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CORRELATION COEFFICIENT AND PATH ANALYSIS IN GRAIN SORGHUM (*Sorghum bicolor* L. Moench)

Netram[1]*, Hemlata Sharma[1], Anushka Kuntal[1], Sunder Nayak[2], Deepak Gupta[3]* and Jogendra Singh[3]

[1]Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

[2]Sardarkrushinagar Dantiwada Agricultural University, Dantiwada, Gujarat, India

[3]Department of Genetics and Plant Breeding, Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan, India

*Corresponding author E-mail: netramchanania@gmail.com

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ABSTRACT

Sorghum (*Sorghum bicolor* (L.) Moench) is an important cereal crop known for its adaptability to arid and semi-arid regions. The present investigation was conducted during *kharif* 2023 at the Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur, to study character association and genetic diversity among sorghum genotypes. The experiment was laid out in an augmented block design comprising 60 test genotypes along with three standard checks (CSV-23, CSV-17 and PRJ-1), where test entries were non-replicated and checks were replicated across blocks. Each genotype was grown in a single 3 m row with a spacing of 45 × 15 cm. Data on fourteen agronomic and quality traits were recorded and subjected to correlation and path coefficient analysis. The results revealed that grain yield per plant exhibited significant positive correlations with number of leaves per plant, stem girth, flag leaf length, panicle length, 100-seed weight, biological yield, harvest index and protein content, whereas negative associations were observed with days to 50% flowering and plant height. Path analysis indicated that number of leaves per plant, panicle length, plant height, protein content, dry fodder yield, days to 50% flowering and days to maturity had positive direct effects on grain yield, while stem girth and biological yield showed negative direct effects. The residual effect (0.2343) indicated that 76.57% of the variability in grain yield was explained by the traits studied. The findings suggest that panicle length, number of leaves per plant, biological yield and harvest index may serve as effective selection criteria for improving grain yield in sorghum under Udaipur conditions.

***Keywords* :** Sorghum, Correlation, Path analysis, Yield components, Genotypes, Rajasthan.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop in the world after wheat, rice, maize and barley and ranks third in India after wheat and rice. It originated in Ethiopia and belongs to the family Poaceae, exhibiting wide genetic diversity (FAOSTAT, 2023). Sorghum is broadly classified into five major races namely Bicolor, Guinea, Caudatum, Durra and Kafir along with their intermediate forms (Harlan and de Wet, 1972). In India, it is popularly known as "Jowar" and is an important dryland crop used for both food and fodder purposes (Rao *et al.*, 2010).

Sorghum is a C4 plant with high photosynthetic efficiency which enables better utilization of sunlight, water and nutrients under high temperature and moisture stress conditions (House, 1985). Because of its exceptional drought and heat tolerance, it is often referred to as the "Camel of Crops" (Doggett, 1988). In India, sorghum is cultivated over about 14.21 lakh hectares with a production of 17.54 lakh tonnes and productivity of 1234 kg ha^{-1} during 2024–25. In Rajasthan, it covers 6.41 lakh hectares with 5.43 lakh tonnes production and productivity of 846 kg ha^{-1} (UPAg–Unified Portal for Agricultural Statistics, 2024–25).

Sorghum is considered a dual-purpose crop providing both grain and fodder for human and livestock consumption (Paterson *et al*., 2009). The grain is used for flour, traditional foods and alcohol production, while the crop residue and green biomass serve as important livestock feed (Taylor *et al.,* 2006). Forage sorghum is valued for its rapid growth, adaptability and high biomass yield (Kumar *et al*., 2011). When harvested at about 50 percent flowering, it contains around 9–10 percent crude protein and balanced fibre content suitable for feeding livestock (FAO, 2018). However, young sorghum plants may accumulate hydrocyanic acid (HCN), which can be toxic to animals; therefore, proper harvesting stage is necessary (Pundir and Singh, 2017).

Grain yield in sorghum is a complex quantitative trait controlled by several component characters such as plant height, panicle length, grains per panicle and test weight. Correlation analysis helps in determining the association among these traits and identifying characters contributing to yield improvement (Falconer and Mackay, 1996). However, correlation alone does not indicate the direct and indirect effects of traits. Path coefficient analysis, which partitions correlation into direct and indirect effects among traits, was originally proposed by Sewall Wright (1921) and later applied in plant breeding studies by Dewey and Lu (1959). Therefore, correlation and path analysis are important tools for identifying key yield contributing traits and formulating effective selection strategies in sorghum breeding programmes (Tirfessa *et al*., 2020).

Materials and Methods

The present investigation was conducted during kharif 2023 at the Instructional Research Farm of Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, India. The experimental site is located in the sub-humid southern plain and Aravalli hill agro-climatic zone of Rajasthan at an altitude of about 582 m above mean sea level. The region experiences a sub-tropical climate characterized by hot summers and mild winters. The average annual rainfall of the area is about 600–650 mm, most of which is received during the south-west monsoon season from June to September. The soil of the experimental field was clay loam in texture, moderately fertile, well drained and slightly alkaline in reaction.

The experimental material consisted of 60 sorghum genotypes along with three standard checks, namely CSV-23, CSV-17 and PRJ-1. The experiment was laid out in a augmented block design with three checks (CSV-23, CSV-17 and PRJ-1) and four blocks. Each genotype was sown in a single row of 3 m length with a spacing of 45 cm between rows and 15 cm between plants. All recommended agronomic practices and plant protection measures were followed to raise a healthy crop.

Observations were recorded on fourteen quantitative traits namely days to 50 percent flowering, days to maturity, plant height, number of leaves per plant, stem girth, flag leaf length, panicle length, panicle width, grain yield per plant, dry fodder yield per plant, 100-seed weight, biological yield per plant, harvest index and protein content.

The genotypic and phenotypic correlation coefficients among grain yield and its component characters were estimated using variance and covariance components following the method suggested by Fisher (1954) and Al-Jibouri *et al*. (1958). The significance of correlation coefficients was tested using the t-test with (n−2) degrees of freedom as described by Panse and Sukhatme (1985). Further, the correlation coefficients were partitioned into direct and indirect effects through path coefficient analysis using the method proposed by Dewey and Lu (1959). The analysis was carried out at the genotypic level to determine the relative contribution of different characters towards grain yield per plant and to identify the most important traits for effective selection in sorghum breeding programmes.

Result and Discussion

The estimates of genotypic and phenotypic correlation coefficients among fourteen traits in sorghum are presented in Table 1. In general, the magnitude of genotypic correlation coefficients was slightly higher than the corresponding phenotypic correlations for most of the characters, indicating that the observed associations among traits were largely governed by genetic factors and less influenced by environmental effects. Similar findings have been reported in sorghum by Prabhakar *et al*. (2020) and Tirfessa *et al*. (2020).

Grain yield per plant exhibited significant positive correlation with several yield contributing traits at both genotypic and phenotypic levels. A strong positive association of grain yield per plant was observed with biological yield per plant (rp = 0.8539; rg = 0.8726), harvest index (rp = 0.5477; rg = 0.5588), 100-seed weight (rp = 0.2612; rg = 0.2687) and protein content (rp = 0.1990; rg = 0.2017). The positive association of grain yield with biological yield and harvest index suggests that genotypes producing higher biomass and efficient partitioning of assimilates towards grains contribute significantly to yield improvement. Similar relationships between grain yield and biological yield have also been reported by Upadhyaya *et al.* (2016) and Reddy *et al.* (2013) in sorghum.

Days to 50 percent flowering showed a significant negative correlation with grain yield per plant (rp = -0.9340; rg = -0.9576), indicating that early flowering genotypes tended to produce higher yield under the experimental conditions. Plant height also exhibited a significant negative association with grain yield (rp = -0.9271; rg = -0.9586), suggesting that taller plants might allocate more assimilates towards vegetative growth rather than grain production. Similar negative associations (1988) and Kumar *et al.* (2011).

Among yield component traits, panicle length showed a strong positive association with grain yield (rp = 0.8613; rg = 0.8817), indicating that longer panicles may accommodate more grains and thereby enhance yield potential. Likewise, panicle width and number of leaves per plant also exhibited positive relationships with grain yield, although the magnitude of correlation was comparatively moderate. These findings are in agreement with the result reported by Paterson *et al.* (2009).

Stem girth exhibited a significant positive correlation with grain yield (rp = 0.2116; rg = 0.2159), which indicates that thicker stems may support better translocation of assimilates towards developing grains. Similarly, flag leaf length showed a positive association with grain yield (rp = 0.1737; rg = 0.1770), suggesting that larger leaf area may contribute to higher photosynthetic activity and biomass accumulation. Such relationships between morphological traits and yield have also been reported by Rao *et al.* (2010).

Dry fodder yield per plant showed a non-significant positive correlation with grain yield, indicating that improvement in fodder yield may not necessarily reduce grain yield in dual-purpose sorghum genotypes. However, it exhibited a strong negative association with protein content, suggesting a possible trade-off between fodder biomass and grain quality traits.

Days to 50 per cent flowering showed a strong positive correlation with days to maturity and plant height, indicating that late flowering genotypes tended to mature later and attain greater plant height. A similar positive association between days to flowering and days to maturity has been reported earlier by Upadhyaya *et al.* (2016), suggesting that these traits are developmentally linked and influenced by similar genetic factors.

Days to maturity exhibited a positive correlation with plant height and biological yield per plant, indicating that genotypes with longer growth duration accumulated greater vegetative biomass. Such relationships between maturity period and plant height in sorghum were also observed by Reddy *et al.* (2013), who reported that longer duration genotypes generally produce more vegetative growth.

Number of leaves per plant showed a strong positive association with stem girth and 100-seed weight, indicating that plants with more leaves tend to develop thicker stems and heavier seeds due to enhanced photosynthetic surface area. Similar findings were reported by Patel *et al.* (2018), who observed that an increased number of leaves contributes to improved plant vigour and seed development in sorghum.

Stem girth exhibited a significant positive correlation with 100-seed weight, harvest index and dry fodder yield per plant. This suggests that plants with thicker stems are able to support better nutrient translocation and biomass production. Similar associations between stem girth, seed weight and fodder yield were also reported by Rani *et al.* (2017) in sorghum.

Flag leaf length showed positive association with panicle length, biological yield per plant and protein content. The flag leaf is considered an important photosynthetic organ contributing assimilates to the developing panicle; therefore, longer flag leaves may enhance panicle development and grain quality. Similar results were also reported by Upadhyaya *et al.* (2016), who observed that flag leaf traits play an important role in determining productivity and grain quality.

Panicle length exhibited significant positive correlation with 100-seed weight, biological yield per plant and harvest index, suggesting that longer panicles may facilitate better seed development and efficient partitioning of assimilates. Similar results were reported by Reddy *et al.* (2013), who noted that panicle traits are major contributors to yield improvement in sorghum.

Panicle width showed a positive association with biological yield per plant and dry fodder yield per plant, indicating that wider panicles are often associated with greater biomass production. Likewise, 100-seed weight showed a significant positive correlation with biological yield per plant and dry fodder yield per plant, suggesting that increased seed weight is linked with better plant productivity. Similar relationships among seed weight and biomass traits have been reported by Patel *et al.* (2018).

Protein content exhibited positive correlation with flag leaf length, panicle length and harvest index, indicating that improvement in these traits may also contribute to better grain quality in sorghum. Similar associations between protein content and yield related traits have been reported earlier by Rani *et al*. (2017).

Overall, the correlation analysis indicated that biological yield per plant, harvest index, panicle length and 100-seed weight were the most important traits positively associated with grain yield. Therefore, these characters may serve as reliable selection criteria for improving grain yield in sorghum breeding programmes. Similar conclusions have been drawn by Upadhyaya *et al.* (2016) and Prabhakar *et al.* (2020), who emphasized the importance of these traits in sorghum yield improvement.

These results suggest that simultaneous improvement of biological yield, harvest index and panicle characteristics could significantly enhance grain yield in sorghum genotypes. However, correlation analysis alone does not reveal the direct and indirect effects of these traits; therefore, path coefficient analysis was carried out to determine the relative contribution of each trait towards grain yield.

Path coefficient analysis at the genotypic level revealed the magnitude of direct and indirect effects of different characters on grain yield per plant in sorghum. Among the studied traits, number of leaves per plant exhibited a high positive direct effect on grain yield, indicating that plants with more leaves contribute to higher photosynthetic capacity and improved assimilate production. Panicle length also showed a strong positive direct effect on grain yield, suggesting that longer panicles enhance grain bearing capacity and ultimately increase yield potential. Similar observations regarding the importance of panicle traits in determining grain yield in sorghum were reported by Upadhyaya *et al*. (2016).

Stem girth showed a comparatively high direct effect on grain yield, indicating that thicker stems support better plant vigour and efficient translocation of nutrients to developing grains. Flag leaf length also exhibited a positive direct effect, suggesting that longer flag leaves enhance photosynthetic activity and supply assimilates to the developing panicle. These findings are in agreement with earlier reports by Reddy *et al.* (2013), who emphasized the role of leaf and stem characters in improving sorghum productivity.

Panicle width and 100-seed weight recorded positive but comparatively smaller direct effects on grain yield. The positive direct effect of 100-seed weight indicates that improvement in seed size contributes to higher grain productivity. Similar results were reported by Patel *et al*. (2018), who observed that seed weight plays a significant role in determining yield potential in sorghum.

Biological yield per plant showed a high negative direct effect on grain yield but exerted a strong positive genotypic correlation with grain yield through indirect effects via panicle length, harvest index and other yield components. Harvest index also exhibited a positive direct effect on grain yield, indicating that efficient partitioning of assimilates from vegetative parts to grains contributes significantly to higher productivity. Similar results highlighting the importance of harvest index in sorghum yield improvement were reported by Rani *et al*. (2017).

Protein content exhibited a moderate positive direct effect on grain yield, indicating that improvement in grain quality traits may also contribute to yield improvement. Dry fodder yield per plant showed a moderate positive direct effect on grain yield, suggesting that plants producing higher fodder biomass may also contribute to better overall productivity. Overall, the path analysis indicated that traits such as number of leaves per plant, panicle length, stem girth, flag leaf length and harvest index play an important role in influencing grain yield in sorghum and therefore should be considered in selection programmes for yield improvement.

The residual effect was estimated at 0.2343, indicating that the characters included in the present study explained 76.57% of the variation in grain yield per plant, while the remaining 23.44% was contributed by other unstudied factors. These findings collaborate with earlier reports by Arunkumar (2013), Khadakabhavi *et al.* (2017), Rohila *et al.* (2020), Chavan *et al.* (2022) and Bharda *et al.* (2023).

Table 1 : Estimation of genotypic and phenotypic correlation coefficients for different traits in sorghum

Characters	R	Days to 50 percent flowering	Days to maturity	Plant height (cm)	Number leaves per plant	Stem girth (cm)	Flag leaf length (cm)	Panicle length (cm)	Panicle width (cm)	100 seeds weight (g)	Biological yield per plant (g)	Harvest index (%)	Dry fodder yield per plant (g)	Protein content (%)	Grain yield per plant (g)
Days to 50 per cent flowering	rp	1	0.8553	0.9866*	-0.0411	0.1576	0.1828*	-0.9446	-0.2614*	0.2366	0.9407	-0.5909	-0.1479*	0.1762	-0.9340*
	rg	1	0.8688	1.0162*	0.0431	0.1602	0.1875*	0.9692	-0.2674*	0.2394	0.9630	0.5998	-0.1486*	0.1795	-0.9576*
Days to maturity	rp		1	0.8662	-0.0614	0.1786	0.0900*	-0.8122	0.3313	0.2977	0.8136*	0.2801	0.2050	0.0496	0.7890
	rg		1	0.8872	-0.0643	0.1802	0.0912*	0.8273	0.3374	0.3016	0.8269*	0.2860	0.2068	0.0494	0.8046
Plant height (cm)	rp			1	0.1004	-0.2224*	0.1688	-0.9292*	-0.2251	0.2939	0.9250	-0.6114**	-0.1818	0.1455	-0.9271*
	rg			1	0.102	-0.2254*	0.1732	-0.9613*	0.2293	0.3030	0.9514	-0.6323**	0.1847	0.1490	-0.9586*
Number of leaves per plant	rp				1	0.9429*	0.0384	0.0002	-0.0705	0.6418*	-0.0049	0.1771	0.2304*	-0.1528*	0.1134*
	rg				1	0.9569*	0.0393	0.0013	-0.0715	0.6501*	-0.0084	0.1798	0.2303*	-0.1539*	0.1183*
Stem girth (cm)	rp					1	-0.048	0.1094	-0.0202	0.7054*	0.1150	0.1250*	0.2589**	-0.1566*	0.2116**
	rg					1	0.0493	0.1096	0.0213	0.7144*	0.1169	0.1285*	0.2594**	-0.1569*	0.2159**
Flag leaf length (cm)	rp						1	0.1503*	-0.0145	-0.1400	0.1846	0.2302*	-0.1866	0.2483*	0.1737*
	rg						1	0.1522*	-0.0144	-0.1412	0.1878	0.2327*	-0.1870	0.2497*	0.1770*
Panicle length (cm)	rp							1	-0.2173	0.3683*	0.9897*	0.6507**	-0.1412	0.1638	0.8613*
	rg							1	0.2231	0.3722*	1.0116*	0.6648**	0.1438	0.1662	0.8817*
Panicle width (cm)	rp								1	-0.0784	0.2191*	-0.2634	0.2913*	-0.1925	0.2504
	rg								1	0.0801	0.2273*	-0.2667	0.2950*	-0.1979	0.2590
100 seed weight (gm)	rp									1	0.3471**	-0.1953	0.3176*	-0.1772*	0.2612*
	rg									1	0.3527**	0.1978	0.3197*	-0.1777*	0.2687*
Biological yield per plant (gm)	rp										1	0.6575*	-0.1321	0.1642	0.8539*
	rg										1	0.6727*	0.1348	0.1654	0.8726*
Harvest index (%)	rp											1	-0.0736	0.3107*	0.5477*
	rg											1	-0.0741	0.3159*	0.5588*
Dry fodder yield per plant (gm)	rp												1	-0.8924	0.1579
	rg												1	-0.8952	0.1603
Protein content (%)	rp													1	0.1990*
	rg													1	0.2017*
Grain yield per plant (gm)	rp														1
	rg														1

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

Table 2 : Path coefficient analysis showing the direct and indirect effect of different traits on grain yield per plant at genotypic levels in sorghum

Characters	Days to 50 percent lowering	Days to maturity	Plant height (cm)	Number of leaves per plant	Stem girth (cm)	Flag leaf length (cm)	Panicle length (cm)	Panicle width (cm)	100-seeds weight (g)	Biological yield per plant (g)	Harvest index (%)	Dry fodder yield per plant (g)	Protein content (%)	Genotypic correlation with grain yield per plant (g)
Days to 50 per cent flowering	**0.3556**	0.3090	0.3614	0.0153	0.0570	0.0667	0.3446	0.0951	0.0851	0.3425	0.2133	0.0528	0.0638	-0.9576*
Days to maturity	0.2535	**0.2918**	0.2589	-0.0188	0.0526	0.0266	0.2414	0.0984	0.0880	0.2413	0.0835	0.0603	0.0144	0.8046
Plant height (cm)	0.4859	0.4242	**0.4782**	0.0488	0.1078	0.0828	0.4597	0.1096	0.1449	0.4549	0.3024	0.0883	0.0712	-0.9586*
Number of leaves per plant	0.0309	-0.0462	0.0732	**0.7177**	0.6867	0.0282	0.0009	-0.0513	0.4665	-0.0060	0.1291	0.1672	-0.1105	0.1183*
Stem girth (cm)	-0.1097	-0.1235	-0.1545	-0.6557	**-0.6852**	-0.0338	-0.0751	-0.0146	-0.4895	-0.0801	-0.0881	-0.1777	0.1075	0.2159**
Flag leaf length (cm)	0.0064	0.0031	0.0059	0.0013	0.0017	**0.0341**	0.0052	-0.0005	-0.0048	0.0064	0.0079	-0.0064	0.0085	0.1770*
Panicle length (cm)	0.4640	0.3961	0.4602	0.0006	0.0525	0.0729	**0.4787**	0.1068	0.1782	0.4843	0.3183	0.0689	0.0796	0.8817*
Panicle width (cm)	0.0042	0.0053	0.0036	-0.0011	0.0003	-0.0002	0.0035	**0.0156**	0.0013	0.0036	-0.0042	0.0046	-0.0031	0.2590
100 seed weight (gm)	-0.0001	-0.0001	-0.0001	-0.0002	-0.0003	0.0100	-0.0001	0.0120	**-0.0004**	-0.0001	-0.0001	-0.0001	0.0001	0.2687*
Biological yield per plant (gm)	-0.6175	-0.5302	-0.6100	0.0054	-0.0750	-0.1204	-0.6486	-0.1458	-0.2262	**-0.6412**	-0.4313	-0.0864	-0.1061	0.8726*
Harvest index (%)	-0.0492	-0.0235	-0.0519	-0.0148	-0.0105	-0.0191	-0.0545	0.0219	-0.0162	-0.0552	**-0.082**	0.0061	-0.0259	0.5588*
Dry fodder yield per plant (gm)	0.0554	0.0771	0.0688	0.0868	0.0967	-0.0697	0.0536	0.1100	0.1192	0.0502	-0.0276	**0.3727**	-0.3336	0.1603
Protein content (%)	0.0782	0.0215	0.0649	-0.0671	-0.0684	0.1088	0.0724	-0.0862	-0.0774	0.0721	0.1376	-0.3900	**0.4357**	0.2017*

Residual effect : 0.305

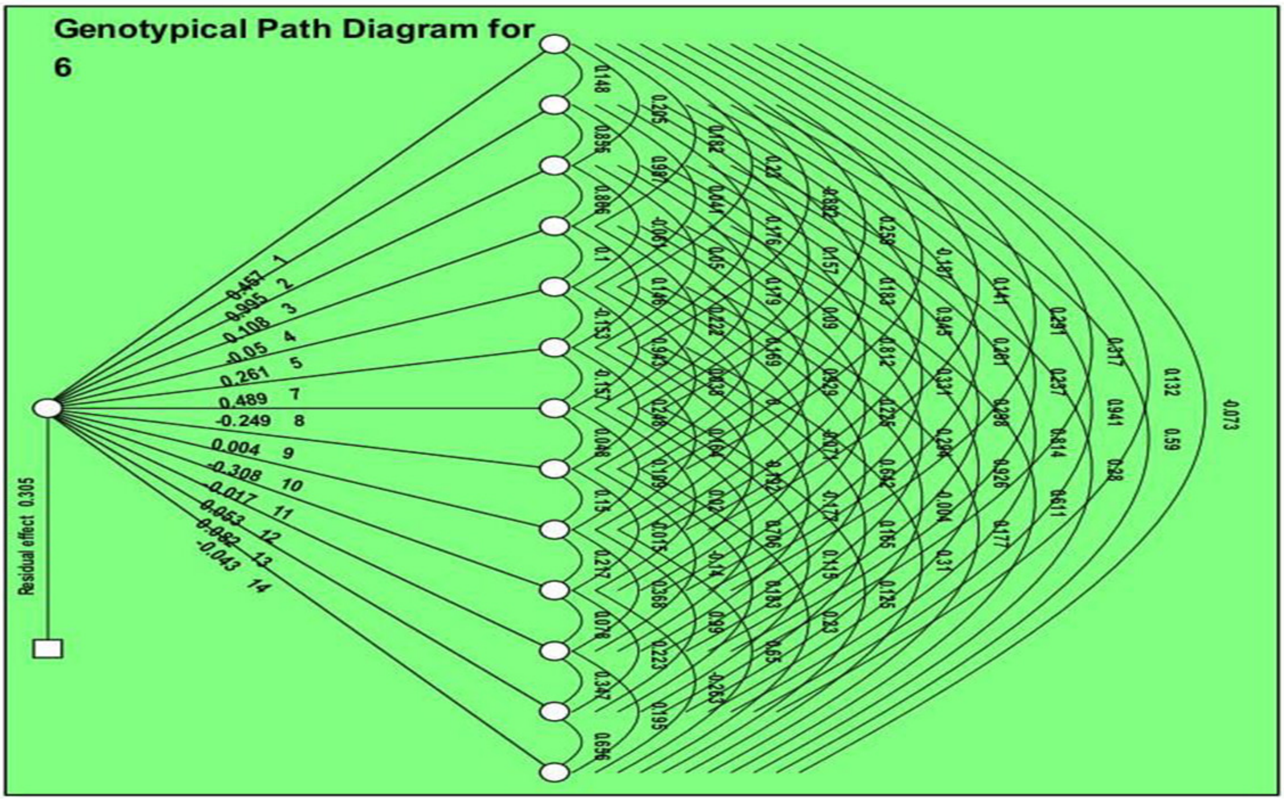

Fig. 1 : Genotypic Path Diagram

Conclusion

The present study revealed significant variability among sorghum genotypes, indicating good scope for selection. Grain yield per plant showed strong positive association with biological yield, harvest index, panicle length and 100-seed weight. Negative correlation with days to 50 percent flowering and plant height suggested the superiority of early and moderately short genotypes. Path analysis indicated that number of leaves per plant, panicle length, stem girth, flag leaf length and harvest index had positive direct effects on yield. Although biological yield showed negative direct effect, it contributed indirectly through other traits. The residual effect indicated that most of the variability in yield was explained by the studied characters. Therefore, selection based on these key traits would be effective for improving grain yield in sorghum. Overall, the study provides useful insights for developing high yielding sorghum genotypes through efficient selection strategies.

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