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Studies on character association and path analysis in forage sorghum

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Abstract
Sorghum bicolor, commonly called sorghum, is an often-cross pollinated crop with a chromosome number 2n=20. It belongs to the grass family Poaceae, subfamily Panicoidae, tribe Andropogonae, and the subtribe Sorghastrae. Sorghum being a short duration, drought and salt tolerant, well adaptive to arid regions is considered promising crop to overcome the fodder shortage in uncertain areas. The present investigation was carried out during *Kharif* season 2021 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. Green fodder yield exhibited significant stable and positive correlation with leaf area, leaves per plant and plant height at genotypic and phenotypic level. These characters may be considered as important yield component in forage sorghum. Leaf stem ratio displayed high order of direct effect on green fodder yield per plant followed by leaves per plant, leaf area, stem girth and total soluble solids at phenotypic and genotypic level, which indicated that the contribution of individual attributes to fodder yield is of importance in planning a sound breeding programme for developing for high yielding varieties.

Keywords: *Sorghum bicolor*, correlation, path analysis

Introduction

Sorghum is a wonderful multipurpose crop, which is used as food, fodder, fuel, sugar, fencing and brooms. In developing countries, sorghum is primarily used as a food and fodder crop, because of its wide range of adaptability to various agro-ecological conditions. Sorghum plays an important role as a major grain cum fodder crop is growing in many regions of the world due to its high productivity and ability to utilize efficiently water even under drought conditions. It is highly palatable and digestible than maize and pearl millet as for as the nutritional quality is concerned. Cereals and tuber crops are the primary sources of carbohydrates. Sorghum is one of the alternative cereal crops that can be used as carbohydrate sources, which is closely related to rice, corn and wheat. Sorghum has higher nutritional content than rice in protein, vitamins and essential minerals. Sorghum contains 8.90%-10.48% crude protein, 2.50%-3.70% fat, 1.40%-3.01% fiber and 61.24%-76.60% sugar. Based on vitamin contents, 100 g of sorghum seeds contained 0.13 mg vitamin B_2, 4.5 mg vitamin B_3 and 0.47 mg vitamin B_6 (Rachman *et al.* 2022) [7]. Sorghum grain is mostly used as food in Africa and Asia, but it is also used to feed cattle in the United States and Australia. Due to its versatile use as a source of food, feed, fodder and fuel, it is under cultivation in tropical, subtropical and even in temperate regions of the world as great millet. Sorghum ranks first among cereal fodder crops and is preferred over maize and pearl millet forage because of its high tolerance to wide variation in soil and moisture conditions and better regeneration capacity. Nutritionally, among the *kharif* fodders, sorghum is a crop par excellence with starch (63-68%), potential of high digestibility (50- 60%), dry matter (20-35%), calcium (0.53%) and phosphorus (0.24%). In addition to fodder purpose, the stalks from sorghum are used as an alternative for the production of syrups, jaggery, citric acids and modified starch. Due to these multipurpose uses from fodder sorghum, several crop improvement programs were made to maximize biomass production as sorghum is still considered a choice of crop for the marginal environment. In India, it is grown for food, feed and fodder purpose on an area of around 5.02 million hectares with 4.80 million tons of grain production per annum. Livestock is a backbone of Indian agriculture, likewise as the most vital component of the rural economy. In livestock production, feed and fodder constitute about 60-70% of the total cost.

Therefore, a continuous and steady supply of green fodder to the animals is essential to increase milk production and reduce livestock production costs. However, within the total net cropped area, hardly 5% is used to grow fodder. That's why, in recent years India is facing an acute shortage of feeds and fodder. The demand of green fodder will reach 1012 million tonnes and of dry fodder 631 million tonnes by 2050. At the present level of growth in forage resources, there will be an 18.4% deficit in green fodder and a 13.2% deficit in dry fodder within the year 2050. To meet out the deficit, green forage has to grow at 1.69% annually. There's little or no scope for increasing the cultivation area due to rapid urbanization and industrialization *etc*. Therefore, it is urgent to emphasize increasing forage crop production per unit area to meet the fodder requirement by evolving high yielding and improved varieties of forage crops (Pal *et al.* 2022) [4]. To fulfill the demands of continuously increasing population, maximizing the yield either fodder or grain is main objective of crop breeding and improvement programmes. Any plant breeding programme's success in developing improved varieties depends on the better understanding of nature and magnitude of genetic variability present within the breeding material. Correlation analysis measures the intensity and direction of associations among characters that are important in a breeding programme and path coefficient analysis allow partitioning of parametric statistic into direct and indirect effects of various traits and therefore help in assessing the cause effect relationship as well as effective selection.

Materials and Methods

The experiment was carried out using ten genotypes of forage sorghum *viz.*, UP Chari-2, HC-136, Pant Chari-2, CSV-17, Pusa Chari-6, Pusa Chari-9, Pusa Chari-23, CSV-15, Pant Chari-8 and Pant Chari-7 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during the season of *Kharif* 2020. All the possible 45 F_1's hybrids, excluding reciprocals were made among these ten genotypes and parents and crosses were evaluated in a completely randomized block design with three replications during *kharif* season 2021. Observations were recorded on the traits *viz*., days to 50% flowering, plant height (cm), leaf breadth (cm), leaf length (cm), stem girth (mm), leaves per plant, leaf area (cm^2), leaf stem ratio, total soluble solids (%) and green fodder yield (g/plant). Correlation estimated the association between various characters by Croxton and Cowden (1964) [2]. Path analysis among the various dependent and independent traits was calculated by Dewey and Lu (1959) [3].

Results and Discussion

Correlation coefficient provides information about the degree and direction of relationship between two or more variable. Correlation coefficient was estimated to find out the association of seed yield with different traits at both genotypic and phenotypic and compared for their significance against tabulated value at five and one per cent levels of significance. Correlation coefficients were calculated to study the association among different characters and are presented in table-1. The phenotypic correlation, in general was similar in sign and slightly higher in magnitude than their genotypic correlation which indicated influenced by the environmental factors, however the higher genotypic expression indicating the inherent relationship among the characters. Similar results were obtained by Sirohi *et al.* (2019) and Prasad and Sridhar (2020) [11, 6]. At phenotypic level, green fodder yield exhibited significant positive correlation with leaf area (0.68) followed by leaves per plant (0.57) and plant height (0.37). Days to 50% flowering emerged significant positive association with plant height (0.29); Plant height revealed significant positive correlation with leaf breadth (0.42), leaf length (0.28), stem girth (0.28), leaves per plant (0.33), leaf area (0.52) and green fodder yield (0.37); Leaf breadth showed significant positive association with leaf length (0.44); Leaf length exhibited significant positive correlation with stem girth (0.61) and leaves per plant (0.24); Stem girth noted significant positive association with leaves per plant (0.53); Leaves per plant recorded significant positive correlation with leaf area (0.50), leaf stem ratio (0.28) and green fodder yield (0.57) and Leaf area exhibited significant positive association with green fodder yield (0.68). At the genotypic level, the estimates of correlation coefficients were generally similar to that observed at the phenotypic level, though, their magnitude was slightly lower than the corresponding phenotypic correlations. Here, also green fodder yield per plant showed significant and positive correlation with leaf area (0.64) followed by leaves per plant (0.51) and plant height (0.34). These characters may be considered as important yield component in forage sorghum (Table-1). These results are similar to earlier reports of Srivastava *et al.* (2019), Singh *et al.* (2021) and Sheetal *et al.* (2021) [12, 10, 9]. At phenotypic level, leaf stem ratio (0.53) displayed high order of direct effect on green fodder yield followed by leaves per plant (0.51), leaf area (0.35), stem girth (0.30) and total soluble solids (0.13). However the character which contributed indirect effects toward green fodder yield per plant was observed plant height through days to 50% flowering, leaf breadth, leaf length, leaves per plant and leaf area; Leaves per plant via plant height, leaf length, stem girth and leaf area; Leaf area through plant height and leaves per plant (Table-2). At genotypic level, leaf stem ratio (0.49) displayed high order of direct effect on green fodder yield followed by leaves per plant (0.48), leaf area (0.32), stem girth (0.29) and total soluble solids (0.15) whereas, the attribute which contributed indirect effects toward green fodder yield per plant was observed plant height through days to 50% flowering, leaf breadth, leaf length, leaves per plant and leaf area; Leaves per plant via plant height, leaf length, stem girth and leaf area; Leaf area through plant height and leaves per plant (Table-2). Magnitudes of residual effects at both phenotypic and genotypic level were found to be low, which indicated that the contribution of individual attributes to fodder yield is of importance in planning a sound breeding programme for developing for high yielding varieties. These findings are in accordance with the results obtained in sorghum by Sameera *et al.* (2021), Chauhan and Pandey (2021) and Patil *et al.* (2022) [8, 1, 5].

Table 1: Estimates of genotypic (G) and phenotypic (P) correlation coefficients for different traits in forage sorghum (*Sorghum bicolor* L. Moench)

Parameters		**Days to 50% flowering**	**Plant height (cm)**	**Leaf breadth (cm)**	**Leaf length (cm)**	**Stem girth (mm)**	**Leaves per plant**	**Leaf area (cm^2)**	**Leaf stem ratio**	**Total soluble solids (%)**	**Green fodder yield (g/plant)**
Days to 50% flowering	G	1.00	0.27**	0.09	0.07	0.02	-0.09	-0.02	0.03	0.14	-0.06
	P	1.00	0.29*	0.10	0.03	0.06	-0.06	-0.01	0.02	0.12	-0.10
Plant height (cm)	G		1.00	0.38*	0.23**	0.33**	0.41**	0.63**	-0.14	-0.10	0.34**
	P		1.00	0.42*	0.28*	0.28**	0.33**	0.52**	-0.12	-0.07	0.37**
Leaf breadth (cm)	G			1.00	0.41**	0.07	0.11	0.07	-0.02	0.02	0.09
	P			1.00	0.44**	0.08	0.08	0.09	-0.04	0.01	0.07
Leaf length (cm)	G				1.00	0.58**	0.39**	0.05	-0.04	-0.12	-0.06
	P				1.00	0.61**	0.24**	0.08	-0.01	-0.09	-0.03
Stem girth (mm)	G					1.00	0.51**	0.01	-0.01	-0.08	-0.07
	P					1.00	0.53**	0.04	-0.01	-0.04	-0.06
Leaves per plant	G						1.00	0.46**	0.25**	-0.14	0.51**
	P						1.00	0.50**	0.28*	-0.11	0.57**
Leaf area (cm^2)	G							1.00	0.14	-0.11	0.64**
	P							1.00	0.12	-0.10	0.68**
Leaf stem ratio	G								1.00	-0.14	0.11
	P								1.00	-0.10	0.10
Total soluble solids (%)	G									1.00	0.09
	P									1.00	0.11
Green fodder yield (g/plant)	G										1.00
	P										1.00

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

Table 2: Estimates of direct and indirect effect of different characters on green fodder yield per plant in forage sorghum (*Sorghum bicolor* L. Moench)

Parameters		**Days to 50% flowering**	**Plant height (cm)**	**Leaf breadth (cm)**	**Leaf length (cm)**	**Stem girth (mm)**	**Leaves per plant**	**Leaf area (cm^2)**	**Leaf stem ratio**	**Total soluble solids (%)**
Days to 50% flowering	G	-0.01	0.21	0.05	-0.01	-0.03	-0.11	-0.02	0.06	-0.02
	P	-0.05	0.25	0.09	-0.03	-0.05	-0.06	-0.03	0.07	-0.04
Plant height (cm)	G	0.01	0.05	0.01	-0.04	-0.09	0.34	0.19	-0.02	0.01
	P	0.08	0.09	0.01	-0.01	-0.07	0.41	0.20	-0.03	0.06
Leaf breadth(cm)	G	0.05	0.29	0.06	-0.02	-0.01	0.06	0.05	-0.04	-0.02
	P	0.05	0.26	0.08	-0.07	-0.01	0.04	0.06	-0.08	-0.01
Leaf length (cm)	G	-0.01	0.21	0.02	-0.08	-0.12	0.21	0.01	-0.08	0.01
	P	-0.04	0.26	0.02	-0.09	-0.10	0.23	0.03	-0.09	0.04
Stem girth (mm)	G	-0.07	0.01	0.04	-0.10	0.29	0.28	0.01	-0.01	0.01
	P	-0.03	0.02	0.05	-0.10	0.30	0.30	0.03	-0.04	0.05
Leaves per plant	G	-0.01	0.22	0.06	-0.07	-0.15	0.48	0.13	-0.04	0.02
	P	-0.08	0.23	0.07	-0.09	-0.10	0.51	0.13	-0.05	0.01
Leaf area (cm2)	G	-0.01	0.33	0.01	-0.08	-0.01	0.17	0.32	0.02	0.01
	P	-0.04	0.35	0.03	-0.08	-0.09	0.26	0.35	0.05	0.02
Leaf stem ratio	G	0.02	-0.07	-0.01	-0.02	0.02	-0.08	0.04	0.49	0.01
	P	0.01	-0.11	-0.04	-0.07	0.01	-0.11	0.04	0.53	0.03
Total soluble solids (%)	G	0.06	-0.04	0.01	0.02	0.02	-0.08	-0.03	-0.01	0.15
	P	0.09	-0.06	0.02	0.08	0.10	-0.05	-0.04	-0.02	0.13

Residual values (G) 0.21 Residual values (P) = 0.27 Bold values indicate direct effect

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