followed by transpiration comes the green fodder yield per plant (41.87%), dry fodder yield per plant (40.57%), leaf area (31.47%), grain yield per plant (24.07%) and test weight (21.19%) with high estimated of GCV, days to 50% flowering (19.83%), panicle length at maturity (16.59%), flag leaf length (16.11%), number of leaves per plant (15.77%), days to maturity (14.39%), plant height at maturity (12.70%) and stomatal count per field (12.10%) with moderate estimates of GCV and leaf temperature (7.63%) with low estimates. The present investigation concluded that the effect of environment to play major role in phenotype of the crop for the given characters.

Heritability and genetic advance

Estimates of the heritability for the present investi-

Table 1. Phenotypic and genotypic coefficients of variation, heritability (broad Sense) and genetic advance expressed as percentage of mean for 14 characters in 30 genotypes of sorghum.

	GCV	PCV	Heritability% (broad sense)	genetic advance as percentage of mean
DTF	19.83	19.88	99.49	40.76
DTM	14.39	14.72	95.53	28.98
LA	31.47	32.87	91.65	62.07
PH	12.7	13.5	88.47	24.61
SCF	12.1	13.55	91.6	25.62
TR	79.95	79.94	99.99	164.69
LT	7.63	7.75	97.08	15.5
NLP	15.77	16.93	86.64	30.27
FLL	16.11	22.83	49.81	23.43
PL	16.59	20.01	92.57	38.17
TW	21.19	22.33	90.69	41.45
GFYP	41.87	41.91	99.84	86.19
DFYP	40.57	41.12	97.31	82.45
GYP	24.07	24.11	99.63	49.49

DTF- Days to 50% flowering; DTM- Days to maturity; LA- Leaf area
PH-Plant height at maturity; SCF- Stomatal count/microscopic field; TR- Transpiration rate of upper surface
LT- Leaf temperature; NLP-Number of leaves per plant; FLL- Flag leaf length
PL- Panicle length at maturity; TW- Test weight; GFYP-Green fodder yield per plant
DFYP- Dry fodder yield per plant; GYP- Grain yield per plant

gation were found significantly higher for all the characters except flag leaf length with moderate heritability of 49.81%. Out of all the highly heritable characters, transpiration rate (99.99%) revealed the highest magnitude of heritability, followed by green fodder yield per plant (99.84%), grain yield per plant (99.63%), days to 50% flowering (99.49%), dry fodder yield per plant (97.31%), leaf temperature (97.08%), days to maturity (95.53%), panicle length (92.57%), leaf area (91.65%), stomatal count per field (91.60%), test weight (90.69%), plant height at maturity (88.47%), number of leaves per plant (86.64%) and flag leaf length (49.81%). The highest magnitude of genetic advance as percentage of mean was estimated for transpiration rate (164.69%), followed by green fodder yield per plant (86.19%), dry fodder yield per plant (82.45%), leaf area (62.07%), grain yield per plant (49.49%), test weight (41.45%), days to 50% flowering (40.76%), length of panicle at maturity (38.17%), number of leaves per plant (30.27%), days to maturity (28.98%), flag leaf length (23.43%), stomatal count per microscopic field (25.62), plant height at maturity (24.61%).and leaf temperature (15.50%) being the lowest.

Correlation analysis

Correlation coefficient is a statistical measure, which measures the degree and magnitude of association between any two casually related variables (Verma and Biradar, 2021). Phenotypic and genotypic estimates of correlation coefficients for the study are arranged in Table 2. Estimation of phenotypic coefficient of correlation revealed that the Grain yield per plant was significantly and positively associated with plant height at maturity (r = 0.250*), stomatal count per microscopic field (r = 0.300**), leaf temperature (r = 0.276**), number of leaves per plant (r = 0.417**), panicle length (r = 0.401**), green fodder yield per plant (r = 0.518**) and dry fodder yield per plant (r = 529**). Whereas,genotypic coefficient of correlation exhibited significantly positive association of leaf area (r = 0.367*), number of leaves per plant (r = 0.448*), panicle length (r = 0.419*), green fodder yield per plant (r = 0.520**) and dry fodder yield per plant (r = 0.538**) with grain yield per plant.

Path coefficient analysis

A path coefficient analysis was carried out to partition the contributions of each growth character to determine its direct and indirect contributions via other measured characters to the grain yield which otherwise referred to as the total contribution of a growth character to grain yield (Goma *et al.* 2022).

Table 2. Genotypic and phenotypic correlations for 14 characters in 30 genotypes of sorghum

		DTM	LA	PH	SCF	TR	LT	NLP	FLL	PL	TW	GFYP	DFYP	GYP
DTF	P	0.973**	0.267*	0.633**	-0.258*	-0.523**	0.393**	0.757**	-0.015	-0.404**	0.231*	0.752**	0.757**	0.147
	G	0.997**	0.275	0.679**	-0.273	-0.524**	0.401*	0.821**	-0.018	-0.419*	0.245	0.754**	0.770**	0.148
DTM	P		0.245*	0.630**	-0.261*	-0.492*	0.353**	0.739**	-0.022	-0.345**	0.203	0.740**	0.741**	0.167
	G		0.258	0.682**	-0.288	-0.504**	0.374*	0.810**	-0.012	-0.368*	0.213	0.757**	0.772**	0.170
LA	P			0.017	0.050	-0.106	0.180	0.362**	0.027	0.006	0.005	0.356**	0.450**	0.349
	G			0.077	0.062	-0.111	0.196	0.411*	0.016	-0.03	0.007	0.371*	0.477**	0.367*
PH	P				-0.120	-0.391**	0.435**	0.623**	-0.017	-0.131	-0.031	0.622**	0.556*	0.250*
	G				-0.117	-0.416*	0.478**	0.717**	-0.030	-0.143	-0.034	0.662**	0.595**	0.265
SCF	P					0.635**	0.155	-0.059	-0.082	0.237*	-0.086	0.138	0.099	0.300**
	G					0.663**	0.165	-0.031	-0.116	0.276	-0.074	0.146	0.115	0.311
TR	P						-0.315**	-0.366**	-0.179	0.358**	-0.080	-0.284**	-0.265*	0.086
	G						-0.320	-0.393*	-0.253	0.373*	-0.084	-0.285	-0.269	0.086
LT	P							0.484**	0.079	-0.218*	-0.173	0.599**	0.550**	0.276**
	G							0.519**	0.114	-0.240	-0.196	0.609**	0.564**	0.278
NLP	P								-0.004	-0.096	0.299**	0.786**	0.787**	0.417**
	G								-0.014	-0.111	0.287	0.842**	0.844**	0.448*
FLL	P									0.034	-0.320**	-0.084	-0.065	-0.027
	G									0.023	-0.489**	-0.121	-0.076	-0.050
PL	P										-0.135	-0.168	-0.203	0.401**
	G										-0.174	-0.174	-0.215	0.419*
TW	P											0.208*	0.188	-0.073
	G											0.219	0.198	-0.077
GFYP	P												0.944**	0.518**
	G												0.958**	0.520**
DFYP	P													0.529**
	G													0.538**

*(significant at p=0.05), **(significant at p=0.01), ***(significant at p=0.001)

The phenotypic and genotypic estimates of path analysis for the study are arranged in Table 3 which showed that dry fodder yield per plant recorded the maximum direct effect (0.559) followed by panicle length (0.377), green fodder yield per plant (0.306), number of leaves per plant (0.178), leaf area (0.048) and stomatal count per microscopic field (0.036). While plant height (-0.026), flag leaf length (-0.042), transpiration rate (-0.049), days to maturity (-0.079), leaf temperature (-0.103), test weight (-0.183) and days to flowering (-0.343) recorded the negative direct effect for phenotypic levels. On the other hand, days to maturity recorded the maximum direct effect (1.975) followed by dry fodder yield per plant (0.721), number of leaves per plant (0.490), panicle length (0.244), stomatal count per microscopic field (0.139) and leaf area (0.049). while leaf temperature (-0.053), plant height (-0.069), green fodder yield per plant (-0.083), flag leaf length (-0.116), test weight (-0.164), transpiration rate (-0.171) and days to flowering (-2.572) recorded the negative direct effect for genotypic level.

At phenotypic level,days to 50 percent flowering observed maximum positive indirect effectvia dry fodder yield per plant (0.423); days to maturity observed the maximum positive indirect effect via dry fodder yield per plant (0.414) and the maximum negative indirect effect was observed via days to 50% flowering (-0.333); Leaf area observed the maximum positive indirect effect via dry fodder yield per plant (0.251); Plant height observed the maximum positive indirect effect via dry fodder yield per plant (0.311) and maximum negative indirect effect was observed via days to 50% flowering (-0.217); Transpiration rate observed the maximum positive indirect effect via days to 50% flowering (0.179) and maximum negative indirect effect was observed via dry fodder yield per plant (-0.148); Leaf temperature recorded the maximum positive indirect effect via dry fodder yield per plant (0.308) and the maximum negative indirect effect was observed via days to 50% flowering (-0.134); Number of leaves per plant showed the maximum positive indirect effect via dry fodder yield per plant (0.440) and the maximum negative indirect effect was observed via days to 50% flowering (-0.259); Panicle length registered the highest positive indirect effect via days to 50% flowering (0.138); Test weight registered the highest positive indirect effect via dry fodder yield per plant (0.105); Green fodder yield per plant showed the maximum positive indirect effect was observed via dry fodder yield per plant (0.528) while maximum negative indirect effect was observed via days to 50% flowering (-0.257); Dry fodder yield per plant registered the highest positive indirect effect via green fodder yield per plant (0.289) While, highest negative indirect effect was observed via days to 50% flowering (-0.259).

At genotypic level,days to 50 % flowering observed maximum positive indirect effect via days to maturity (1.969); Days to maturity observed the maximum positive indirect effectvia dry fodder yield per plant (0.557); leaf area observed the maximum positive indirect effectvia days to maturity (0.510); plant height observed the maximum positive indirect effect via days to maturity (1.349); stomatal count per microscopic field observed the maximum positive indirect effect via days to maturity (0.702). Transpiration rate was observed to bear the maximum positive indirect effect was via days to 50% flowering (1.349); leaf temperature recorded the maximum positive indirect effect was via days to maturity (0.740); number of leaves per plant showed the maximum positive indirect effect via days to flowering (1.601); panicle length registered the highest positive indirect effect via days to flowering (1.078); test weightregistered the highest positive indirect effect via days to maturity (0.421); green fodder yield per plantshowed the maximum positive indirect effect via days to maturity (1.497); dry fodder yield per plant registered the highest positive indirect effect via days to maturity (1.527). Residual effect refers to the effect of other possible independent variables not included in the study on dependent variables (Kavya *et al.,* 2020). Residual effect was found to be 0.3797 for phenotypic path coefficient while for genotypic path coefficient it was 0.346.If the residual effect is high, some other factors which have not been considered here need to be included in this analysis to account fully for the variation in yield (Kavya *et al.,* 2020). Results obtained in the study were in accordance with the findings of Ezeaku and Mohammed (2006) for test weight, Dhutmal *et al.* (2015) for Total biomass, Khandelwal *et al.* (2015) for test weight, panicle length and leaf area, Amare *et al.* (2015) for plant height, Vendruscolo *et al.* (2016) for green fodder yield and dry fodder yield, Hundekar *et al.* (2016) for test weight, panicle length, days to 50%flowering, days to maturity and plant height, Goswami *et al.* (2020). For the leaf area, panicle width, day to maturity and 1000-grain weight, Verma and Biradar (2021) for panicle length, plant height and test weight.

Conclusion

The character flag leaf length showed moderate level of heritability coupled with high genetic advance, leaf temperature showed high heritability and low genetic advance andrest of all the characters displayed high heritability coupled with high genetic advance However, for transpiration rate genetic advance was maximum (164.69%) which is exceptionally high. the possible reason could be the presence of high variability for the character also the character discussed possess higher influence of environment which could be the other reason for higher magnitude of genetic advance. Estimation of phenotypic coefficient of correlation for grain yield per plant was significantly and positively associated with plant height at maturity, stomatal count per microscopic field, leaf temperature, number of leaves per plant, panicle length, green fodder yield per plant and dry fodder yield per plant. Genotypic coefficient of correlation for the grain yield per plant was significantly and positively associated with leaf area, number of leaves per plant, panicle length, green fodder yield per plant and dry fodder yield per plant. Based on the path coefficient analysis

Table 3. Direct and indirect effects on grain yield at phenotypic and genotypic level in sorghum genotypes

		DTF	DTM	LA	PH	SCF	TR	LT	NLP	FLL	PL	TW	GFYP	DFYP	Correlation with GYP
DTF	P	-0.342	-0.076	0.012	-0.016	-0.009	0.025	-0.040	0.135	0.001	-0.152	-0.042	0.230	0.423	0.147
	G	-2.572	1.969	0.013	-0.046	-0.038	0.089	-0.021	0.402	0.002	-0.102	-0.040	-0.062	0.555	0.148
DTM	P	-0.333	-0.078	0.011	-0.016	-0.009	0.024	-0.036	0.131	0.001	-0.130	-0.037	0.226	0.414	0.167
	G	-2.565	1.975	0.012	-0.047	-0.040	0.086	-0.019	0.396	0.002	-0.089	-0.034	-0.063	0.557	0.170
LA	P	-0.091	-0.019	0.048	-0.001	0.001	0.005	-0.018	0.064	-0.001	0.002	-0.001	0.109	0.251	0.349
	G	-0.707	0.509	0.048	-0.005	0.008	0.019	-0.010	0.201	-0.001	-0.007	-0.001	-0.030	0.344	0.367*
PH	P	-0.217	-0.049	0.003	-0.026	-0.004	0.019	-0.044	0.111	0.001	-0.049	0.005	0.190	0.311	0.250*
	G	-1.746	1.348	0.003	-0.068	-0.016	0.071	-0.025	0.351	0.003	-0.035	0.005	-0.055	0.429	0.265
SCF	P	0.088	0.020	0.002	0.003	0.036	-0.031	-0.016	-0.010	0.003	0.089	0.015	0.042	0.055	0.300**
	G	0.702	-0.568	0.003	0.008	0.139	-0.113	-0.008	-0.015	0.013	0.067	0.012	-0.012	0.083	0.311
TR	P	0.179	0.038	-0.005	0.010	0.023	-0.048	0.032	-0.065	0.007	0.135	0.014	-0.087	-0.148	0.086
	G	1.349	-0.996	-0.005	0.028	0.092	-0.170	0.017	-0.192	0.029	0.091	0.013	0.023	-0.193	0.086
LT	P	-0.134	-0.027	0.008	-0.011	0.005	0.015	-0.103	0.086	-0.003	-0.082	0.031	0.183	0.308	0.276**
	G	-1.032	0.739	0.009	-0.033	0.023	0.054	-0.053	0.254	-0.013	-0.058	0.032	-0.050	0.406	0.278
NLP	P	-0.259	-0.058	0.017	-0.016	-0.002	0.017	-0.050	0.178	0.001	-0.036	-0.054	0.240	0.440	0.417**
	G	-2.113	1.600	0.020	-0.049	-0.004	0.067	-0.027	0.489	0.001	-0.027	-0.047	-0.070	0.609	0.448*
FLL	P	0.005	0.001	0.001	0.001	-0.002	0.008	-0.008	-0.001	-0.042	0.012	0.058	-0.025	-0.036	-0.027
	G	0.048	-0.042	0.001	0.002	-0.016	0.043	-0.006	-0.007	-0.116	0.007	0.080	0.010	-0.054	-0.050
PL	P	0.138	0.027	0.001	0.003	0.008	-0.017	0.022	-0.017	-0.001	0.377	0.024	-0.051	-0.113	0.401**
	G	1.078	-0.727	-0.001	0.009	0.038	-0.063	0.012	-0.054	-0.003	0.244	0.028	0.014	-0.155	0.419*
TW	P	-0.079	-0.016	0.001	0.001	-0.003	0.003	0.017	0.053	0.013	-0.051	-0.183	0.063	0.105	-0.073
	G	-0.631	0.420	0.001	0.002	-0.010	0.014	0.010	0.140	0.056	-0.042	-0.163	-0.018	0.143	-0.077
GFYP	P	-0.257	-0.058	0.017	-0.016	0.005	0.013	-0.061	0.140	0.003	-0.063	-0.038	0.306	0.528	0.518**
	G	-1.940	1.496	0.018	-0.045	0.020	0.048	-0.032	0.412	0.014	-0.042	-0.035	-0.083	0.690	0.520**
DFYP	P	-0.259	-0.058	0.021	-0.014	0.003	0.012	-0.056	0.140	0.002	-0.076	-0.034	0.289	0.559	0.529**
	G	-1.980	1.526	0.023	-0.041	0.016	0.045	-0.029	0.413	0.008	-0.052	-0.032	-0.079	0.720	0.538**

*(Significant at p=0.05), **(significant at p=0.01), ***(significant at p=0.001)

days to 50% flowering, days to maturity, green fodder yield per plant, dry fodder yield per plant, panicle length, flag leaf length was major components contributing towards grain yield per plant hence selection for these characters should be prioritized.

Depending upon the above mentioned result the conclusion drawnis that the variability present forthree physiological characters is due to high influence of environment, while collection of data somewhat viz. watercrowfoot (*Ranunculus aquatilis);* has quite different leaves when growing in running water than when growing on land. Other ten morphological characters were comparatively less variable than physiological characters but could be efficiently exploited for making dual purpose sorghum varieties.

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Conflict of Interest

Authors declare no conflict of interest

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