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Short Communication

Trait association and magnitude of direct and indirect effects on yield in sorghum (*Sorghum bicolor* L. Moench) genotypes

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Sorghum is popularly known as "Jowhar" in India. It is also known as a "Camel Crop" because it is high-energy and drought tolerant nature. Sorghum is truly a versatile crop, which can be grown as grain, forage and as well as a multipurpose sweet crop. To meet this climate change challenges and to resist the adverse effects of environment faced by humans today, crop such as sorghum is of great interest and performs relatively well under water scarcity , increased temperatures and healthiest and nutritious as compared with the major cereal crops rice, wheat, and maize. It is not just used for forage, food, bioenergy and broom, but also for bioremediation of contaminated cropland and also has great potential in the phytoremediation of contaminated soil (Liu *et al.,* 2020). Being a C4 plant and an excellent daily growth rate and biomass (>18-22 g m-2), sorghum is one among the most efficient crops in conversion of solar energy and heat, use of water and drought resisting crop that is environmentally friendly. Sorghum is world's fifth most important food grain crop grown widely in tropical and sub tropical regions of the world and relatively less researched crop than other cereals after wheat, rice, maize and barley (Ramya *et al.,*2010). Sorghum grain is an important raw material for alcohol beverages in many countries. In India, sorghum ranks third in area and production after rice and wheat (Ritter et al., 2007) and is a staple food and provides carbohydrates to the people in North Karnataka, Maharashtra, A.P., Gujarat, Madhya Pradesh and Rajasthan. Yield is a polygenic trait, knowledge of the magnitude and type of association between yield and its component traits, greatly helps in assessing the contribution of remaining characters towards yield which is highly influenced by the fluctuations in environment. The study of interactions among traits is essential for assessing the possibility of joint selection for two or more characters. Path coefficient analysis segregates correlation coefficient into direct and indirect contributions of various traits towards dependent variable, thus guiding the cause-effect relationship as well as effective selection. Hence, keeping above the point in consideration the present investigation aimed to accesses the association among different traits and magnitude of direct and indirect effects on yield in sorghum genotypes.

The field experiment under study was "Assessment of association among different traits and magnitude of direct and indirect effects on yield in Sorghum (*Sorghum bicolor* (L.) Moench) genotype, conducted at Bagusala farm, M. S. Swaminathan School of Agriculture, Centurion

University of Technology and Management (CUTM), Paralakhemundi, Gajapati district, Odisha during *rabi* 2020-21. It is located in typical sub-humid and sub-tropical climatic conditions of average annual rainfall is 1350 mm, with mean temperatures of 44°C to 18°C and an average annual relative humidity of 74%. The experimental materials comprising sixty four sorghum germplasms collected from ICAR- Indian Institute of Millets Research (IIMR), Rajendranagar, Hyderabad, Telangana. The germplasms were evaluated in a field experiment under Randomized Block Design (RBD) with three replications and spacing 45cm×15cm. Recommend fertilizer dose (N:P:K) 80:60:40 kg/ha and all the cultural practices were followed to raise healthy crop. The data were recorded from five randomly selected plants for each genotype in each replication on following twenty quantitative characters *viz.,* days to 50 % flowering, days to maturity, plant height (cm), leaf length(cm), leaf breadth (cm), number of leaves /plant, nodes per plant, stem width(cm), panicle length (cm), panicle width (cm), number of primary branches/panicle, dry panicle weight, fodder yield per plant (g), 100-grain weight (g), grain yield per plant (g), dry matter production (t ha-1), total soluble sugars, protein content, starch content, and chlorophyll content. The replication wise mean value of the genotypes was subjected to statistical analysis using INDOSTAT-9.2 software.

Results and Discussion

Trait association

The results on phenotypic and genotypic correlation coefficients analysis were represented in tables 1 and 2, respectively. The estimates of correlation coefficient at both genotypic and phenotypic level highlighted that the trait grain yield per plant had significant to highly significant positive association with the traits dry panicle weight (rp=0.698** & rg=0.700**), leaf width (rp=0.609** & rg=0.657**), Dry matter production (rp=0.522** & rg=0.540**), fodder yield (rp=0.518** & rg=0.535**), leaf length (rp=0.430** & rg=0.483**), stem width (rp=0.401** & rg=0.436**), number of leaves (rp=0.336** & rg=0.367**), number of nodes (rp=0.332** & rg=0.362**), panicle width (rp=0.254** & rg=0.284**), number of primary branches (rp=0.202** & rg=0.241**), and plant heoght (rp=152* & rg=165*). The highly significant and positive association of yield with dry panicle weight specifies the strong association of this trait with grain yield per plant and this could be successfully exploited for enhancing the yielding potential of sorghum. Similar findings were observed for grain yield per plant and dry panicle weight, panicle width, leaf length, stem width by Akatwijuka *et al.*, 2019; Aminon *et al.*, 2015. For the traits green fodder yield per plant was found to be significantly and positively correlated with plant height, leaf length, leaf breadth, stem diameter which are in close conformity with the finding of Prakash et al., (2010). Subalakhshmi *et al.*, 2019 reported that the trait days to 50% flowering had positive significance correlation with days to maturity and leaf width. For the traits green fodder yield was found to be significant positive correlation with the parameters like number of leaves per plant, leaf length, plant height and dry matter production, which were in close conformity wih the finding of Deep *et. al.,* 2020; Kisua *et. al.,* 2015; and Jain and Patel, 2013, also reported positive correlation between number of leaves and plant height in sorghum.

Path coefficient analysis

The direct and indirect effects at both phenotypic and genotypic level are presented in the table 3 and 4, respectively. Partitioning of yield and its component traits into direct and indirect effects revealed that the characters dry panicle weight (0.697) had maximum positive direct effect on grain yield per plant at phenotypic level followed by the fodder yield (0.053) and 100-seed weight (0.028). These results are in close conformity with the finding of Ezeaku *et. al.,* 2006 for dry panicle weight and Subalakhshmi *et al.,*2019 of 100-seed weight. Hence these traits can be considered as selection indices for sorghum improvement programme. The residual effect at both genotypic and phenotypic level are found minimum i.e. 0.0601 and 0.0224, respectively. Low residual effect values disclose that the independent traits explain 90% of the variability in grain yield per plant. Therefore almost all the important yield contributing to traits are included in the present study. The similar results were obtained by Reddy *et. al.,*1988 in rice.

Conclusion

Trait association and path coefficient analysis disclose the influence of independent character on dependant character like yield. Results of correlation analysis pointed out highly significant and positive association at both phenotypic and genotypic levels by dry panicle weight

Table 1: Phenotypic Correlation coefficient of twenty different traits in grain, fodder and sweet Sorghum

Characters	DTF	NOL	NON	LL	LW	SW	CC	PL	PW	DPW	NPB	DTM	PTH	HSW	FY	DMP	P	TSS	S	GYP
DTF	1	0.011	0.017	0.120	0.198**	0.140*	0.090	0.165*	0.005	0.064	0.123	0.727**	-0.038	-0.072	0.077	0.103	0.137	-0.011	0.045	0.061
NOL		1	0.988**	0.298**	0.127	0.109	-0.224**	-0.004	0.144*	0.343**	0.155*	0.039	0.417**	-0.297**	0.616**	0.571**	-0.232**	-0.070	0.177*	0.336**
NON			1	0.296**	0.125	0.103	-0.224**	-0.018	0.129	0.339**	0.146*	0.037	0.425**	-0.303**	0.621**	0.572**	-0.242**	-0.068	0.186**	0.332**
LL				1	0.644**	0.410**	-0.086	0.081	0.129	0.437**	0.222**	0.143*	0.176*	-0.020	0.484**	0.506**	0.086	-0.128	-0.146*	0.433**
LW					1	0.583**	0.130	-0.050	0.179*	0.611**	0.177*	0.212**	-0.126	0.177*	0.470**	0.515**	0.150*	0.031	-0.109	0.609**
SW						1	0.053	0.105	0.171*	0.399**	0.148*	0.188**	-0.168*	-0.068	0.506**	0.529**	0.234**	-0.039	0.031	0.401**
CC							1	0.109	-0.027	-0.033	0.224**	0.126	-0.121	-0.137	-0.013	-0.027	-0.158*	-0.086	0.046	-0.033
PL								1	0.383**	0.052	-0.088	0.115	0.348**	-0.444**	0.097	0.100	-0.096	-0.228**	0.117	0.058
PW									1	0.257**	0.006	-0.028	0.164*	-0.011	0.167*	0.175*	-0.035	0.039	0.080	0.254
DPW										1	0.207**	0.107	0.154*	-0.046	0.513**	0.518**	-0.045	-0.154*	-0.112	0.698**
NPB											1	0.178*	0.002	-0.139	0.298**	0.302**	0.164*	-0.038	0.090	0.202**
DTM												1	-0.123	-0.106	0.107	0.135	0.120	-0.104	-0.035	0.106
PTH													1	-0.259**	0.202**	0.158*	-0.173*	-0.133	0.076	0.152*
HSW														1	-0.189**	-0.165*	0.301**	0.484**	-0.263**	-0.043
FY															1	0.979**	0.029	-0.067	0.091	0.518**
DMP																1	0.028	-0.059	0.077	0.522**
P																	1	0.098	-0.110	-0.042
TSS																		1	0.678**	-0.153*
S																			1	-0.112

*&**: significant level at 5% and 15%, respectively. DTF: Days to 50% flowering, NOL: Number of leaves, NON: No. of nodes, LL: leaf length(cm), LW: leaf width(cm), SW: stem width(mm), CC: chlorophyll content, PL: panicle length(cm), PW: panicle width(cm), DPW: Dry panicle weight(g), NPB: no. of primary branches per panicle, DTM: days o maturity, PTH: plant height(cm), HSW: hundred seed weight(g), FY: fodder yield per plant (g), DMP: Dry matter production(t/ha), P: protein(mg/g), TSS: total soluble sugars(%), S: starch(%).

Table 2: Genotypic Correlation coefficient of twenty different traits in grain, fodder and sweet Sorghum

Character	DTF	NOL	NON	LL	LW	SW	CC	PL	PW	DPW	NPB	DTM	PTH	HSW	FY	DMP	P	TSS	S	GYP
DTF	1	-0.019	-0.008	0.224**	0.250**	0.189**	0.134	0.249**	-0.004	0.111	0.197**	0.833**	-0.006	-0.064	0.089	0.127	0.181*	-0.006	0.067	0.108
NOL		1	0.998**	0.312**	0.119	0.112	-0.239**	-0.024	0.121	0.371**	0.194**	0.016	0.453**	-0.318**	0.644**	0.599**	-0.242**	-0.071	0.184**	0.367**
NON			1	0.317**	0.116	0.102	-0.240**	-0.032	0.107	0.366**	0.177*	0.021	0.463**	-0.324**	0.648**	0.601**	-0.252**	-0.070	0.192**	0.362**
LL				1	0.699**	0.434**	-0.115	0.084	0.133	0.494**	0.217**	0.248**	0.183*	-0.024	0.531**	0.550**	0.094	-0.146*	-0.163*	0.483**
LW					1	0.629**	0.134	-0.054	0.185**	0.660**	0.194**	0.276**	-0.170*	0.192*	0.493**	0.537**	0.156*	0.033	-0.110	0.657**
SW						1	0.058	0.107	0.191**	0.433**	0.154*	0.244**	-0.208**	-0.066	0.535**	0.564**	0.246**	-0.043	0.036	0.436**
CC							1	0.121	-0.042	-0.034	0.226**	0.177*	-0.146*	-0.147*	-0.014	-0.023	-0.163*	-0.093	0.047	-0.033
PL								1	0.424**	0.052	-0.091	0.180*	0.359**	-0.475**	0.103	0.100	-0.102	-0.242**	0.122	0.061
PW									1	0.282**	0.015	-0.064	0.193**	-0.017	0.187**	0.201**	-0.042	0.048	0.092	0.284**
DPW										1	0.247**	0.170*	0.167*	-0.047	0.532**	0.539**	-0.048	-0.158*	-0.118	0.7
NPB											1	0.264*	-0.002	-0.149*	0.328**	0.331**	0.178*	-0.039	0.083	0.241**
DTM												1	-0.146*	-0.139*	0.143*	0.18*	0.174*	-0.153*	-0.056	0.165*
PTH													1	-0.282**	0.229**	0.186**	-0.196**	-0.145*	0.091	0.165*
HSW														1	-0.193**	-0.172*	0.312**	0.499**	-0.273**	-0.047
FY															1	0.985**	0.029	-0.067	0.092	0.535**
DMP																1	0.029	-0.058	0.076	0.540**
P																	1	0.099	-0.111	-0.044
TSS																		1	0.686*	-0.157*
S																			1	-0.118

*&**: significant level at 5% and 15%, respectively. DTF: Days to 50% flowering, NOL: Number of leaves, NON: No. of nodes, LL: leaf length(cm), LW: leaf width(cm), SW: stem width(mm), CC: chlorophyll content, PL: panicle length(cm), PW: panicle width(cm), DPW: Dry panicle weight(g), NPB: no. of primary branches per panicle, DTM: days o maturity, PTH: plant height(cm), HSW: hundred seed weight(g), FY: fodder yield per plant (g), DMP: Dry matter production(t/ha), P: protein(mg/g), TSS: total soluble sugars(%), S: starch(%).

Table 3: Phenotypic path coefficient analysis for direct and indirect effects of yield and yield components in grain, fodder and sweet sorghum genotypes

Character	DTF	NOL	NON	LL	LW	SW	CC	PL	PW	DPW	NPB	DTM	PTH	HSW	FY	DMP	P	TSS	S
DTF	**-0.006**	0	0	-0.001	-0.001	-0.001	-0.001	-0.001	0.001	0.004	-0.001	-0.004	0.001	0.001	-0.002	-0.001	-0.001	0	0
NOL	0	**0.009**	0.009	0.003	0.001	0.001	-0.002	0.002	0.001	0.003	0.001	0.000	0.004	-0.003	0.006	0.005	-0.002	-0.001	0.002
NON	-0.001	-0.029	**-0.029**	-0.009	-0.005	-0.003	0.007	0.001	-0.004	-0.01	-0.004	-0.001	-0.013	0.009	-0.018	-0.017	0.007	0.002	-0.006
LL	-0.002	-0.003	-0.003	**-0.012**	-0.008	-0.005	0.001	-0.001	-0.002	-0.005	-0.003	-0.002	-0.002	0.000	-0.007	-0.006	-0.001	0.002	0.002
LW	0.001	-0.001	0.000	0.001	**0.001**	0.001	0.001	0.000	0.002	0.001	0.000	0.001	0.002	0.000	0.001	0.001	0.004	0.001	0.003
SW	0.004	0.002	0.004	-0.001	-0.001	**-0.002**	0.000	0.002	0.110	-0.001	0.001	0.000	0.004	0.002	-0.001	-0.001	-0.001	0.002	0.000
CC	-0.001	0.002	0.002	0.001	-0.001	0.000	**-0.007**	-0.001	0.001	0.000	-0.002	-0.001	0.001	0.001	0.004	0.003	0.001	0.001	0.010
PL	0.001	0.004	0.000	0.001	0.003	0.001	0.001	**0.009**	0.003	0.001	-0.001	0.001	0.003	-0.004	0.001	0.001	-0.001	-0.002	0.001
PW	0.010	-0.002	-0.001	-0.001	-0.001	-0.001	0.002	-0.003	**-0.006**	-0.002	0.002	0.100	-0.001	0.000	-0.001	-0.001	0.002	0.003	-0.001
DPW	0.064	0.343	0.338	0.436	0.61	0.398	-0.033	0.052	0.256	**0.697**	0.206	0.107	0.154	-0.046	0.512	0.516	-0.045	-0.153	-0.111
NPB	0.003	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.004	-0.001	**-0.003**	-0.001	0.001	0.001	-0.001	-0.001	-0.001	0.001	0.000
DTM	0.004	0.000	0.004.	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.001	**0.005**	-0.001	-0.001	0.001	0.001	0.001	-0.001	0.002
PTH	0.002	0.001	0.003	0.001	0.002	0.020	0.00	0.001	0.100	-0.003	0.00	0.001	**0.003**	-0.001	0.002	0.001	0.001	0.002	0.004
HSW	-0.002	-0.009	-0.009	-0.001	0.005	-0.002	-0.004	-0.013	0.002	-0.001	-0.004	-0.003	-0.008	**0.028**	-0.005	-0.005	0.009	0.014	-0.008
FY	0.004	0.034	0.034	0.027	0.026	0.028	-0.001	0.005	0.009	0.028	0.016	0.006	0.011	-0.01	**0.053**	0.054	0.003	-0.004	0.005
DMP	-0.003	-0.016	-0.016	-0.014	-0.015	-0.015	0.001	-0.003	-0.005	-0.014	-0.009	-0.004	-0.005	0.006	-0.027	**-0.029**	-0.001	0.002	-0.002
P	-0.001	0.001	0.001	0.004	-0.001	-0.001	0.001	0.010	0.000	0.001	-0.001	-0.002	0.001	-0.001	0.002	0.000	**-0.004**	0.000	0.001
TSS	0	0.002	0.002	0.004	-0.001	0.001	0.003	0.007	-0.001	0.005	0.001	0.003	0.004	-0.016	0.002	0.002	-0.003	**-0.032**	-0.022
S	0.001	0.005	0.005	-0.004	-0.003	0.001	0.001	0.003	0.002	-0.003	0.003	-0.001	0.002	-0.008	0.003	0.002	-0.003	0.019	0.029
GYP	0.061	0.336	0.332	0.430	0.609	0.401	-0.033	0.058	0.254	0.698	0.202	0.106	0.152	-0.043	0.518	0.522	-0.042	-0.153	-0.112

Residual effect: 0.0601; DTF: Days to 50% flowering, NOL: Number of leaves, NON: No. of nodes, LL: leaf length(cm), LW: leaf width(cm), SW: stem width(mm), CC: chlorophyll content, PL: panicle length(cm), PW: panicle width(cm), DPW: Dry panicle weight(g), NPB: no. of primary branches per panicle, DTM: days o maturity, PTH: plant height(cm), HSW: hundred seed weight(g), FY: fodder yield per plant (g), DMP: Dry matter production(t/ha), P: protein(mg/g), TSS: total soluble sugars(%), S: starch(%); GYP: grain yield per plant

Table 4: Genotypic path coefficient analysis for direct and indirect effects of yield and yield components in grain, fodder and sweet sorghum genotypes

Character	DTF	NOL	NON	LL	LW	SW	CC	PL	PW	DPW	NPB	DTM	PTH	HSW	FY	DMP	P	TSS	S
DTF	**0.014**	0.000	0.001	0.003	0.003	0.003	0.002	0.003	0.000	0.002	0.003	0.011	0.001	-0.001	0.001	0.002	0.003	0.002	0.001
NOL	-0.006	**0.326**	0.325	0.102	0.039	0.036	-0.078	-0.008	0.04	0.121	0.063	0.005	0.148	-0.104	0.21	0.195	-0.079	-0.023	0.06
NON	0.003	-0.351	**-0.352**	-0.113	-0.041	-0.036	0.084	0.011	-0.038	-0.129	-0.062	-0.007	-0.163	0.114	-0.228	-0.212	0.089	0.025	-0.068
LL	-0.004	-0.005	-0.005	**-0.016**	-0.011	-0.007	0.002	-0.001	-0.002	-0.008	-0.004	-0.004	-0.003	0.003	-0.009	-0.011	-0.002	0.002	0.003
LW	0.001	0.001	0.001	0.004	**0.006**	0.004	0.001	0.000	0.001	0.004	0.001	0.002	-0.001	0.001	0.003	0.003	0.001	0.001	-0.001
SW	-0.001	-0.001	-0.001	-0.002	-0.003	**-0.005**	0.003	-0.001	-0.001	-0.002	-0.001	-0.001	0.001	0.001	-0.004	-0.004	-0.001	0.002	0.003
CC	-0.001	0.002	0.002	0.001	-0.001	0.001	**-0.007**	-0.001	0.000	-0.002	-0.002	-0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
PL	-0.002	0.002	0.001	0.001	0.003	0.001	0.002	**0.001**	0.002	0.001	0.000	0.001	0.003	0.002	0.004	0.003	0.002	0.000	0.002
PW	0.001	-0.001	-0.001	-0.002	-0.001	-0.001	0.000	-0.002	**-0.004**	-0.001	0.002	0.001	-0.001	0.000	-0.002	-0.002	0.002	0.001	0.004
DPW	0.112	0.371	0.367	0.495	0.662	0.434	-0.034	0.052	0.282	**0.702**	0.248	0.171	0.167	-0.048	0.533	0.54	-0.047	-0.158	-0.119
NPB	-0.003	-0.003	-0.003	-0.003	-0.003	-0.002	-0.003	0.001	0.002	-0.004	**-0.014**	-0.004	0.001	0.002	-0.006	-0.005	-0.003	0.001	-0.001
DTM	-0.005	0.000	0.001	-0.002	-0.002	-0.002	-0.001	-0.001	0.001	-0.001	-0.002	**-0.006**	0.001	0.001	-0.001	-0.001	-0.001	0.001	0.000
PTH	0.001	0.001	0.002	0.001	0.003	-0.002	0.000	0.002	0.001	0.001	0.000	0.002	**0.001**	0.001	0.001	0.002	0.010	0.004	0.002
HSW	0.000	0.002	0.002	-0.002	-0.001	0.001	0.001	0.003	0.000	0.001	0.001	0.001	0.002	**-0.005**	0.001	0.001	-0.002	-0.003	0.002
FY	0.013	0.092	0.093	0.076	0.07	0.076	-0.003	0.015	0.027	0.076	0.047	0.02	0.033	-0.028	**0.143**	0.141	0.004	-0.01	0.013
DMP	-0.014	-0.067	-0.067	-0.061	-0.06	-0.063	0.003	-0.011	-0.022	-0.06	-0.037	-0.021	-0.02	0.019	-0.105	**-0.111**	-0.003	0.007	-0.009
P	-0.001	0.001	0.001	0.000	-0.001	-0.001	0.001	0.000	0.002	0.001	-0.001	-0.001	0.001	-0.001	0.001	0.003	**-0.004**	0.001	0.000
TSS	0.001	0.000	-0.001	0.001	0.000	0.000	-0.001	0.010	0.001	0.002	0.002	0.001	-0.004	0.002	-0.001	0.001	0.001	**0.001**	0.002
S	0.000	0.001	-0.002	0.003	0.001	0.001	0.003	0.000	0.001	-0.001	0.004	-0.001	0.002	0.002	0.003	0.002	0.001	0.002	0.001
GYP	0.108	0.367	0.362	0.483	0.657	0.436	-0.033	0.061	0.284	0.700	0.241	0.165	0.165	-0.047	0.535	0.540	-0.044	-0.157	-0.118

Residual effect: 0.0224; DTF: Days to 50% flowering, NOL: Number of leaves, NON: No. of nodes, LL: leaf length(cm), LW: leaf width(cm), SW: stem width(mm), CC: chlorophyll content, PL: panicle length(cm), PW: panicle width(cm), DPW: Dry panicle weight(g), NPB: no. of primary branches per panicle, DTM: days o maturity, PTH: plant height(cm), HSW: hundred seed weight(g), FY: fodder yield per plant (g), DMP: Dry matter production(t/ha), P: protein(mg/g), TSS: total soluble sugars(%), S: starch(%); GYP: grain yield per plant.

leaf width followed by moderately significant and positive association by dry matter production and fodder yield with the dependent character grain yield per plant. Partitioning of yield and its component traits at phenotypic levels into direct and indirect contribution of the traits exhibited highest positive direct effects on grain yield per plant were dry panicle weight followed by fodder yield and 100-seed weight. Hence, these parameters may be considered as selection indices in sorghum breeding programmes.

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Author contributions

Conceptualizations of research (PK,VNR); Designing of experiment (PK, NNG, VNR); Contribution of experimental materials (ME, NNG); Execution of field/ lab experiment and data collection (NNG, PK, RG); Data interpretation (PK, NNG): Manuscript writing, reviewing and editing (PK, GNN).

Conflict of interest

No

Declaration

The authors declare no conflict of interest.

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