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Research Article

Correlation and path analysis study of different characters for grain yield and fodder purpose in sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract
The present study was carried out to find the correlation and path coefficient analysis of 40 genotypes of sorghum for forage and grain yield and its attributes. The experiment was laid out in a Randomized Block Design with three replications at the Sorghum Research Station, SDAU, Deesa, Gujarat during *Kharif*- 2018. The analysis of variance revealed significant differences among the genotypes for all the traits studied. The high values of GCV and PCV were recorded for leaf: stem ratio followed by dry fodder yield per plant, grain yield per plant, panicle length and panicle width. The genotypic path coefficient analysis revealed that leaf area, panicle width, day to maturity and 1000-grain weight exhibited high and positive direct effect on grain yield per plant. The genotypic path coefficient analysis revealed that days to flowering, leaf width, the number of leaf per plant, leaf length and panicle width exhibited high and positive direct effect on dry fodder yield per plant.

Key words
Correlation, Fodder, Grain yield, Path analysis, Sorghum

INTRODUCTION

Sorghum or Great millet [*Sorghum bicolor* (L.) Moench] is one of the most important cereal crop in the world because of its adaptation to a wide range of ecological conditions, suitability for low input cultivation and diverse uses (Doggett, 1988). It is a C_4 plant with higher photosynthetic efficiency and higher abiotic stress tolerance (Nagy *et al*.,1995; Reddy *et al*.,2009). The height of cultivated sorghum varieties varies from 0.5 m to 6.0 m. Cultivated sorghum have been classified into 5 races *viz*., *Bicolor, Guinea, Caudatum, Durra* and *Kafir* and ten intermediate races corresponding to the pair wise combination of major races. These are identified according to the morphological traits, especially panicle, grain and glume traits (Harlan and de Wet, 1972).

Sorghum is fifth most important cereal crop globally and is the dietary staple of more than 500 million people in 30 countries. It is grown on 40 m ha in 105 countries of Africa, Asia, Oceania and the Americas. Africa and India account for the largest share (near about 70%) of global sorghum area while USA, Mexico, Nigeria, Sudan and Ethiopia are the major sorghum producers (Kumar *et al*., 2011a). Worldwide, it is cultivated on 44.27 million ha with a production of 63.35 million metric tonnes and productivity of 1.43 metric tonnes/ha (USDA, 2017). It is the fourth important cereal in India after rice, wheat and pearl millet. In India sorghum mainly used as food, feed and forage crop. Besides this it also provides raw material for the production of starch, fibre, dextrose syrup bio fuels, vinegar, alcohol, and other products. The area under this crop in India is about 5.14 million hectares with an annual production of 4.57 million tonnes and productivity of 889 kg/ha. The major states in the country where this cereal grain is produced are Maharashtra, Karnataka, Madhya

Pradesh, Andhra Pradesh, Rajasthan and Gujarat. In Gujarat, area, production and productivity of sorghum is 0.10 million hectares, 0.15 million tonnes and 1408 kg/ha, respectively (Anonymous, 2017).

In order to make sorghum as an enterprising and remunerative crop, obviously there is an urgent need to initiate research to develop varieties and hybrids having faster growth, early to medium maturity and higher grain and fodder yield with good quality parameters. To improving the genetic potential for grain and fodder yield in sorghum is a prime concern for the breeder. It is noted that the cultivated sorghums are highly variable and suggested that to enhance the productivity levels of sorghum, prior information on the nature and the magnitude of genetic variability present in germplasm collection is a pre-requisite. Assessment of genetic variability in the base population is the first step in any breeding programme. Variability should be determined with the help of certain parameters, such as genotypic and phenotypic coefficient of variation, heritability estimates and genetic advance. This study aims at finding the variability presented among the selected genotypes.

A path coefficient is simply standardized partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects. Grain yield and dry fodder yield per plant is the result of direct and indirect effects of several yield contributing characters. To know the contribution of various characters towards grain yield, the significant genotypic correlations of different traits with grain yield per plant were partitioned into their direct and indirect effects. This will provide more precise information for the selection of important traits, which may contribute more towards grain yield.

MATERIAL AND METHODS

The experimental material consisting of 40 genotypes were grown in the Randomized Block Design (RBD) with three replications. The experimental material was planted in field during *Kharif* in the year 2018. The observation on five randomly selected plants were recorded for days to flowering, days to maturity, plant height(cm), the number of leaf per plant, stem girth (mm), leaf width (cm), leaf area (cm^2) (Model No.: LI-310006), leaf: stem ratio, panicle length (cm), panicle width (cm), dry fodder yield per plant (g), grain yield per plant (g), protein content (%) (by micro Kjeldahl's method). The mean of the data recorded were used for statistical analysis. The analysis of variance was calculated with the method suggested by Panse and Sukhatme (1985). The genotypic and phenotypic coefficients of variation (GCV and PCV) were estimated as per Burton (1952), while, classification of GCV and PCV were followed by Johnson *et al.*(1955), heritability in broad sense and genetic advance (GA) as suggested by Allard (1960). The Path analysis was performed according to the method suggested by Dewey and Lu (1959).

Table 1. Phenotypic and genotypic coefficients of variation, heritability (broad Sense) and genetic advance expressed as percentage of mean for 15 characters in 40 genotypes of sorghum.

Character	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability (Broad Sense) (%)	Genetic advance expressed as percentage of mean
Days to flowering	7.75	7.43	91.80	14.66
Days to maturity	5.34	5.09	91.00	10.01
Plant height (cm)	9.33	5.70	37.30	7.18
Number of leaf per plant	12.16	9.63	62.70	15.71
Stem girth (mm)	11.38	9.10	63.90	14.98
Leaf length (cm)	7.83	6.47	68.20	11.01
Leaf width (cm)	13.07	11.66	79.60	21.42
Leaf area (cm)	16.12	13.84	73.70	24.49
Leaf: Stem ratio	39.88	38.82	94.80	77.85
Panicle length (cm)	28.85	27.98	94.10	55.90
Panicle width (cm)	23.29	21.98	89.10	42.75
Dry fodder yield per plant (g)	39.80	38.76	94.80	77.75
1000- Grain weight (g)	15.32	15.16	98.00	30.92
Grain yield per plant(g)	35.39	33.92	91.80	66.96
Protein content (%)	14.02	13.88	98.10	28.33

RESULT AND DISCUSSION

The genotypic and phenotypic coefficients of variation for all the traits are presented in **Table 1.** Higher expression of genotypic coefficient of variation and phenotypic coefficient of variation was observed for leaf: stem ratio, dry fodder yield per plant, grain yield per plant, panicle length and panicle width. The moderate genotypic coefficient of variation was noted for the character *viz.*, 1000-grain weight, protein content, leaf area and leaf width, whereas days to maturity, plant height, leaf length, days to flowering, and the number of leaf per plant showed lower magnitude of genotypic coefficient of variation. Only stem girth and the number of leaf per plant was observed with moderate PCV and low GCV.

The high values of GCV and PCV were recorded for leaf: stem ratio followed by dry fodder yield per plant, grain yield per plant, panicle length and panicle width. Similar high estimates of GCV and PCV in sorghum have been observed by Warkad *et al.* (2008), Godbharle *et al.* (2010) and Seetharam and Ganesamurthy (2013). The moderate values of GCV and PCV were observed for leaf area, 1000-grain weight, protein content, leaf width, the number of leaf per plant and stem girth. Nearby results for moderate GCV and PCV was also observed by Kumar *et al.* (2011b) and Malik *et al.* (2015). The low values of GCV and PCV was observed for plant height, leaf length, days to flowering and day to maturity. Similar results are also recorded by Jain and Patel (2014), Gebrie and Genet (2019).

The genotypic coefficient of variation measures the amount of variation present in a particular character. High values of heritability in the broad sense are helpful in identifying the appropriate character for selection and in enabling the breeder to select superior genotypes on the basis of phenotypic expression of quantitative traits and its utilization in future breeding programme (Johnson *et al*.,1955). In the present study, maximum heritability (broad sense) was observed for protein content followed by 1000-grain weight, dry fodder yield per plant, leaf: stem ratio, panicle length, grain yield per plant, days to flowering, days to maturity, panicle width, leaf width and leaf area. The heritability estimates were found to be moderate for leaf length, stem girth, the number of leaf per plant and plant height. Similar result for heritability by Seetharam and Ganesamurthy (2013) and Swamy *et al.*(2018).

The genetic advance expressed as percentage of mean was found maximum for leaf: stem ratio, dry fodder yield per plant, grain yield per plant, panicle length, panicle width, thousand grains weight, protein in grain, leaf area and leaf width. Similar results have also been reported by Godbharle *et al.* (2010) Seetharam and Ganesamurthy (2013) and Swamy *et al.* (2018). Moderate values of genetic advance expressed as percentage of mean was recorded for the number of leaf plant, stem girth, days to flowering, leaf length and days to maturity, while it was low for plant height. Moderate estimates of genetic advance expressed as percentage of mean in sorghum has been reported by Seetharam and Ganesamurthy (2013) for the number of leaf per plant and leaf length; Swamy *et al.* (2018) for day to maturity. High estimates of heritability coupled with high genetic advance expressed as percentage of mean were observed for leaf: stem ratio, dry fodder yield per plant, grain yield per plant, panicle length, panicle width, thousand grains weight, protein content, leaf area and leaf width which may be attributed to the preponderance of an additive gene action and possess a high selective value and thus, the selection pressure could profitably be applied on these characters for their rationale improvement. Similar results in sorghum have also been reported by Warkad *et al.* (2008), Malik *et al.* (2015), Seetharam and Ganesamurthy (2013) and Swamy *et al.*(2018).

The correlation coefficients between yield and its component traits among themselves were estimated at genotypic and phenotypic levels. The correlations at genotypic level were relatively greater than their corresponding phenotypic correlations. The results of genotypic and phenotypic correlation coefficients between yield and its components are given in **Table 2**. In most of the cases the direction and magnitude of genotypic and phenotypic correlations between different characters remained almost same.

In the present study, grain yield per plant was found to be significantly and positively correlated with leaf width, leaf area, panicle width, dry fodder yield per plant and 1000-grain weight at the genotypic level. The positive and significant genotypic association has been reported by Seetharam and Ganesamurthy (2013), Patil *et al.* (2014), Eudalamaw *et al.* (2017), Deshmukh *et al.* (2018) and Swamy *et al.* (2018), Jankovic *et al.* (2012), Jain and Patel (2014). The grain yield per plant also registered positive, but non-significant correlation with days to flowering, days to maturity, leaf length and panicle length.

Grain yield per plant was found to be significantly negative and correlated with protein content at genotypic level. Grain yield per plant was found to be non-significantly and negative correlated with plant height, the number of leaf per plant stem girth and leaf: stem ratio at genotypic level. The non-significantly and negative genotypic association has been reported by Eudalamaw *et al.* (2017) and Deshmukh *et al.* (2018) between grain yield per plant and plant height; Verma *et al.* (2015) between grain yield per plant and the number of leaf per plant; Soujanya *et al.* (2018) between grain yield per plant and leaf: stem ratio.
Grain yield per plant was found to be non-significant and positive correlated with days to flowering, days to maturity, leaf length and panicle length. The non-significantly and positively genotypic association has been reported by Patil *et al.* (2014) between grain yield per plant and

days to flowering also between grain yield per plant and days to maturity; Gebrie and Genet (2019) between grain yield per plant and leaf length; Seetharam and Ganesamurthy (2013), Eudalamaw *et al.* (2017) and Sowmy *et al.* (2018) between grain yield per plant and panicle length.

Table 2. Genotypic (r_g) and phenotypic (r_p) correlation coefficients among 15 characters in 40 genotypes of sorghum.

Characters		DF	DM	PH	NLP	SG	LL	LW	LA	LSR	PL	PW	DFY	TSW	PC	GYP
DF	r_g		1.000**	0.690**	0.684**	0.263**	0.421**	0.064**	0.644**	-0.262**	-0.299**	0.0004	0.403**	0.185*	0.321**	0.024
	r_p		0.994**	0.425**	0.527**	0.187*	0.341**	0.074	0.548**	-0.248**	-0.283**	-0.006	0.383**	0.177	0.308**	0.013
DM	r_g			0.707**	0.681**	0.254**	0.439**	0.065	0.650**	-0.254**	-0.308**	0.002	0.420**	0.177	0.327**	0.039
	r_p			0.399**	0.523**	0.207 *	0.335**	0.067	0.539**	-0.241**	0.288**	-0.004	0.396**	0.167	0.311**	0.024
PH	r_g				0.559**	0.223*	0.363**	-0.061	0.425**	-0.303**	-0.211*	0.205*	0.283**	0.198*	0.251**	-0.050
	r_p				0.376 **	0.137	0.297**	0.023	0.368 **	-0.121	-0.123	0.121	0.182*	0.127	0.172	-0.038
NLP	r_g					0.170	0.537**	-0.376**	0.559**	-0.015	-0.253**	-0.157	0.262**	0.381**	0.024	-0.027
	r_p					0.158	0.323**	-0.274**	0.589 **	-0.032	-0.191*	-0.093	0.204*	0.314**	0.014	-0.047
SG	r_g						0.270**	0.516**	0.646**	0.071	-0.195*	0.174	0.314**	0.186*	0.317**	-0.050
	r_p						0.157	0.373**	0.457 **	0.083	-0.088	0.180*	0.228*	0.150	0.254 **	-0.025
LL	r_g							-0.128	0.629**	-0.317**	0.290**	0.139	0.336**	0.202*	-0.170	0.055
	r_p							0.010	0.585 **	-0.218*	0.258**	0.165	0.280**	0.168	-0.130	0.029
LW	r_g								0.499**	-0.046	-0.143	0.195*	0.371**	-0.123	0.141	0.323**
	r_p								0.509 **	-0.018	-0.115	0.178	0.322**	-0.115	0.129	0.273**
LA	r_g									-0.175	-0.174	0.066	0.579**	0.214*	0.046	0.210*
	r_p									-0.134	-0.131	0.091	0.496**	0.190 *	0.044	0.155
LSR	r_g										0.015	0.117	-0.188*	0.086	0.118	-0.060
	r_p										0.012	0.118	-0.179	0.085	0.115	-0.051
PL	r_g											0.614**	0.075	0.018	-0.322**	0.041
	r_p											0.599**	0.064	0.010	-0.313**	0.028
PW	r_g												0.383**	0.052	-0.052	0.243**
	r_p												0.357**	0.046	-0.048	0.216*
DFY	r_g													0.064	-0.055	0.291**
	r_p													0.062	-0.052	0.268**
TSW	r_g														0.070	0.229*
	r_p														0.067	0.221*
PC	r_g															-0.252**
	r_p															-0.239**

*, ** Significant at 5% and 1% levels, respectively.
GYP: Grain yield per plant (g), **DF**: Days to flowering, **DM**: Days to maturity, **PH**: Plant height (cm), **NLP**: Number of leaf per plant, **SG:** Stem girth (mm), **LL**: Leaf length (cm), LW: Leaf width (cm), **LA:** Leaf area (cm^2), **LSR:** Leaf: Stem ratio, **PL**: Panicle length (cm), **PW**: Panicle width (cm), **DFY:** Dry fodder yield per plant (g) **TSW**: 1000-grain weight (g), **PC:** Protein content (%)

In the present study, dry fodder yield per plant was found to be significantly and positively correlated with leaf area, days to maturity, days to flowering, panicle width, leaf width, leaf length, stem girth, plant height, the number of leaf per plant and grain yield per plant at the genotypic level. Such positive interrelationship between dry fodder yield per plant and these attributes has also been reported in sorghum by several researchers. The positive and significant genotypic association has been reported by Navneet and Singh (2012), Jain and Patel (2014) and Rana *et al.* (2016) between fodder yield per plant and leaf width and leaf length; Rana *et al.* (2016) between fodder yield per plant and stem girth; and plant height and the number of leaf per plant and between fodder yield per plant and plant height and the number of leaf per plant by Jain and Patel (2014).

The phenotypic path coefficient analysis revealed that days to maturity, leaf width, 1000- grain weight exhibited high and positive direct effect on grain yield per plant and was found to be the most important yield components. The genotypic path coefficient analysis revealed that leaf area, panicle width, days to maturity and 1000-grain weight exhibited high and positive direct effect on grain yield per plant and was found to be the most important yield components. The character panicle width was moderate and positive direct effect on grain yield per plant at phenotypic level. The character protein content was negligible and positive direct effect on grain yield per plant at genotypic level. High and positive direct effect of leaf area on grain yield per plant had been reported in sorghum by Premalatha *et al.* (2006); panicle width on grain yield per plant by El-Din *et al.* (2012), Seetharam and Ganesamurthy (2013), Patil *et al.* (2014) and Eudalamaw *et al.* (2017); days to maturity on grain yield per plant by El-Din *et al.* (2012), Patil *et al.* (2014), Ramaling hundekar *et al.* (2016) and Deshmukh *et al.* (2018); 1000-grain weight on grain yield per plant by Premalath *et al.* (2006), Bisen *et al.* (2010), Kumar *et al.* (2011b), Jain and Patel (2014), Patil *et al.* (2014), Eudalamaw *et al.* (2017) and Deshmukh *et al.* (2018); protein content on grain yield per plant by Seetharam and Ganesamurthy (2013) and Patil *et al.* (2014). Thus, these characters *viz.* leaf area, panicle width, days to maturity and 1000-grain weight turned out to be the major components of grain yield per plant and direct selection for these traits will be rewarding for yield improvement.

Table 3. Genotypic (G) and phenotypic (P) path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on grain yield per plant in 40 genotypes of sorghum

Characters		DF	DM	PH	NLP	SG	LL	LW	LA	LSR	PL	PW	DFY	TSW	PC	Correlation with GYP
DF	G	**-1.201**	0.989	-0.211	-2.447	-0.277	-0.748	-0.253	3.815	0.018	0.257	0.0004	-0.018	0.087	0.011	0.024
	P	**-1.398**	1.405	-0.013	0.029	-0.039	0.004	0.031	-0.077	0.014	0.057	-0.002	0.034	0.059	-0.092	0.013
DM	G	-1.201	**0.988**	-0.216	-2.438	-0.269	-0.779	-0.255	3.850	0.017	0.265	0.002	-0.019	0.083	0.012	0.039
	P	-1.389	**1.414**	-0.013	0.029	-0.044	0.004	0.028	-0.075	0.014	0.058	-0.001	0.035	0.056	-0.092	0.024
PH	G	-0.828	0.698	**-0.306**	-2.000	-0.236	-0.645	0.238	2.518	0.021	0.181	0.220	-0.012	0.093	0.009	-0.050
	P	-0.595	0.564	**-0.032**	0.021	-0.029	0.003	0.010	-0.051	0.007	0.025	0.032	0.016	0.04	-0.051	-0.038
NLP	G	-0.821	0.673	-0.171	**-3.578**	-0.180	-0.955	1.478	3.309	0.001	0.218	-0.169	-0.012	0.179	0.001	-0.027
	P	-0.736	0.740	-0.012	**0.055**	-0.033	0.004	-0.117	-0.082	0.002	0.039	-0.024	0.018	0.105	-0.004	-0.047
SG	G	-0.316	0.251	-0.068	-0.610	**-1.058**	-0.480	-2.029	3.826	-0.005	0.167	0.187	-0.014	0.088	0.011	-0.050
	P	-0.262	0.292	-0.004	0.009	**-0.211**	0.002	0.158	-0.064	-0.005	0.018	0.047	0.020	0.050	-0.076	-0.025
LL	G	-0.505	0.433	-0.111	-1.923	-0.286	**-1.777**	0.505	3.723	0.022	-0.249	0.149	-0.015	0.095	-0.006	0.055
	P	-0.476	0.474	-0.009	0.018	-0.033	**0.011**	0.004	-0.082	0.012	-0.052	0.043	0.025	0.056	0.039	0.029
LW	G	-0.076	0.064	0.018	1.344	-0.546	0.228	**-3.934**	2.958	0.003	0.123	0.209	-0.016	-0.058	0.005	0.323**
	P	-0.104	0.094	-0.001	-0.015	-0.079	0.000	**0.425**	-0.071	0.001	0.023	0.047	0.029	-0.038	-0.038	0.273**
LA	G	-0.773	0.642	-0.130	-1.999	-0.683	-1.117	-1.964	**5.924**	0.012	0.150	0.071	-0.026	0.101	0.002	0.210*
	P	-0.766	0.762	-0.012	0.032	-0.096	0.007	0.216	**-0.140**	0.008	0.027	0.024	0.044	0.063	-0.013	0.155
LSR	G	0.314	-0.251	0.093	0.052	-0.075	0.564	0.182	-1.037	**-0.069**	-0.013	0.126	0.009	0.040	0.004	-0.060
	P	0.346	-0.340	0.004	-0.002	-0.017	-0.002	-0.007	0.019	**-0.057**	-0.002	0.031	-0.016	0.028	-0.034	-0.051
PL	G	0.359	-0.305	0.065	0.907	0.206	-0.515	0.563	-1.032	-0.001	**-0.859**	0.660	-0.003	0.008	-0.011	0.041
	P	0.395	-0.407	0.004	-0.010	0.019	0.003	-0.049	0.018	-0.001	**-0.203**	0.157	0.006	0.003	0.093	0.028
PW	G	-0.0004	0.002	-0.063	0.562	-0.184	-0.247	-0.76	0.393	-0.008	-0.528	**1.076**	-0.017	0.024	-0.002	0.243**
	P	0.008	-0.005	-0.004	-0.005	-0.038	0.002	0.076	-0.013	-0.007	-0.122	**0.262**	0.032	0.015	0.014	0.216*
DFY	G	-0.484	0.415	-0.087	-0.937	-0.333	-0.596	-1.461	3.430	0.013	-0.064	0.412	**-0.044**	0.030	-0.002	0.291**
	P	-0.536	0.560	-0.006	0.011	-0.048	0.003	0.137	-0.069	0.010	-0.013	0.094	**0.089**	0.021	0.015	0.268**
TSW	G	-0.222	0.175	-0.060	-1.365	-0.197	-0.359	0.483	1.269	-0.006	-0.016	0.056	-0.003	**0.471**	0.002	0.229*
	P	-0.247	0.236	-0.004	0.017	-0.032	0.002	-0.049	-0.027	-0.005	-0.002	0.012	0.005	**0.333**	-0.020	0.221*
PC	G	-0.386	0.323	-0.077	-0.087	-0.328	0.302	-0.554	0.273	-0.008	0.276	-0.056	0.002	0.033	**0.035**	-0.252**
	P	-0.431	0.439	-0.005	0.001	-0.054	-0.001	0.055	-0.006	-0.007	0.064	-0.013	-0.005	0.022	**-0.298**	-0.239**

*, ** Significant at 5% and 1% levels, respectively.
Residual effect, R_g = 0.7956 and R_p = 0.8139 N.B.: Values at diagonal indicated direct effects of respective character.
GYP: Grain yield per plant (g), **DF**: Days to flowering, **DM**: Days to maturity, **PH**: Plant height (cm), **NLP**: Number of leaf per plant, **SG:** Stem girth (mm), **LL**: Leaf length (cm), **LW**: Leaf width (cm), **LA:** Leaf area (cm^2), **LSR:** Leaf: Stem ratio, **PL**: Panicle length (cm), **PW**: Panicle width (cm), **DFY:** Dry fodder yield per plant (g), **TSW**: 1000-grain weight (g), **PC:** Protein content (%)

The character days to flowering had high and negative direct effect on grain yield per plant at phenotypic level. The character's protein content, stem girth and panicle length had moderate and negative direct effect on grain yield per plant at phenotypic level. The character's leaf width, the number of leaf per plant, leaf length, days to flowering, stem girth, panicle length and plant height had high and negative direct effect on grain yield per plant at genotypic level. The character's leaf: stem ratio and dry fodder yield per plant had negligible and negative direct effect on grain yield per plant at genotypic level. High and negative direct effect of leaf width on grain yield per plant has also been reported in sorghum by Seetharam and Ganesamurthy (2013) and Soujanya *et al.* (2018); leaf length on grain yield by Jain and Patel (2014) and Soujanya *et al.* (2018); days to flowering on grain yield by Seetharam and Ganesamurthy (2013), Jain and Patel (2014), Deshmukh *et al.* (2018) and Soujanya *et al.*(2018); stem girth on grain yield by Seetharam and Ganesamurthy (2013); plant height on grain yield by Seetharam and Ganesamurthy (2013), Patil *et al.* (2014) and Ramaling hundekar *et al.*

Table 4. Genotypic (G) and phenotypic (P) path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on dry fodder yield per plant in 40 genotypes of sorghum

Characters		DF	DM	PH	NLP	SG	LL	LW	LA	LSR	PL	PW	TSW	GYP	PC	Correlation with DFY
DF	G	**4.643**	-4.705	-0.078	1.155	-0.059	0.469	0.133	-1.234	0.023	0.085	0.0002	-0.019	-0.001	-0.009	0.403**
	P	**-1.122**	1.345	-0.005	-0.201	-0.012	-0.083	-0.021	0.475	0.027	0.015	-0.002	-0.001	-0.032	0.001	0.383**
DM	G	4.646	**-4.702**	-0.080	1.152	-0.057	0.488	0.136	-1.245	0.022	0.088	0.001	-0.018	-0.001	-0.009	0.420**
	P	-1.115	**1.354**	-0.004	-0.200	-0.013	-0.082	-0.019	0.467	0.026	0.015	-0.001	-0.001	-0.032	0.002	0.396**
PH	G	3.202	-3.323	**-0.114**	0.945	-0.050	0.404	-0.126	-0.814	0.027	0.060	0.098	-0.020	0.002	-0.007	0.283**
	P	-0.477	0.540	**-0.011**	-0.143	-0.009	-0.073	-0.007	0.319	0.013	0.007	0.045	-0.001	-0.018	-0.003	0.182*
NLP	G	3.175	-3.204	-0.064	**1.690**	-0.038	0.599	-0.785	-1.070	0.001	0.072	-0.076	-0.039	0.001	-0.001	0.262**
	P	-0.591	0.708	-0.004	**-0.381**	-0.010	-0.079	0.078	0.510	0.003	0.010	-0.034	-0.002	-0.001	-0.003	0.204*
SG	G	1.223	-1.196	-0.025	0.288	**-0.223**	0.301	1.078	-1.237	-0.006	0.055	0.084	-0.019	0.002	-0.009	0.314**
	P	-0.210	0.280	-0.001	-0.060	**-0.063**	-0.038	-0.106	0.396	-0.009	0.005	0.066	-0.001	-0.027	-0.002	0.228*
LL	G	1.955	-2.062	-0.041	0.908	-0.060	**1.114**	-0.268	-1.204	0.028	-0.082	0.067	-0.020	-0.002	0.005	0.336**
	P	-0.382	0.453	-0.003	-0.123	-0.010	**-0.244**	-0.003	0.508	0.023	-0.014	0.061	-0.001	0.014	0.002	0.280**
LW	G	0.295	-0.305	0.007	-0.635	-0.115	-0.143	**2.089**	-0.957	0.004	0.041	0.094	0.012	-0.013	-0.004	0.371**
	P	-0.083	0.090	-0.0003	0.105	-0.024	-0.002	**-0.285**	0.441	0.002	0.006	0.065	0.001	-0.013	0.020	0.322**
LA	G	2.999	-3.056	-0.048	0.944	-0.144	0.700	1.043	**-1.916**	0.015	0.050	0.032	-0.022	-0.008	-0.001	0.579**
	P	-0.615	0.729	-0.004	-0.224	-0.029	-0.143	-0.145	**0.867**	0.014	0.007	0.034	-0.001	-0.005	0.011	0.496**
LSR	G	-1.215	1.193	0.034	-0.025	-0.016	-0.353	-0.097	0.335	**-0.088**	-0.004	0.056	-0.008	0.002	-0.003	-0.188*
	P	0.278	-0.326	0.001	0.012	-0.005	0.053	0.005	-0.116	**-0.108**	-0.001	0.043	-0.001	-0.012	-0.004	-0.179
PL	G	-1.388	1.450	0.024	-0.428	0.043	0.323	-0.299	0.334	-0.001	**-0.285**	0.295	-0.002	-0.002	0.009	0.075
	P	0.317	-0.389	0.001	0.073	0.006	-0.063	0.033	-0.114	-0.001	**-0.053**	0.221	-0.0001	0.033	0.002	0.064
PW	G	0.002	-0.008	-0.023	-0.265	-0.039	0.155	0.406	-0.127	-0.010	-0.175	**0.481**	-0.005	-0.009	0.001	0.383**
	P	0.007	-0.005	-0.001	0.035	-0.011	-0.040	-0.051	0.079	-0.013	-0.032	**0.369**	-0.0004	0.005	0.016	0.357**
TSW	G	0.858	-0.833	-0.022	0.645	-0.042	0.225	-0.256	-0.410	-0.007	-0.005	0.025	**-0.101**	-0.009	-0.002	0.064
	P	-0.198	0.226	-0.001	-0.120	-0.010	-0.041	0.033	0.165	-0.009	-0.001	0.017	**-0.008**	-0.007	0.016	0.062
GYP	G	0.113	-0.182	0.006	-0.046	0.011	0.061	0.675	-0.403	0.005	-0.012	0.117	-0.023	**-0.039**	0.007	0.291**
	P	-0.346	0.420	-0.002	-0.005	-0.016	0.032	-0.037	0.038	-0.012	0.017	-0.018	-0.001	**-0.105**	-0.017	-0.052
PC	G	1.493	-1.538	-0.028	0.041	-0.069	-0.189	0.294	-0.088	-0.010	0.092	-0.025	-0.007	0.010	**-0.029**	-0.054
	P	-0.014	0.032	0.0004	0.018	0.002	-0.007	-0.078	0.135	0.005	-0.002	0.080	-0.002	0.025	**0.073**	0.268**

*, ** Significant at 5% and 1% levels, respectively.

Residual effect, R_g = 0.7956 and R_p = 0.7390 N.B.: Values at diagonal indicated direct effects of respective character.
DFY: Dry fodder yield per plant (g), **DF**: Days to flowering, **DM**: Days to maturity, **PH**: Plant height (cm), **NLP**: Number of leaf per plant, **SG:** Stem girth (cm), **LL**: Leaf length (cm), **LW**: Leaf width (cm), **LA:** Leaf area (cm^2), **LSR:** Leaf: Stem ratio, **PL**: Panicle length (cm), **PW**: Panicle width (cm), **GYP:** Grain yield per plant (g), **TSW**: 1000-grain weight (g), **PC:** Protein content (%)

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(2016); dry fodder yield per plant on grain yield by Patil *et al.* (2014) and Deshmukh *et al.* (2018).

It was clear from the path analysis that the leaf area, panicle width, days to maturity and 1000- grain weight were the most important components manifested high and positive direct effect on grain yield per plant and hence, they may be considered as the most important yield contributing characters and due emphasis should be placed on these components while selecting for high yielding types in sorghum. Apart from this, leaf width and panicle length possessed high and negative direct effect on grain yield per plant, but its positively correlated with grain yield per plant was primarily formed through its indirect contribution through various yield components.

Direct and indirect effects of fourteen casual variables on dry fodder yield per plant are presented in **Table 4.** The phenotypic path coefficient analysis revealed that days to maturity (1.354), leaf area (0.867) and panicle width (0.369) exhibited high and positive direct effect on dry fodder yield per plant and was found to be the most important yield components. The genotypic path coefficient analysis revealed that days to flowering (4.643), leaf width (2.089), the number of leaf per plant (1.690), leaf length (1.114) and panicle width (0.481) exhibited high and positive direct effect on dry fodder yield per plant and was found to be the most important yield components. High and positive direct effect of days to flowering on fodder yield per plant has also been reported in sorghum by Prakash *et al.* (2010), Jain and Patel (2012), Rana *et al*. (2016) and Soujanya *et al.* (2018); leaf width on fodder yield per plant by Prakash *et al.* (2010), Jain and Patel (2012) and Jain and Patel (2014); number of leaf per plant on fodder yield per plant by Jain and Patel (2010), Prakash *et al.* (2010), Jain and Patel (2012), Jain and Patel (2014), Rana *et al.* (2016) and Soujanya *et al.* (2018); leaf length fodder yield per plant by Prakash *et al.* (2010), Jain and Patel (2014) and Rana *et al*. (2016). Thus, these characters *viz.*, days to flowering, leaf width, the number of leaf per plant, leaf length and panicle width turned out to be the major components of fodder yield and direct selection for these traits will be rewarding for yield improvement.

The characters days to flowering (-1.122) and the number of leaf per plant (-3.81) had high and negative direct effect on dry fodder yield per plant at phenotypic level. The character's days to maturity (-4.702) and leaf area (-1.916) had high and negative direct effect on dry fodder yield per plant at genotypic level. The character's panicle length (-0.285) and stem girth (-0.223) had moderate and negative direct effect on dry fodder yield per plant while plant height (-0.114) and 1000-grain weight (-0.101) had had low and negative direct effect on dry fodder yield per plant at genotypic level. The character's leaf: stem ratio (-0.088), grain yield per plant (-0.039) and protein content (-0.029) had negligible and negative direct effect on dry fodder yield per plant at genotypic. Negative direct effect of plant height on fodder yield per plant have also been reported in sorghum by Jain and Patel (2014) and Rana *et al.* (2016); leaf: stem ratio on fodder yield per plant by Prakash *et al.* (2010); protein content on fodder yield per plant by Rana *et al.* (2016).

In addition, the results showed high value of residual effect in path analysis for grain yield and fodder yield, which indicated that still there was a need to study more hidden heritable traits along with these traits in sorghum improvement programme.

The present results on path analysis that the days to flowering, leaf width, the number of leaf per plant, leaf length and panicle width were the most important components manifested high and positive direct effect on fodder yield per plant and hence, these traits may be considered while selecting for high fodder yielding types in sorghum. Apart from this, days to maturity, leaf area, panicle length, stem girth, plant height, 1000-grain weight and grain yield per plant possessed high and negative direct effect on grain yield per plant, but it's positively and significantly correlation with fodder yield per plant was primarily formed through its indirect contribution through various yield components.

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