Study on correlation and path analysis in forage sorghum [*Sorghum bicolor* (L.) Moench]

Abstract

This investigation is conducted to determine character association and path coefficient analysis using 35 genotypes of forage sorghum at the Crop Research Centre of the Sardar Vallabhbhai Patel University of Agriculture and Technology in Meerut. InKharif 2022, testing of all 35 genotypes of forage sorghum was conducted using a randomized block design with three replications. Observations were recorded for days to 50% flowering, plant height (cm), leaf breadth (cm), leaf length (cm), number of leaves per plant, total soluble solids (%), leaf area (cm^2), stem girth (mm), leaf stem ratioand green fodder yield per plant (g). Correlation coefficient studies indicated that green fodder yield per plant was found highly significant positiveassociation with leaf breadth, stem girth, leaf area, leaf length, number of leaves per plant, plant height and leaf stem ratio at both genotypic and phenotypic level, indicated that selection of these attributes may be helpful to increase fodder yield in sorghum. The results of genotypic and phenotypic path analysis indicated that stem girth had a strong positive direct effect on green fodder yield per plant, followed by leaf breadth and number of leaves per plant at both genotypic and phenotypic levels. Improving these attributes can increase fodder yield. The character showing indirect effect like Leaf breadth, leaf length, leaf area, and leaf stem ratio via another component trait, indirect selection through such trait can lead to improvement in green fodder yield.

Key words: Sorghum, Correlation, Path analysis, Fodder

Introduction

Sorghum is one of the main multipurpose crops cultivated for both grain and fodder is sorghum. In the grass family (poaceae), the genus Sorghum contains roughly 25 species of flowering plants. Sorghum is also known as *orshallu, milo, durra,* and Indian millet. Sorghum contains nutrient such as vitamin B1, niacin, 10% protein, 3.4% fat, carbohydrates and trace level of iron. It has several economic significant potential applications, including food (grain), feed (grain and biomass), fuel (ethanol production), fibre (paper), fermentation (ethanol production), and fertilizer (using organic by products), it is one of the five principal cultivated species in the world. The majority of types are nitrogen-efficient, resistant to heat and drought, and particularly significant in dry regions where the grain is a staple food for the impoverished and rural populations [1]. It is one of the world's most important grain crop after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*), and barley (*Hordeum vulgare*) is sorghum [*Sorghum bicolor* (L.) Moench]. Along with maize and pearl millet (*Pennisetum glaucum* L.), it is a significant dry land cereal crop in the semi-arid tropics.

With an annual grain yield of roughly 58 million tons, it is produced in an area of 37 million hectares in at least 80 nations with 1.5 t/h average productivity [2]. Due to changes in the climate, there has been a significant droughts were seen during past year and huge decline in soil fertility which result in decrease in sorghum productivity.It is one of the known kharif crop for animal fodder, genetic improvement in its agronomic character for forage will certainly reduce the gap between fodder demand and supply for the maximizing livestock production [3]. Despite being the world's greatest producer of milk, there is still a scarcity of milk and its by-products [4]. There is more pressure on the import of powdered milk in this circumstance. The analysis of correlations among quantitative traits is essential to ascertain whether numerous qualities can be selected at the same time and, if so, how selection for secondary traits influences the genetic gain for the main feature that is being studied. When two desirable features have a positive genetic correlation, plant breeders have an easier time concurrently increasing both traits. The correlation study of several factors offers insight into the significance of both direct and indirect selection in influencing the ultimate yield of crop species. The direct and indirect causes of association provide estimates of the relative importance of each causative element, and the path coefficient analysis is a particularly powerful tool for identifying specific forces that act to produce strong correlations [27]. Thus, in order to simultaneously improve yield and yield components, one must be aware of the associations between features and the route coefficient [25,26]. A path coefficient analysis was done to determine the yield's direct and indirect contributors.

Materials and Methods

Thirty five (35) different genotypes of forage sorghum used as the experimental material for this study. The genotypes are listed in the accompanying table.

List 1: Varieties of forage sorghum

Sl. No.	Genotype	Sl. No.	Genotype	Sl. No.	Genotype
1.	Pant Chari-3	**13.**	Pratap Chari-1080	**25.**	UP Chari-2
2.	Jawahar Chari-6	**14.**	Pusa Chari-6	**26.**	Pant Chari-8
3.	SSG-59-3	**15.**	CSV-17	**27.**	Rajasthan Chari-1
4.	MP Chari	**16.**	Pant Chari-2	**28.**	UP Chari-1
5.	Pant Chari-4	**17.**	HC-260	**29.**	G-48
6.	Pant Chari-5	**18.**	HC-136	**30.**	CSV-21
7.	CSV-15	**19.**	Pusa Chari-615	**31.**	GFS-5
8.	HJ-513	**20.**	UP Chari-3	**32.**	IC-0597651
9.	SSV-84	**21.**	Pant Chari-7	**33.**	IC-0347571
10.	Varsha	**22.**	Pusa Chari-23	**34.**	IC-056030
11.	UP Chari-4	**23.**	HC-171	**35.**	IC-0568396
12.	Rajasthan Chari-2	**24.**	Pusa Chari-9		

A well prepared field plot was used to seed 35 genotypes of the experimental materials. In the kharif season of 2022, the experiment was set up in a randomized block design with three replications. It was sowed on June 28, 2022, in a 4-row plot that measured five meters in length. Observations were recorded for days to 50% flowering, plant height (cm), leaf breadth (cm), leaf length (cm), number of leaves per plant, total soluble solids (%), leaf area (cm^2), stem girth (mm), leaf stem ratioand green fodder yield per plant (g). Five (5)plants were randomly selected and harvested from each plot and then observations for different characters were recorded on these plants.

Statistical analysis

According to Fisher (1918), [5] the correlations was calculated using the analysis of variance and covariance. The investigiation of path-coefficient was carried out in accordance with Wright (1921) [6] and Dewey and Lu (1959) [7] clarifications.

Results and Discussions

Mean parameters distribution

The mean performance of 35 genotype for 10 characters are studied. The mean for days to 50% flowering range from 71.67 days for genotype G-48 to 92.00 days for Pant Chari-2. Plant height range from 256.39 cm for genotype Varsha to 353.22 cm for Up Chari-2. Leaf breadth ranges from 4.10 cm for Pusa Chari-615 to 7.54 cm for HC-136. Leaf length ranges from 52.07 cm for genotype CSV-15 to 91.15 cm for UP Chari 1. Number of leaves per plant ranges from 10.67 for genotype HJ-513 to 16.62 for UP Chari 1. Total soluble solids ranges from 6.97% for genotype Pusa Chari-615 to 11.99% for Pant Chari-2. Leaf area varies from 195.85 cm^2 for Pusa Chari-615 to 460.36 $cm^2$for HC-136. Stem girth ranges from 7.48 mm for HJ – 513to 16.83 mm for UP Chari 1. Leaf stem ratio ranges from 0.16 for genotype Pant Chari -3 to 0.27 for genotype HC -260. Green fodder yield ranges from 127.67 g/plant for genotype Pusa Chari -615 to 538.08 g/plant for UP Chari-1.

Correlation Analysis

Correlation coefficients for each of the 35 genotypes for the attributes were computed at the genotypic and phenotypic levels, and the results are displayed in Table 1. At the phenotypic level, there was a strong positive association between the amount of green fodder produced per plant and the stem girth (0.857). This was followed by the leaf breadth (0.851), leaf area (0.841), and leaf length (0.833), plant height (0.354), leaf stem ratio (0.263), The findings of Kumar et al. [8] and Pal et al. [9] are generally supported by these results

On the other hand, days to 50% flowering (-0.021) and green fodder yield per plant had a slight but non-significant correlation. There was a positive but non-significant correlation between total soluble solids and green fodder yield per plant (0.101). Days to 50% flowering showed a positive and significant correlation (0.198) with the number of leaf stem ratio Similar finding for this characters have been reported by Singh et al. [10]**.** Plant height exhibited a significant positive relationship with leaf length (0.467), leaf area (0.469), number of leaves per plant (0.317), stem girth (0.351), and green fodder yield per plant (0.354), but non significantcorrleationwith total soluble solids (0.100) and leaf stem ratio (0.180). This is in contrast to a non-significant negative association with plant height (-0.022), leaf breadth (-0.091), leaf length (-0.089), leaf area (-0.078), stem girth (-0.021), and green fodder yield per plant (-0.021) was consistent with the findings of Jain et al. [11]. It was observed that there was a positive and statistically significant correlation between leaf breadth and the following variables: leaf length (0.791), number of leaves per plant (0.706), leaf area (0.831), stem girth (0.683), leaf stem ratio (0.252), and green fodder yield per plant (0.851) these result are in conformity with the findings of Kumar et.al [12] favorable and negligible association with total soluble solids (0.004). The leaf length exhibited positive and significant association with the number of leaves per plant (0.710), leaf area (0.864), stem girth (0.767), leaf stem ratio (0.385), and green fodder yield per plant (0.833). These results are consistent with past research published by Patil et *al*. [13] Khandelwal et al.[14]. There is a weak negativenon significant correlation (-0.012) between leaf length and total soluble solids.

Number of leaves per plant showed positive significant correlation with leaf area (0.751), stem girth (0.497), leaf stem ratio (0.311) and green fodder yield per plant (0.691) whereas negative but non-significant association with total soluble solids (-0.024) These results supplement the findings of Mengesha et al. [15]whereas negative but non-significant association with total soluble solids (-

0.024); Total soluble solids exhibited positive and non-significant correlation with number of leaf area (0.013), stem girth (0.168) and green fodder yield per plant (0.101) while negative significant association with leaf stem ratio (-0.326) This is in accordance with the report of Kumar and Singh [16]**.** Leaf area revealed positive and significant association with stem girth (0.738), leaf stem ratio (0.377) and green fodder yield per plant (0.841) Similar results were also reported by, Dubey et al.[17]. Stem girth noted positive significant correlation with green fodder yield per plant (0.857) These findings are in close confirmation with the results reported by Dev et al. [18**]**, whereas positive non-significant association with leaf stem ratio (0.176); Leaf stem ratio recorded positive and significant correlation with green fodder yield per plant (0.263).Similar results were also attained by Sumonthantet al[19].

The yield of green fodder per plant was significantly correlated at the genotypic level with leaf breadth (0.891), stem girth (0.885), leaf area (0.874), leaf length (0.871), number of leaves per plant (0.744), plant height (0.432), and leaf stem ratio (0.317). Days to 50% flowering (-0.032) had a negative but not statistically significant correlation with the yield of green fodder per plant. Total soluble solids and green fodder output per plant had a positive but negligible correlation (0.111). These outcomes generally concur with the finding Sirohi et al. [20] and Srivastava et al. [21].

Path coefficient analysis

Table 2 shows the analysis's findings in relation to the genotypic and phenotypic path coefficients to show the direct and indirect effects of each feature on the amount of green fodder yield by each plant. The genotypic correlation was further divided into direct and indirect effects using path coefficient analysis to obtain a clear picture of the relationship between the dependent variable and independent/contributing qualities.

At genotypic level, stem girth (0.523) displayed maximum order of direct effect on green fodder yield per plant followed by leaf breadth (0.417) and number of leaves per plant (0.175), and at phenotypic level, stem girth (0.448) displayed maximum order of direct effect on green fodder yield per plant followed by leaf breadth (0.351) and number of leaves per plant (0.109).

At genotypic level maximum negative direct effect showed for plant height (-0.063) followed by leaf length (-0.023) and leaf area (-0.007). At phenotypic level maximum negative direct effect showed for plant height (-0.065) followed by leaf length (-0.079) and leaf area (-0.096) which were similar with the findings ofDamor et al. [22].

At genotypic and phenotypic level attribute which contributed indirectly high to green fodder yield per plant were observed Leaf breadth via plant height, leaf length, number of leaves per plant, leaf area, stem girth and leaf stem ratio; Number of leaves per plant through leaf breadth, leaf length and leaf area; Stem girth via plant height, leaf breadth, leaf length, number of leaves per plant, leaf area and leaf stem ratio supporting the findings ofArunah et al. [23], Endalamaw et al. [24].

Conclusion

The study revealed a highly significant positive association between the number of leaves per plant, plant height, leaf stem ratio, leaf breadth, stem girth, leaf area, and leaf length. This suggests that selecting for these attributes could potentially increase the yield of fodder in sorghum. The association was observed at both the genotypic and phenotypic levels.Green fodder yield per plant and its contributing characters were analyzed using genotypic and phenotypic path coefficient analysis. The results indicated that stem girth had a high positive direct effect on green fodder yield per plant, followed by leaf breadth and number of leaves per plant at both genotypic and phenotypic levels. Improving these attributes was suggested to increase fodder yield. The character showing indirect effect viaanother component trait, indirect selection through such trait can lead to improvement in green fodder yield.

Table-1: Estimates of the correlation coefficients between various characteristics of forage sorghum (*Sorghum bicolor*L.Moench) at the genotypic (G) and phenotypic (P) levels.

Characters		Days to 50% flowering	Plant height (cm)	Leaf breadth (cm)	Leaf length (cm)	No.of leaves per plant	Total soluble solids (%)	Leaf area (cm^2)	Stem girth (mm)	Leaf stem ratio	Green fodder yield per plant (g)
Days to 50% flowering	G	1.000	-0.084	-0.137	-0.081	0.045	0.202	-0.126	-0.028	0.263*	-0.032
	P	1.000	-0.022	-0.091	-0.089	0.037	0.146	-0.078	-0.021	0.198*	-0.021
Plant height (cm)	G		1.000	0.483**	0.589**	0.374**	0.117	0.576**	0.447**	0.172	0.432**
	P		1.000	0.398**	0.467**	0.317**	0.100	0.469**	0.351**	0.180	0.354**
Leaf breadth (cm)	G			1.000	0.863**	0.780**	0.004	0.885**	0.729**	0.301**	0.891**
	P			1.000	0.791**	0.706**	0.004	0.831**	0.683**	0.252*	0.851**
Leaf length (cm)	G				1.000	0.772**	-0.015	0.925**	0.810**	0.469**	0.871**
	P				1.000	0.710**	-0.012	0.864**	0.767**	0.385**	0.833**
No. of leaves per plant	G					1.000	-0.027	0.826**	0.527**	0.372**	0.744**
	P					1.000	-0.024	0.751**	0.497**	0.311**	0.691**
Total soluble solids (%)	G						1.000	0.028	0.181	-0.382**	0.111
	P						1.000	0.013	0.168	-0.326**	0.101
Leaf area (cm^2)	G							1.000	0.776**	0.423**	0.874**
	P							1.000	0.738**	0.377**	0.841**
Stem girth (mm)	G								1.000	0.232	0.885**
	P								1.000	0.176	0.857**
Leaf stem ratio	G									1.000	0.317**
	P									1.000	0.263*
Green fodder yield per plant (g)	G										1.000
	P										1.000

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

Table-2: Path coefficient study demonstrating the genotypic and phenotypic effects of ten characters on the green fodder yield in forage sorghum (*Sorghum bicolor* L. Moench).

Characters		Days to 50% flowering	Plant height (cm)	Leaf breadth (cm)	Leaf length (cm)	No. of leaves per plant	Total soluble solids (%)	Leaf area (cm^2)	Stem girth (mm)	Leaf stem ratio
Days to 50% flowering	G	**0.004**	0.005	-0.057	0.002	0.008	0.009	0.001	-0.015	0.012
	P	**0.021**	0.001	-0.032	-0.007	0.004	0.005	-0.008	-0.009	0.003
Plant height (cm)	G	0.001	**-0.063**	0.202	-0.013	0.065	0.005	-0.004	0.233	0.008
	P	-0.002	**-0.065**	0.140	0.037	0.034	0.004	0.045	0.157	0.003
Leaf breadth (cm)	G	-0.001	-0.031	**0.417**	-0.020	0.136	0.003	-0.007	0.381	0.013
	P	-0.002	-0.026	**0.351**	0.062	0.077	0.005	0.080	0.306	0.004
Leaf length (cm)	G	0.001	-0.037	0.360	**-0.023**	0.135	-0.001	-0.007	0.423	0.021
	P	-0.002	-0.030	0.278	**-0.079**	0.077	0.001	0.083	0.344	0.006
No. of leaves per Plant	G	0.001	-0.024	0.326	-0.018	**0.175**	-0.002	-0.006	0.276	0.017
	P	0.003	-0.020	0.248	0.056	**0.109**	-0.001	0.072	0.222	0.005
Total soluble solids (%)	G	0.001	-0.007	0.002	0.000	-0.005	**0.043**	0.001	0.095	-0.017
	P	0.003	-0.007	0.001	-0.001	-0.003	**0.035**	0.002	0.075	-0.005
Leaf area (cm^2)	G	0.001	-0.037	0.369	-0.021	0.144	0.001	**-0.007**	0.406	0.019
	P	-0.002	-0.030	0.292	0.068	0.082	0.001	**-0.096**	0.330	0.005
Stem girth (mm)	G	0.002	-0.028	0.304	-0.018	0.092	0.008	-0.006	**0.523**	0.010
	P	0.003	-0.023	0.240	0.060	0.054	0.006	0.071	**0.448**	0.003
Leaf stem ratio	G	0.001	-0.011	0.126	-0.011	0.065	-0.016	-0.003	0.121	**0.045**
	P	0.004	-0.012	0.089	0.030	0.034	-0.011	0.036	0.079	**0.014**

Residual values (G) = 0.070   Residual values (P) = 0.113, Bold values indicate direct effects

References

[1] Chavhan, M., Jawale, L.N. and Bhutada, P.O. (2022). Correlation and path analysis studies in *kharif* sorghum [*Sorghum bicolor* (L.) Moench] inbred lines. *Journal of Pharmacognosy and Phytochemistry*, **11(4)**:140-144.

[2]Zeba A., Bibi, A., Fatima, B., Iqbai, M.A., Awais M.,Tahir, A., Shakil, Q.andZahid, I. (2022). Utilization of multivariate analysis to ascertain selection criteria for enhanced nutritious fodder yield and contributing attributes in sorghum [*sorghum bicolor* (L.) Moench] *Plant Cell Biotechnology and Molecular Biology*, **23(21&22)**:70-79.

[3] Shafiqurrahaman, M., Dahiya, G. S., Dehinwal, A. K., & Kumar, V. (2024). Genetic Diversity Analysis for Morphological Traits in Sorghum (*Sorghum bicolor* (L.) Moench). *Ekin Journal of Crop Breeding and Genetics*, **10(1)**:27-35.

[4]Reenu, Satyawan A., Manisha, Kavita R., Priyanka D. and Atman P., (2022).Exploiting the heterosis and correlation analysis studies in forage sorghum for quality improvement. *Forage Res.* **48(1)**:31-36.

[5] Fisher, R.A. (1918**).** The correlation among relatives on the supposition of Mendelian inheritance. *Trans. Royal Society of Edinberg*,**52**:399-43.

[6] Wright, S. (1921).Correlation and causation. *J. Agric. Res.*,**20**:557-585.

[7] Dewey, D. and Lu, K.H. (1959). A correlation and path coefficient analysis in crested wheat grass seed production. *Agron. J.*, **51**:515-518.

[8] Kumar, R., Singh, S.K., Chand, P., Kumar, M., Gupta, S. and Kumar, M. (2019**)**. Path analysis studies on forage Sorghum. *Journal of Experimental Zoology India*,**22(1)**:1474-1480.

[9] Pal, D., Pandey, P.K., Verma, S.K., Baskheti, D.C., Prasad, B. and Gaur, A.K. (2022).Assessment of genetic diversity in forage sorghum [*Sorghum bicolor* (L.) Moench] for fodder yield and its component traits using D^2 statistics. *The Pharma Innovation Journal*, **11(3)**:2190-2192.

[10] Singh, S.K., Singh, A. and Kumar, R. 2016. Genetic variability, character association and path analysis in forage sorghum. Progressive Agriculture, **16(2)**:214-218

[11] Jain, S.K., Elangovan, M. and Patel, N.V. (2017). Correlation and path coefficient analysis for agronomical traits in forage sorghum [*Sorghum bicolor*(L.) Moench]. *Indian Journal Plant Genet. Resou*., **23(1)**:15-1.

[12] Kumar, N. and Singh, S.K. 2012. Character association and path analysis in forage sorghum. Progressive Agriculture, **12(1)**:148-153.

[13] Patil, C.N., Rathod, A.H., Vaghela, P.O., Yadav, S.R., Patade, S.S. and Shinde, A.S. (2014). Study of correlation and path analysis in dual purpose sorghum [*Sorghum bicolor* (L.) Moench]. *International journal of agricultural science*, **10(2)**:608-611.

[14] Khandelwal, V., Shukla, M., Jodha, B.S., Nathawat, V.S. and Dashora, S.K. (2016**)**. Genetic parameters and character association in sorghum [*Sorghumbicolor*(L.) Moench]. *Indian Journal of Science and Technology*,**8(22)**:1-5.

[15] Mengesha, G.H., Hailemarian, F.M., Mindaye, T.T., Lakew, B. and Verma, R.P.S. 2019. Correlation and path analysis of yield, yield contributing and malting quality traits of Ethiopian sorghum [*Sorghum bicolor* (L.) Moench] genotypes. *African Journal of Plant Science*, **13(8)**:209-220.

[16] Kumar, N. and Singh, S.K. 2012. Character association and path analysis in forage sorghum. Progressive Agriculture, **12(1)**:148-153.

[17] Dubey, M.K., Pandey, P.K., Shrotria, P.K., Chauhan, P. and Pandey, G. 2016. Assessment of variability, correlation and path analysis for yield and yield related traits in sorghum genotypes. Green Farming, **7(6)**:1291-1295.

[18] Dev, A., Singh, S. K., Chand, P., Kumar, M., Kumar, M., Poonia, M. and Srivastava, M. 2019. Genetic variability, character association and path analysis in forage sorghum. *Journal of Pharmacognosy and Phytochemistry*, **8(5)**:1135-1139

[19] Sumonthant, Kumari, P., Pahuja, S.K., Tokas, J. and Yashveer, S. (2021). Identification of dual type sorghum genotypes based on correlation and path coefficient studies. *Forage Res.*,**46(4)**:302-307.

[20]Sirohi, M., Singh, S.K., Chand, P., Kumar, M., Gupta, S. and Kumar, M. (2019). Character association and path analysis in forage sorghum. *J. Exp. Zool. India*, **22(1)**:1469-1473.

[21] Srivastava, M., Singh, S.K., Chand, P., Kumar, M., Kumar, M., Gangwar, H.K. and Dev, A. (2019). Studies on path analysis in forage sorghum [*Sorghum bicolor* (L.) Moench]. *Journal of Pharmacognosy and Phytochemistry*,**8(5)**:993-996.

[22] Damor, H.I., Parmar, H.P., Gohil, D.P. and Patel, A.A. (2018). Genetic variability, character association and path coefficient in forage sorghum [*Sorghum bicolor* (L.) Moench]. *Green Farming*, **9(2)**:218-223.

[23] Arunah, U.L., Chiezay, U.F., Aliyu, L. and Ahmed, A. (2015). Correlation and path analysis between sorghum yield to growth and characters. *Journal of Biology*, **5(19)**:88-94.

[24] Endalamaw, C., Adugna, A. and Mohammed, H. (2017). Correlation and path coefficient analysis of agronomic and quality traits in a bioenergy crop, sweet sorghum [*Sorghum bicolor* (L.) Moench]. *African Journal of Biotechnology*, **16(47)**:2189-2200.

25. Arunkumar B. Genetic variability, character association and path analysis studies in sorghum (Sorghum bicolor (L) Moench). The Bioscan. 2013 Nov 26;8(4):1485-8.

26. Sihag N, Shrotria PK, Pandey PK. Correlation and Path Analysis of Sorghum [Sorghum bicolor (L.) Moench]. Current Journal of Applied Science and Technology. 2023 Oct 5;42(34):32-6.

27. Kumar R, Singh SK, Singh SV, Bagare V, Singh A, Yaday V, Chowdhury S, Mishra P. Correlation and Path Coefficient Analysis for Yield and It's Attributing Traits in Forage Sorghum [Sorghum bicolor (L) moench]. International Journal of Plant & Soil Science. 2023 Oct 4;35(20):818-23.