RESEARCH ARTICLE Agricultural Science Digest, Volume 46 Issue 2: 214-219 (April 2026)

Study on Character Association and Path Coefficient Analysis in Forage Sorghum [*Sorghum bicolor* (L.) Moench]

Pushpendra[1], S.K. Singh[1], Mayank Tiwari[1], Nikhil[1], Rahul Singh Chauhan[1], Mukesh Kumar[1], Shri Kant[2], L.K. Gangwar[1]

10.18805/ag.D-6132

ABSTRACT

Background: Forage sorghum [*Sorghum bicolor* (L.) Moench] is a valuable crop known for its resilience, adaptability to diverse agro-climatic conditions and primary source of nutritional fodder. Correlation and path coefficient analysis provide valuable insights into the magnitude and direction of relationships among different traits, thereby aiding in the selection of superior genotypes. This study aims to explore the correlation patterns among key morphological and green fodder yield-related traits in forage sorghum and also determine the direct and indirect effects of these traits.

Methods: The experimental design involved ten diverse parents and their 45 F_1 hybrids, excluding reciprocals, in a half diallel fashion. The materials were evaluated using a complete randomized block design with three replications where data were collected on ten morphological and green fodder yield related traits: days to 50% flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant, leaf area, leaf stem ratio, total soluble solids and green fodder yield.

Result: Green fodder yield showed significant and positive correlations with plant height, leaf length, leaf breadth, stem girth, leaves per plant and leaf area at both genotypic and phenotypic levels. These traits are likely important components of yield in forage sorghum. Among these traits, leaf breadth exhibited the highest direct effect on green fodder yield per plant, followed by stem girth, leaf area, leaf stem ratio and leaves per plant at both phenotypic and genotypic levels. This suggests that the contributions of individual attributes to fodder yield are significant and should be considered in breeding programs aimed at developing high-yielding varieties.

Key words: Correlation coefficient, Forage sorghum, Path coefficient.

INTRODUCTION

Forage sorghum [*Sorghum bicolor* (L.) Moench] is a warm-season annual grass widely cultivated for its high biomass production and nutritional value. It is an important crop for livestock feed, particularly in regions with hot and arid climates where other forage options may be limited. Forage sorghum is known for its ability to withstand drought and heat stress, making it a resilient crop in challenging environments.

In terms of nutritional value, forage sorghum is comparable to corn silage, providing a good source of energy and fiber for ruminant animals. It is also known for its high sugar content, which can contribute to improved palatability and feed intake by livestock. Its forage contains over 50% digestible nutrients, including 8% protein, 2.5% fat and 45% nitrogen-free extract (NFE) (Sutariya *et al.,* 2013). Overall, forage sorghum is a valuable crop for farmers looking to enhance their livestock feed options, particularly in regions with challenging growing conditions. Its ability to thrive in hot and dry climates, coupled with its nutritional value, makes it a resilient and valuable addition to agricultural systems.

Sorghum is the world's fifth most important cereal after maize, rice, wheat and barley (Balakrishna *et al.* 2019). It is cultivated over 40 million hectares in 105 countries across Africa, Asia, Oceania and the Americas. Africa and India contribute to nearly 70% of the global sorghum area, with the USA, Mexico, Nigeria, Sudan and Ethiopia being the major sorghum producers. In India, sorghum is primarily utilized as a food, feed and forage crop. Additionally, it serves as a raw material for producing starch, fiber, dextrose syrup, biofuels, vinegar, alcohol and various other products. The major states in the country where this cereal grain is produced are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Rajasthan and Gujarat (Goswami *et al.,* 2020). In India, the cultivation area for this crop covers approximately 3.8 million hectares, yielding an annual

[1]Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250 110, Uttar Pradesh, India.

[2]Department of Genetics and Plant Breeding, Chaudhary Chhotu Ram (PG) College, Muzaffarnagar-251 001, Uttar Pradesh, India.

Corresponding Author: Pushpendra, Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250 110, Uttar Pradesh, India.
Email: puspendra230295@gmail.com

How to cite this article: Pushpendra, Singh, S.K., Tiwari, M., Nikhil, Chauhan, R.S., Kumar, M., Kant, S. and Gangwar, L.K. (2026). Study on Character Association and Path Coefficient Analysis in Forage Sorghum [*Sorghum bicolor* (L.) Moench]. *Agricultural Science Digest.* **46(2):** 214-219. doi: 10.18805/ag.D-6132.

Submitted: 22-07-2024 **Accepted:** 28-12-2024 **Online:** 18-02-2025

production of 4.15 million tonnes and productivity rate of 1092 kg/ha (FAO STAT, 2022).

The examination of relationships among traits is crucial for evaluating the potential for joint selection of two or more traits. Path coefficient analysis partition the correlation coefficient into direct and indirect effects of various traits on the dependent variable, aiding in more effective selection. It helps to clarify these correlations and provides insight into how component traits contribute to the identification of key traits. In addition to correlation studies, path coefficient analysis is valuable for understanding the various pathways through which component characters influence the improvement of fodder yield.

MATERIALS AND METHODS

The present study investigates the character associations and path coefficients between green fodder yield and its attributing traits in forage sorghum. The research was conducted at the Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) India during the *kharif* seasons of 2021 and 2022. Ten diverse parents were planted in well prepared field and forty five crosses were generated by half diallel crossing fashion in first sowing season during *kharif* 2021 (Table 1), In second season during *kharif* 2022 the forty five crosses along with ten parents were planted each in 2 row plot that measured 4 meters in randomized block design with three replication for evaluation. Ten important green fodder yield related traits were recorded *viz*. days to 50% flowering, plant height (cm), leaf length (cm), leaf breadth (cm), stem girth (cm), leaves per plant, leaf area $(cm)^2$, leaf stem ratio, total soluble solid (TSS) % and green fodder yield per plant(g) using five randomly selected plants from each plot. The correlation coefficient was estimated according to Fisher (1918) and Wright (1921) by the R software version 4.2.3 using corrplot package. The path analysis was investigated according to Dewey and Lu (1959) using indostat software.

RESULTS AND DISCUSSION

Distribution of mean parameters

The mean performance of 55 genotypes (10 parents and 45 F_1 Crosses) for 10 characters are given in Table 2. The mean for days to 50% flowering is 84.43, plant height mean was 308.28 cm, mean of leaf length was 75.92 cm, leaf breadth mean was 5.05 cm, mean of stem girth was 12.65 mm, leaves per plant mean was 11.50, mean of leaf area was 274.01 $(cm)^2$, leaf stem ratio mean was 0.19, mean of total soluble solid (TSS) was 12.58% and green fodder yield per plant mean was 216.42 g.

Correlation coefficient analysis

The correlation coefficients among yield and its component traits were estimated at both genotypic and phenotypic levels. The genotypic and phenotypic correlations are generally similar in sign but genotypic correlation was relatively higher than their corresponding phenotypic correlation among ten characters and the values are given in (Fig 1 and 2). At the phenotypic level, the green fodder yield showed a significant positive correlation with stem girth (0.76), followed by leaf area (0.67), leaf breadth (0.63), leaves per plant (0.56), leaf length (0.48) and plant height (0.35). However, days to 50% flowering did not show a

Table 1: Experimental material.

Parents	F_1 hybrid	F_1 hybrid
CSV-21	CSV-21 × CSV-17	GSF-5 × UP Chari-3
HC-260	CSV-21 × Pant Chari-8	GSF-5 × HC-136
Pusa Chari-615	HC-260 × Pusa Chari-615	GFS-5 × CSV-17
GFS-5	HC-260 × GFS-5	GFS-5 × Pant Chari-8
G-48	HC-260 × G-48	G-48 × Rajathan Chari-1
Rajasthan Chari-1	HC-260 × Rajathan Chari-1	G-48 × UP Chari-3
UP Chari-3	HC-260 × UP Chari-3	G-48 × HC-136
HC-136	HC-260 × HC-136	G-48 × CSV-17
CSV-17	HC-260 × CSV-17	G-48 × Pant Chari-8
Pant Chari-8	HC-260 × IC0597651	Rajathan Chari-1 × UP CHARI-3
	Pusa Chari-615 × GFS-5	Rajathan Chari-1 × HC-136
F_1 hybrid	Pusa Chari-615 × G-48	Rajathan Chari-1 × CSV17
CSV-21 × HC-260	Pusa Chari-615 × RajathanChari-1	Rajathan Chari-1 × Pant Chari-8
CSV-21 × Pusa Chari-615	Pusa Chari-615 × UP Chari-3	UP CHARI-3 × HC-136
CSV-21 × GFS-5	Pusa Chari-615 × HC-136	UP CHARI-3 × CSV-17
CSV-21 × G-48	Pusa chari-615 × CSV-17	UP Chari-3 × Pant Chari-8
CSV-21 × Rajathan Chari-1	Pusa Chari-615 × Pant Chari-8	HC-136 × CSV-17
CSV-21 × UP Chari-3	GSF-5 × G-48	HC-136 × Pant Chari-8
CSV-21 × HC-136	GSF-5 × Rajathan Chari-1	CSV-17 × Pant Chari-8

Table 2: Mean value with traits.

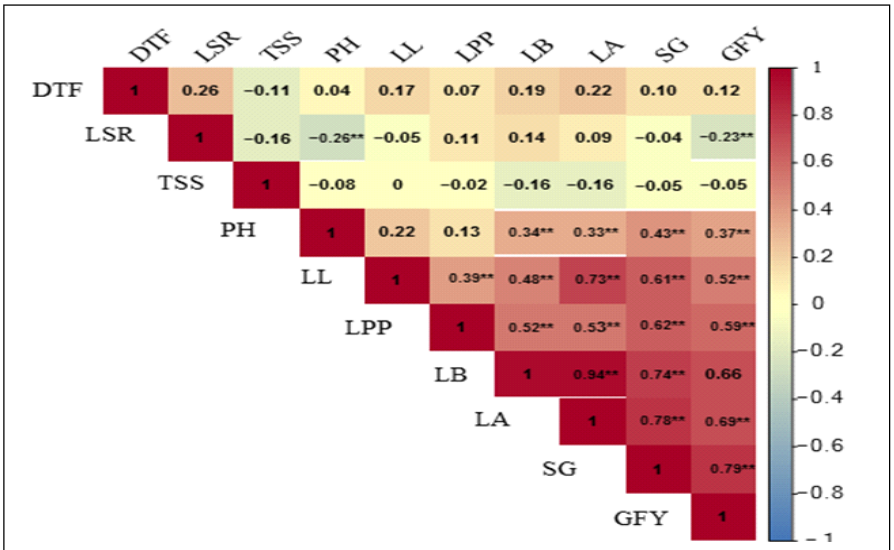
Traits name	Mean value
Days to 50% flowering	84.43 cm
Plant height	308.28 cm
Leaf length	75.92 cm
Leaf breadth	5.05 cm
Stem girth	12.65 mm
Leaves per plant	11.50
Leaf area	274.01 $(cm)^2$
Leaf stem ratio	0.19
Total soluble solid	12.58%
Green fodder yield	216.42 g

significant positive association with green fodder yield (0.11). Leaf stem ratio (-0.23) and total soluble solids (-0.05) exhibited a negative significant correlation with green fodder yield. Plant height showed a significant positive association with leaf breadth (0.35), stem girth (0.40), leaf area (0.34) and green fodder yield (0.35). Leaf length exhibited a significant positive correlation with leaf breadth (0.44), stem girth (0.56), leaves per plant (0.36), leaf area (0.70) and green fodder yield (0.48). Leaf breadth had a significant positive association with stem girth (0.70), leaves per plant (0.48), leaf area (0.93) and green fodder yield (0.63). Stem girth showed a significant positive correlation with leaves per plant (0.57), leaf area (0.74) and green fodder yield (0.76). Leaves per plant were significantly positively associated with leaf area (0.50) and green fodder yield (0.56). The similar result in forage sorghum with same traits was obtained by Iraddi *et al.* (2013); Rana *et al.* (2016) and Singh *et al.* (2023).

At the genotypic level, green fodder yield per plant exhibited a significant positive correlation with stem girth (0.79) followed by leaf area (0.69), leaf breadth (0.66), leaves per plant (0.59), leaf length (0.51) and plant height (0.37). Similar result on genotypic positive significant correlation was obtained by different studies like Prasad and Sridhar (2020); Arvinth *et al.* (2021) and Patil *et al.* (2022). In present investigation, the genotypic correlation coefficient was found to be higher than the phenotypic correlation coefficient, which is consistent with the finding of a previous study conducted by Thakur *et al.* (2023).

Analysis of direct and indirect effect

The results obtained at both genotypic and phenotypic levels are presented in Table 3. At the phenotypic level, leaf breadth (0.54) exhibited a high direct effect on green fodder yield, followed by stem girth (0.46), leaf area (0.41), leaf stem ratio (0.38) and leaves per plant (0.27). However, the character that contributed indirect effects toward green fodder yield per plant was observed in leaf breadth through leaf length (0.26) and stem girth (0.39); stem girth *via* plant height (0.19), leaf length (0.26), leaf breadth (0.32), leaves per plant (0.26) and leaf area (0.34) and leaf area through leaf length (0.27). The similar result has also been noticed by Damor *et al.* (2018); Sirohi *et al.* (2019) and Singh *et al.* (2022).

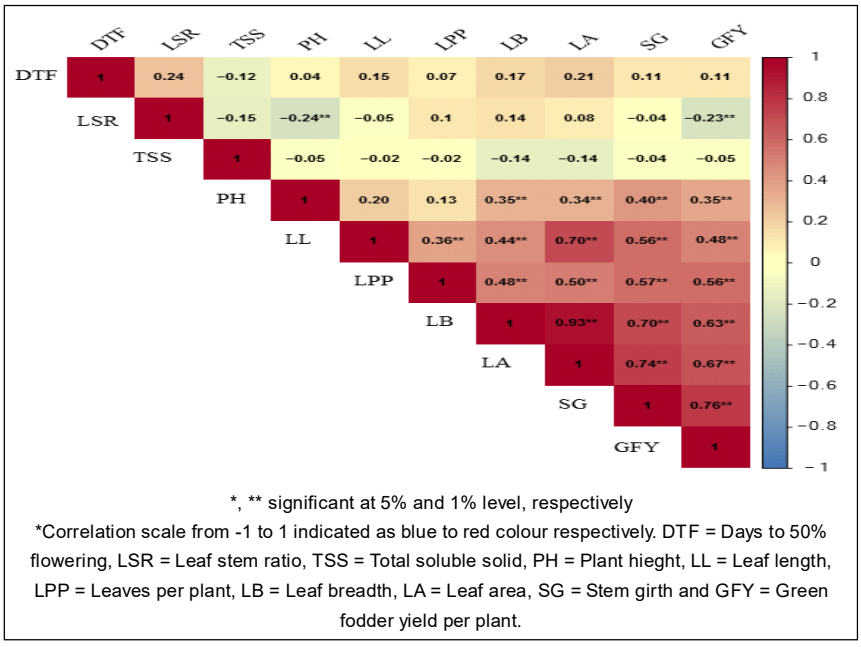


*, ** significant at 5% and 1% level, respectively

*Correlation scale from -1 to 1 indicated as blue to red colour respectively. DTF = Days to 50% flowering, LSR = Leaf stem ratio, TSS = Total soluble solid, PH = Plant hieght, LL = Leaf length, LPP = Leaves per plant, LB = Leaf breadth, LA = Leaf area, SG = Stem girth and GFY = Green fodder yield per plant.

Fig 1: Estimates of genotypic (G) correlation coefficient for various traits in forage sorghum [*Sorghum bicolor* (L.) Moench].

At the genotypic level, leaf breadth (0.49) exhibited a high direct effect on green fodder yield, followed by stem girth (0.49), leaf area (0.35), leaf stem ratio (0.31) and leaves per plant (0.21). The attribute that contributed indirect effects toward green fodder yield per plant was observed in days to 50% flowering through leaf area (0.21) and leaf stem ratio (0.25); leaf breadth through leaf length (0.24) and stem girth (0.37); stem girth via plant height (0.21), leaf length (0.29), leaf breadth (0.36), leaves per plant (0.30) and leaf area (0.38) and leaf area through leaf length (0.25). The magnitudes of residual effects at both the phenotypic and genotypic levels were found to be low residual values (Genotypic = 0.21 and Phenotypic = 0.27). The earlier finding by Singh *et al.* (2017); Prasad and Sridhar (2020); Shamini



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

*Correlation scale from -1 to 1 indicated as blue to red colour respectively. DTF = Days to 50% flowering, LSR = Leaf stem ratio, TSS = Total soluble solid, PH = Plant hieght, LL = Leaf length, LPP = Leaves per plant, LB = Leaf breadth, LA = Leaf area, SG = Stem girth and GFY = Green fodder yield per plant.

Fig 2: Estimates of phenotypic (G) correlation coefficient for various traits in forage sorghum [*Sorghum bicolor* (L.) Moench].

Table 3: 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 length (cm)	Leaf breadth (cm)	Stem girth (mm)	Leaves per plant	Leaf area (cm^2)	Leaf stem ratio	Total soluble solids (%)
Days to 50% flowering	G	**0.09**	-0.13	0.03	0.09	0.05	0.01	-0.08	-0.08	0.04
	P	**0.06**	-0.06	0.01	0.02	0.05	0.01	-0.02	-0.07	0.04
Plant height (cm)	G	0.03	**-0.03**	0.03	0.16	0.21	0.03	-0.12	0.08	0.02
	P	0.03	**-0.01**	0.02	0.18	0.19	0.03	-0.03	0.07	0.02
Leaf length (cm)	G	0.01	-0.08	**0.13**	0.24	0.29	0.08	0.25	0.02	0.01
	P	0.01	-0.02	**0.18**	0.26	0.26	0.07	0.27	0.01	0.03
Leaf breadth (cm)	G	0.09	-0.01	0.06	**0.49**	0.36	0.11	0.03	-0.04	0.02
	P	0.01	-0.03	0.03	**0.54**	0.32	0.10	0.10	-0.04	0.05
Stem girth (mm)	G	0.01	-0.01	-0.08	0.37	**0.49**	0.13	-0.07	0.02	0.02
	P	0.07	-0.05	-0.05	0.39	**0.46**	0.12	-0.08	0.01	0.01
Leaves per plant	G	0.07	-0.04	0.05	0.05	0.30	**0.21**	-0.09	-0.03	0.08
	P	0.05	-0.01	0.03	0.07	0.26	**0.27**	0.05	-0.03	0.07
Leaf area (cm^2)	G	0.21	-0.10	-0.09	0.06	0.38	0.11	**0.35**	-0.03	0.05
	P	0.01	-0.03	-0.06	0.03	0.34	0.11	**0.41**	-0.02	0.04
Leaf stem ratio	G	0.25	0.08	-0.07	0.07	-0.02	0.02	-0.03	**0.31**	0.06
	P	0.07	0.03	-0.04	0.02	-0.02	0.02	-0.01	**0.38**	0.05
Total soluble solids (%)	G	-0.01	0.02	-0.04	-0.08	-0.02	-0.04	0.05	0.05	**-0.04**
	P	-0.82	0.07	-0.05	-0.02	-0.02	-0.04	0.015	0.04	**-0.03**

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

and Selvi (2022) supported these results. Similar result were also reported in little millet by Amaravel *et al.* (2023).

On other hand, at genotypic level the maximum negative direct effect on green fodder yield was exhibited by total soluble solids (-0.04), followed by plant height (-0.03). However, negative direct effect at phenotypic level was observed with total soluble solids (-0.03) and plant height (-0.01). The negative indirect effect has been reported by Dev *et al.* (2019) and Singh *et al*. (2023).

CONCLUSION

The genotypic correlation coefficient was found to be slightly higher than the phenotypic correlation coefficient, indicating that it was less influenced by environmental factors, however the higher genotypic expression indicating the inherent relationship among the characters. This study manifested that green fodder yield showed significant and positive correlation with plant height, leaf length, leaf breadth, stem girth, leaves per plant and leaf area at genotypic and phenotypic level. The findings indicate that these traits have strong positive correlations with green fodder yield. So, in this context, these characters may be considered as important yield component in forage sorghum suggesting that these traits could be targeted for improvement in breeding programs.

The path coefficient analysis revealed that leaf breadth had a significant direct effect on green fodder yield per plant, followed by stem girth, leaf area, leaf stem ratio and leaves per plant at both the phenotypic and genotypic levels. This suggests that understanding the contribution of these individual attributes is crucial in planning of effective breeding programs for the development of high-yielding forage sorghum varieties.

ACKNOWLEDGEMENT

The present study was supported by the University fund of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, (UP) India.

Conflict of interest

The authors declare that they have no conflicts of interest.

REFERENCES

Amaravel, M., Nirmalakumari, A., Geetha, S., Sathya, K. and Renuka, R. (2023). Understanding the genetic basis of yield-related traits in little millet *(Panicum sumatrense* Roth. ex. Roem. and Schultz.) germplasm through association and diversity analysis. *Agricultural Science Digest*. **43(6):** 733-740. doi: 10.18805/ag.D-5766.

Arvinth, S., Patel, R.N., Gami, R.A. and Joshi, A.H. (2021). Genetic variability, character association and path analysis of forage sorghum [*Sorghum bicolor* (L.) Moench]. *Forage Res*. **47(2):** 153-158.

Balakrishna, D., Vinodh, R., Madhu, P., Avinash, S., Rajappa, P.V. and Bhat, B.V. (2019). Tissue Culture and Genetic Transformation in *Sorghum bicolor*. In Breeding Sorghum for Diverse End Uses. Woodhead Publishing. pp 115-130.

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.

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.

Dewey, D.R. and Lu, K.H. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal.* **51:** 515-518.

Faostat (2022). Food and Agriculture Organization of the United Nations.

Fisher, R.A. (1918). The correlation among relatives on the supposition of Mendelian inheritance. *Trans. Royal Society of Edinberg.* **52:** 399-433.

Goswami, S.J., Patel, P.T., Gami, R.A., Patel, R.N. and Khatri, A.B. (2020). Correlation and path analysis study of different characters for grain yield and fodder purpose in sorghum [*Sorghum bicolor* (L.) Moench]. *Electronic Journal of Plant Breeding.* **11(4):** 1053-1061.

Iraddi, V., Raddy, T.D., Umakanth, A.V., Rani, C., Raddy, V.V. and Bhave, M.H.V. (2013). Genetic variability, heritability and character association studies in sweet sorghum [*Sorghum bicolor* (L.) Moench]. *Journal of Research ANGRAU*. **41(1):** 30-38.

Patil, R.C., Kalpande, V.V. and Thawari, S.B. (2022). Correlation studies in land races of *kharif* sorghum [*Sorghum bicolor* (L.) Moench]. *The Pharma Innovation Journal*. **11(1):** 562-564.

Prasad, B.V.V. and Sreedhar, V. (2020). Assessment of variability, correlation and path analysis for yield and yield related traits in yellow pericarp sorghum germplasm lines [*Sorghum bicolor* (L.) Moench]. *Journal of Pharmacognosy and Phytochemistry.* **9(1):** 870-873.

Prasad, B.V.V. and Sridhar, V. (2020). Estimation of genetic diversity for yield in yellow pericarp sorghum germplasm line [*Sorghum bicolor* (L.) Moench]. *Journal of Pharmacognosy and Phytochemistry*. **9(1):** 833-836.

Rana, H.R., Prajapati, K.N., Suthar, K.J. and Kher, H.R. (2016). Study of variability, correlation and path analysis in sorghum [*Sorghum bicolor* (L.) Moench]. *The Bioscan.* **11(1):** 259-263.

Shamini, K. and Selvi, B. (2022). Association studies in sorghum for stay green and yield associated traits. *J. of Curr. Crop Sci. Technol.* **109(1):** 7-9.

Singh, A., Singh, S.K., Chand, P., Kerkhi, S.A., Kumar, M. and Singh, R.V. (2017). Variability, character association and path analysis studies in forage sorghum. *Journal of Plant Development Science*. **9(7):** 691-694.

Singh, M., Singh S.K., Gangwar L.K., Chand, P. and Kumar, M. (2022). Studies on character association and path analysis in forage sorghum. *The Pharma Innovation Journal*. **11(7):** 3421-3424.

Singh, S.K., Singh, M., Gangwar, L.K. and Singh, B. (2023). Study on path analysis in forage sorghum [*Sorghum bicolor* (L) moench]. *International Journal of Farm Sciences* **13(1):** 81-86.

Sirohi, M., Singh, S.K., Chand, P., Kumar, M., Gupta, S. and Kumar, M. (2019). Character association and path analysis in forage sorghum. *Journal of Experimental Zoology India*. **22(1):** 1469-1473.

Sutaria, G.S., Ramdevputra, M.V., Ansodaria, S.V. and Akbari, K.N. (2013). Effects of potassium and zinc nutrition on yield and quality of forage sorghum. *Indian Journal of Agricultural Research.* **47(6):** 540-544.

Thakur, B.S., Thakur, A., Mehta, D.K., Dogra, R.K. and Kansal, S. (2023). Character association and path analysis in heterotic recombinant inbred lines in garden pea (*Pisum sativum* L.). *Agricultural Science Digest*. **43(5):** 581-586. doi: 10.18805/ag.D-5303.

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