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Character association and cause-effect analysis of yield-contributing traits in sorghum [*Sorghum bicolor* (L.) Moench] genotypes

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ABSTRACT

Grain yield in sorghum is a complex, polygenically controlled trait that seldom responds well to selection when handled in isolation, making an understanding of how it is built from its component characters essential for efficient breeding. The current investigation was carried out on the same set of twenty-two diverse sorghum genotypes examined earlier for genetic variability and divergence, evaluated in a Randomised Block Design with three replications during rabi 2025-26 at the Research Farm, School of Agricultural Sciences, G. H. Raison University, Saikheda, Madhya Pradesh, India, to work out the genotypic and phenotypic correlation of grain yield per plant with ten component traits and of resolving these correlations into their direct and indirect components through path coefficient analysis. Genotypic correlations were generally higher than the corresponding phenotypic correlations for most characters, indicating a strong inherent genetic association that is partly masked at the phenotypic level by environmental influences. Harvest index ($r_g = 0.9075$, $r_p = 0.8821$) and biological yield per plant ($r_g = 0.8417$, $r_p = 0.7779$), together with panicle length and panicle width ($r_g = 0.87-0.89$), recorded a strong, highly significant, positive association with grain yield at both levels. At the same time, the vegetative and phenological traits showed weak or, in the case of days to 50% flowering, a significant negative phenotypic association with yield. Path analysis showed that harvest index exerted by far the highest direct effect on grain yield, both genotypically (0.883) and phenotypically (0.694), closely matching its correlation coefficient and thereby confirming it as the most dependable trait for direct selection; biological yield per plant was the second most consistent direct contributor (0.316 and 0.514, respectively). In marked contrast, panicle length and, more so, panicle width exerted only a modest, or even negative, direct effect despite their high positive correlation with yield; this association was transmitted almost entirely indirectly through harvest index and biological yield, reflecting the very high mutual correlation between the two panicle traits. The vegetative traits had small positive direct effects that were consistently and substantially offset by negative indirect effects operating through harvest index, explaining their weak or negative net correlation with grain yield. With a negligible residual effect (0.0014 genotypic; 0.0009 phenotypic), the ten component traits accounted for almost the entire variation observed in grain yield, validating the choice of causal traits. These results indicate that a selection index built around harvest index, biological yield per plant and panicle dimensions, rather than reliance on any single trait, offers the most efficient route to grain yield improvement in sorghum.

Keywords: *Sorghum bicolor*, Genotypic correlation, Phenotypic correlation, Path coefficient analysis, Direct effect, Indirect effect, Harvest index, Grain yield

Introduction

Sorghum bicolor remains one of the most dependable cereals of the semi-arid tropics, valued for its resilience to drought and heat and for the multiple roles it plays as food, feed, fodder, and industrial raw material across large parts of Africa and Asia (1). Grain yield, however, is not a simple, independently inherited character; it is the result of a chain of developmental and physiological processes and is therefore influenced simultaneously, and often unequally, by a large number of component traits (2). Selection practised on yield alone, without reference to the traits that build it up, is consequently slow and unreliable, and breeders have long relied on the study of trait interrelationships to make selection more precise and efficient.

The simplest way of quantifying such interrelationships is the correlation coefficient, which measures the degree and direction of association between two characters and may be partitioned into a genotypic and a phenotypic component, the former reflecting the true, heritable association arising from pleiotropy and genetic linkage, and the latter also carrying the influence of the environment (3, 13). A trait that is strongly and heritably correlated with grain yield is, in principle, an efficient basis for indirect selection. Correlation alone,

however, cannot distinguish a real, causal contribution to yield from one that is merely borrowed from another, more strongly acting trait through their mutual association, and when several component traits are themselves highly intercorrelated, as is frequently the case for morphological and yield traits, simple correlation coefficients can be misleading regarding which trait to select for.

Path coefficient analysis, first proposed by Wright (4) and adapted for use in plant selection by Dewey and Lu (5), overcomes this limitation by partitioning each correlation coefficient into a direct effect, representing the trait's own causal contribution to yield, and a series of indirect effects, representing its contribution mediated through the other component traits, thereby offering a far more dependable basis for choosing selection criteria than correlation coefficients alone. Correlation and path coefficient studies conducted on sorghum across a range of germplasm and agro-ecologies have repeatedly demonstrated that the identity of the traits exerting a genuine direct effect on grain yield, as opposed to those merely correlated with it, varies with the germplasm and the growing conditions under study (2, 6-9), underscoring the need for germplasm- and location-specific correlation and path analysis rather than extrapolation from unrelated material.

A companion investigation on the present set of twenty-two sorghum genotypes, conducted at the same location and during the same crop season, had already established wide genetic variability, high heritability for all eleven traits studied, and a distinct pattern of genetic divergence resolved through Mahalanobis's D^2 statistic and Tocher's clustering (10); it showed, in particular, that grain yield per plant combined high heritability with high genetic advance as a percentage of the mean, a combination pointing to the presence of exploitable additive gene action, while none of the ten remaining traits, evaluated individually, offered the same promise. What that earlier investigation could not address, since it dealt with the extent of variability and divergence rather than with the architecture of the yield trait itself, is precisely how these ten component traits act upon grain yield, and whether their association with it is direct or is merely transmitted through other, more influential traits.

Beyond the choice of parents and traits, two complementary developments are worth noting here. Participatory plant breeding, in which farmers evaluate and select material alongside breeders in their own fields, has been shown to shorten the varietal development and adoption cycle considerably and is increasingly favoured for delivering locally relevant, better-adopted cultivars (18). Equally, any genetic gain achieved through trait-based selection can only be expressed in the field if the resulting seed establishes well at sowing, a requirement increasingly met through seed priming, a simple pre-sowing hydration treatment shown to improve germination, seedling vigour and early stress tolerance (19). The correlation and path coefficient analysis reported here is therefore best viewed as one link, albeit a fundamental one, in this larger chain running from trait dissection to field delivery. The present investigation was therefore undertaken on the same genetic material to (i) work out the genotypic and phenotypic correlation of grain yield per plant with ten yield-contributing traits, and (ii) partition these correlations into their direct and indirect effects through path coefficient analysis, to identify the traits that would serve as the most dependable basis for selection for grain yield improvement in sorghum under the Saikheda agro-climatic conditions.

Materials and methods

Experimental site, plant material and crop management

The present investigation used the same experimental material, site and crop season as the companion study on genetic variability and divergence in this germplasm (10): twenty-two sorghum genotypes (SPV-2831, SPV-2048, SPV-1830, SPV-1626, RSV-458, RSLG-2438, B-35, 774-B, PJ-1430, PJ-2510, PC-1080, RC-2, SSG-59-3, CSV-10, CSV-23, CSH-17, SU-1557, SU-1570, SU-1708, PR-105, SSV-74 and SSV-84) were evaluated in a Randomised Block Design with three replications during the rabi season of 2025-26 at the Research Farm, School of Agricultural Sciences, G. H. Rasoni University, Saikheda,

Madhya Pradesh, India (21.51° N, 78.76° E). Full details of the plot layout, spacing, fertiliser dose, agronomic package of practices and the meteorological conditions prevailing during the crop season are reported in the companion paper (10) and are not repeated here.

Observations recorded

Observations were recorded, as before (10) with reference of other field crops too (14, 15) on five randomly selected and tagged plants in each plot of every replication for eleven quantitative traits: days to 50 per cent flowering (DF50), days to maturity (DM), plant height (PH, cm), stem girth (SG, cm), leaf length (LL, cm), leaf width (LW, cm), panicle length (PaL, cm), panicle width (PaW, cm), grain yield per plant (GY, g), biological yield per plant (BY, g) and harvest index (HI, %). Days to 50 per cent flowering and days to maturity were recorded on a plot basis, while the remaining nine traits were recorded on the 5 tagged plants and averaged to a plot mean. Grain yield per plant was treated as the dependent (effect) variable, and the remaining 10 traits as the causal (independent) variables for the correlation and path analyses reported here.

Statistical analysis

Genotypic and phenotypic variance-covariance components for all possible pairs of the eleven traits were first derived from the Randomised Block Design analysis of variance, and genotypic and phenotypic correlation coefficients were then computed from these components following the standard method of Al-Jibouri *et al.* (3) as elaborated by Singh and Chaudhary (11, 16-17). Path coefficient analysis was carried out separately on the genotypic and the phenotypic correlation matrices, with grain yield per plant as the dependent variable and the remaining ten traits as causal variables, following the procedure of Wright (4) as adapted for plant breeding use by Dewey and Lu (5); each correlation coefficient of a component trait with grain yield was thereby partitioned into a direct effect (the standardised partial regression coefficient of that trait on grain yield) and a set of indirect effects transmitted through every other causal trait, and the residual effect was worked out as the square root of $(1 - R^2)$, R^2 being the coefficient of multiple determination of the ten causal traits on grain yield. All computations, including the correlation and path coefficient matrices, were performed in R (version 4.5.1) using the 'metan' package (12). The correlograms and path-effect matrices (Table 1-4) were rendered as heatmaps using R graphics, with the significance of each correlation coefficient tested against the tabulated values for $(n - 2)$ degrees of freedom at the 5 per cent and 1 per cent levels of probability.

Results and discussion

Genetic variability

As reported in detail in the companion study on this material (10), all eleven traits recorded highly significant genotypic mean squares. Broad-sense heritability was high (81.59-97.61%) for every trait (Fig. 1). Genetic advance as a percentage of the mean, however, was high only for grain yield per plant (25.45%), and low to moderate for the remaining ten traits (11.47-18.56%), which by itself gives little indication of how these traits actually act upon grain yield, or of which among them would make the most efficient basis for indirect selection. Similar findings have also been reported for other cereal crops (14). This is precisely the gap that the correlation and path coefficient analysis reported below was designed to close.

Genotypic and phenotypic correlation among yield-contributing traits

The genotypic and phenotypic correlation coefficients among the eleven traits are presented in Tables 1 & 2, respectively, with genotypic values above the diagonal and phenotypic values below it. For almost every pair of traits, the genotypic correlation was of a somewhat higher magnitude than the corresponding phenotypic correlation, a pattern also noted by Mohammedi Begum *et al.* (7) in sorghum, and one that points to a strong inherent genetic association

between these traits that is partly diluted at the phenotypic level by environmental variation.

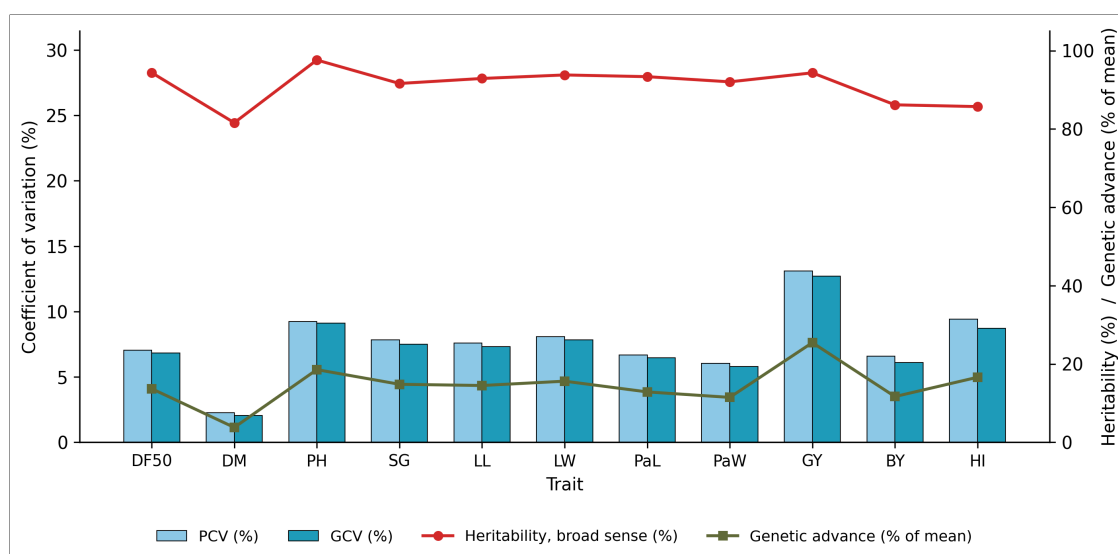


Figure 1. Phenotypic and genotypic coefficients of variation, broad-sense heritability and genetic advance as a percentage of the mean for eleven quantitative traits in the 22 sorghum genotypes (reproduced from the companion study, ref. 10, for context).

Two distinct groups of traits emerged from the correlogram. The first, comprising the vegetative and phenological traits, days to 50 per cent flowering, days to maturity, plant height, stem girth, leaf length and leaf width, were all strongly and significantly positively intercorrelated with one another at both levels ($r_g = 0.74-0.99$), reflecting the tightly coordinated nature of vegetative development in this crop. The second group, comprising panicle length, panicle width, grain yield, biological yield and harvest index, was likewise strongly and positively intercorrelated internally ($r_g = 0.68-0.96$), but showed little or no significant correlation with the first group. Grain yield per plant recorded strong, highly significant, positive correlation with panicle length ($r_g = 0.8713$, $r_p = 0.8202$), panicle width ($r_g = 0.8945$, $r_p = 0.8397$), biological yield per plant ($r_g = 0.8417$, $r_p = 0.7779$) and harvest index ($r_g = 0.9075$, $r_p = 0.8821$) at both levels, while its correlation with the vegetative traits was weak and, for the most part, statistically non-significant; days to 50 per cent flowering was the sole exception, recording a significant negative phenotypic correlation with

grain yield ($r_p = -0.3803$) even though the corresponding genotypic correlation, though larger in magnitude ($r_g = -0.3989$), fell short of significance.

A particularly informative feature of Table 1 & Table 2 is the strong, significant negative correlation of harvest index with every one of the vegetative traits ($r_g = -0.43$ to -0.63), a pattern consistent with a resource-partitioning trade-off in which excessive vegetative growth, taller plants, thicker stems and broader leaves, competes with, rather than supports, the proportion of biomass ultimately converted into grain. Similar antagonism between plant stature and yield efficiency has been noted in sorghum by Angadi and Somu (6), who reported a significant negative correlation of grain yield with plant height. In the present material, this antagonism appears to act specifically through the harvest index rather than directly through grain yield. This distinction could only be resolved by extending the analysis to both direct and indirect effects, as done below.

Table 1: Genotypic correlation coefficients among eleven quantitative traits in 22 sorghum genotypes

Traits	DF50	DM	PH	SG	LL	LW	PaL	PaW	GY	BY	HI
DF50	1 **										
DM	0.9239 **	1 **									
PH	0.9006 **	0.8636 **	1 **								
SG	0.8374 **	0.7387 **	0.9655 **	1 **							
LL	0.8502 **	0.8052 **	0.9855 **	0.9935 **	1 **						
LW	0.8366 **	0.796 **	0.9784 **	1.0031 **	0.9892 **	1 **					
PaL	-0.0972	0.1117	0.1284	0.2251	0.2766	0.2657	1 **				
PaW	-0.0352	0.1834	0.1622	0.2083	0.305	0.2574	0.9619 **	1 **			
GY	-0.3989	-0.2092	-0.1856	-0.1363	-0.0557	-0.0823	0.8713 **	0.8945 **	1 **		
BY	0.0281	0.1128	0.3231	0.4219	0.4516 *	0.4382 *	0.8905 **	0.8846 **	0.8417 **	1 **	
HI	-0.6318 **	-0.4049	-0.5305 *	-0.5292 *	-0.4292 *	-0.4607 *	0.6769 **	0.7186 **	0.9075 **	0.5375 **	1 **

Where, ** $P \leq 0.01$: significant at 1% level; * $P \leq 0.05$: significant at 5% level, DF50 = days to 50% flowering, DM = days to maturity, PH = plant height (cm), SG = stem girth (cm), LL = leaf length (cm), LW

= leaf width (cm), PaL = panicle length (cm), PaW = panicle width (cm), GY = grain yield per plant (g), BY = biological yield per plant (g), and HI = harvest index (%).

Table 2: Phenotypic correlation coefficients among eleven quantitative traits in 22 sorghum genotypes

Traits	DF50
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Table 2: Phenotypic correlation coefficients among eleven quantitative traits in 22 sorghum genotypes

DF50	1 **	DM										
DM	0.7738 **	1 **	PH									
PH	0.8642 **	0.7542 **	1 **	SG								
SG	0.784 **	0.6468 **	0.909 **	1 **	LL							
LL	0.7941 **	0.6881 **	0.9333 **	0.922 **	1 **	LW						
LW	0.7912 **	0.6847 **	0.938 **	0.9287 **	0.9367 **	1 **	PaL					
PaL	-0.0917	0.1092	0.1198	0.2005	0.2484 *	0.2343	1 **	PaW				
PaW	-0.029	0.1467	0.1617	0.1881	0.277 *	0.2283	0.909 **	1 **	GY			
GY	-0.3803 **	-0.1851	-0.1817	-0.1223	-0.0629	-0.0775	0.8202 **	0.8397 **	1 **	BY		
BY	0.014	0.1419	0.2947 *	0.3386 **	0.3963 **	0.3858 **	0.8262 **	0.7968 **	0.7779 **	1 **	HI	
HI	-0.5668 **	-0.3725 **	-0.4896 **	-0.4368 **	-0.3907 **	-0.405 **	0.5875 **	0.6386 **	0.8821 **	0.3916 **	1	1 **

Genotypic path coefficient analysis

The genotypic path coefficients, with grain yield per plant as the dependent variable and the remaining ten traits as causal variables, are presented in Table 3, the bold diagonal cells giving the direct effect of each trait and the off-diagonal cells in each row giving its indirect effect transmitted through the trait named in that column. The residual effect was negligible (0.0014), indicating that the ten causal traits together accounted for nearly all of the genotypic variability in grain yield and that the choice of causal traits for this analysis was appropriate.

The harvest index recorded the far highest direct effect on grain yield (0.883). This value was very nearly equal to its total correlation with grain yield (0.9075), confirming that the strong association between the two traits is overwhelmingly a direct, causal one rather than one borrowed from other traits; harvest index is therefore the single most dependable trait for direct phenotypic selection for grain yield in this material. This finding closely parallels that of Rao *et al.* (9), who likewise reported the harvest index as the trait with the highest direct effect on grain yield in sorghum (0.9125 at the genotypic level), lending external support to the present result. Biological yield per plant was the second most substantial direct contributor (0.316), again in reasonably close agreement with its correlation coefficient (0.8417), making it, together with harvest index, the most trustworthy basis for indirect selection identified in this study.

Panicle length and panicle width told a rather different story. Despite recording among the highest correlations with grain yield of any trait studied ($r_g = 0.8713$ and 0.8945 , respectively), their own direct effects were modest for panicle length (0.183) and actually negative for panicle width (-0.213). The bulk of their correlation with grain yield was instead transmitted indirectly, chiefly through harvest index (0.598 and 0.635, respectively) and, to a lesser extent, through biological yield per plant (0.281 and 0.279). Since panicle length and panicle width were themselves very highly inter-correlated ($r_g = 0.9619$), this divergence between a high total correlation and a small or negative direct effect is a classic signature of multicollinearity among causal traits (5), and cautions against selecting directly on panicle width in isolation, since its true, unconfounded contribution to yield, once the influence of harvest index and biological yield is accounted for, is small. A broadly comparable caution regarding the interpretation of panicle-related traits under path analysis was also raised by

Mohammedi Begum *et al.* (7) in their study of sorghum yield components.

The vegetative and phenological traits, days to 50 per cent flowering, days to maturity, plant height, stem girth, leaf length and leaf width, all possessed small. In most cases, positive, direct effects on grain yield (0.09 to 0.23), indicating that, considered on their own, these traits are not inherently detrimental to yield. In every case, however, this positive direct contribution was substantially, and in several cases almost entirely, cancelled out by a large negative indirect effect transmitted through harvest index (-0.36 to -0.56), which explains why their net correlation with grain yield was weak, and in the case of days to 50 per cent flowering, negative. Plant height illustrates this especially clearly: its direct effect (0.233) was the largest recorded among the vegetative traits and would, on its own, indicate a favourable contribution to yield, yet its net correlation with grain yield was weak and non-significant ($r_g = -0.1856$) once the strongly negative indirect path through harvest index (-0.469) is added back. This pattern reinforces the resource-partitioning interpretation offered above, that vegetative vigour in this material acts principally by depressing harvest index rather than by depressing grain yield directly, and that a compact, harvest-index-efficient plant type, rather than one selected for greater height, leaf size or duration, would better serve grain yield improvement.

Where, $**P \leq 0.01$: significant at 1% level; $*P \leq 0.05$: significant at 5% level, DF50 = days to 50% flowering, DM = days to maturity, PH = plant height (cm), SG = stem girth (cm), LL = leaf length (cm), LW = leaf width (cm), PaL = panicle length (cm), PaW = panicle width (cm), GY = grain yield per plant (g), BY = biological yield per plant (g), and HI = harvest index (%).

Phenotypic path coefficient analysis

The phenotypic path coefficients (Table 4) reinforced the pattern already established at the genotypic level, with an even smaller residual effect (0.0009), again confirming that the ten causal traits accounted for practically all of the phenotypic variation in grain yield. Harvest index (0.694) and biological yield per plant (0.514) remained, by a clear margin, the two traits with the largest direct effects on grain yield, and both values corresponded closely with their respective phenotypic correlation coefficients (0.8821 and 0.7779), confirming that these two associations hold up under field conditions and are not merely genotypic artefacts.

Table 3: Genotypic path coefficients showing the direct (bold diagonal) and indirect (off-diagonal) effects of ten component traits on grain yield per plant in 22 sorghum genotypes.

Traits	DF50	DM	PH	SG	LL	LW	PaL	PaW	BY	HI
DF50	0.09255	-0.17715	0.20952	-0.04413	0.07947	0.00024	-0.01783	0.00748	0.00887	-0.55794
DM	0.08551	-0.19175	0.20093	-0.03893	0.07527	0.00023	0.02048	-0.03898	0.0356	-0.35754
PH	0.08335	-0.1656	0.23265	-0.05088	0.09212	0.00028	0.02354	-0.03447	0.10193	-0.46853
SG	0.07751	-0.14165	0.22464	-0.0527	0.09288	0.00029	0.04128	-0.0443	0.13311	-0.46739
LL	0.07868	-0.1544	0.22927	-0.05236	0.09348	0.00028	0.05072	-0.06482	0.14249	-0.37907

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Table 3: Genotypic path coefficients showing the direct (bold diagonal) and indirect (off-diagonal) effects of ten component traits on grain yield per plant in 22 sorghum genotypes.

LW	0.07742	-0.15264	0.22763	-0.05286	0.09247	0.00028	0.04872	-0.05472	0.13826	-0.4069
PaL	-0.009	-0.02141	0.02987	-0.01186	0.02586	0.00008	0.1834	-0.20445	0.28095	0.59783
PaW	-0.00325	-0.03516	0.03773	-0.01098	0.02851	0.00007	0.1764	-0.21255	0.27909	0.63462
BY	0.0026	-0.02163	0.07516	-0.02223	0.04222	0.00012	0.16331	-0.18802	0.3155	0.47468
HI	-0.05847	0.07763	-0.12343	0.02789	-0.04013	-0.00013	0.12415	-0.15274	0.16958	0.88313
Residual 0.0014										

Consistent with the genotypic-level analysis, the direct effects of panicle length (-0.012) and panicle width (-0.003) on grain yield were negligible, or even marginally negative, at the phenotypic level as well, despite their substantial phenotypic correlation with grain yield (0.8202 and 0.8397, respectively); here too, the association was transmitted almost entirely indirectly, through biological yield per plant (0.424 and 0.409) and harvest index (0.408 and 0.443). The direct effects of the six vegetative and phenological traits were all close to zero at the phenotypic level (-0.012 to 0.028), with their already-weak

correlation with grain yield again explained chiefly by a negative indirect path through harvest index (-0.26 to -0.39). The close agreement between the genotypic and phenotypic path patterns for every trait studied strengthens confidence that harvest index and biological yield per plant are genuinely causal determinants of grain yield in this material, and not associations confounded by the environment, and that they can be relied upon for direct selection with reasonable certainty.

Table 4: Phenotypic path coefficients showing the direct (bold diagonal) and indirect (off-diagonal) effects of ten component traits on grain yield per plant in 22 sorghum genotypes.

Traits	DF50	DM	PH	SG	LL	LW	PaL	PaW	BY	HI
DF50	-0.00973	-0.00393	0.00969	0.02267	-0.0089	-0.00526	0.00109	0.0001	0.00719	-0.39324
DM	-0.00753	-0.00507	0.00846	0.01873	-0.00771	-0.00455	-0.00129	-0.00051	0.07287	-0.2585
PH	-0.00841	-0.00383	0.01122	0.02626	-0.01046	-0.00623	-0.00142	-0.00056	0.15134	-0.33961
SG	-0.00762	-0.00328	0.01017	0.02775	-0.0103	-0.00612	-0.00241	-0.00062	0.17352	-0.30339
LL	-0.00772	-0.00349	0.01047	0.02661	-0.01121	-0.00622	-0.00295	-0.00096	0.20357	-0.27099
LW	-0.0077	-0.00347	0.01052	0.02669	-0.0105	-0.00665	-0.00278	-0.00079	0.19812	-0.28105
PaL	0.00089	-0.00055	0.00134	0.00588	-0.00278	-0.00156	-0.01186	-0.00314	0.42428	0.4076
PaW	0.00028	-0.00074	0.00182	0.00519	-0.00311	-0.00152	-0.01078	-0.00348	0.40929	0.44305
BY	-0.00014	-0.00072	0.00331	0.00979	-0.00444	-0.00256	-0.0098	-0.00275	0.51354	0.27169
HI	0.00551	0.00189	-0.00549	-0.01266	0.00438	0.00269	-0.00697	-0.00221	0.2011	0.69386
Residual 9e-04										

Where, $**P \leq 0.01$: significant at 1% level; $*P \leq 0.05$: significant at 5% level, DF50 = days to 50% flowering, DM = days to maturity, PH = plant height (cm), SG = stem girth (cm), LL = leaf length (cm), LW = leaf width (cm), PaL = panicle length (cm), PaW = panicle width (cm), GY = grain yield per plant (g), BY = biological yield per plant (g), and HI = harvest index (%)

Breeding implications

Taken together with the companion study on this material (10), which had identified RSLG-2438 and the Cluster III genotypes (SPV-2831, CSV-10, PR-105) as combining high grain and biological yield with wide genetic divergence, the present results sharpen the basis on which such genotypes, and any others considered for future hybridisation, should be evaluated. Rather than favour genotypes for mere vegetative vigour, greater height, longer duration or larger leaves, which this analysis shows to act on yield mainly by depressing harvest index, selection would be more productively directed towards genotypes combining a high harvest index with a high biological yield per plant, using moderate to high panicle width and panicle length as supporting, rather than primary, selection criteria. A selection index built around these traits in combination, rather than relying on any one trait alone, and applied within and between the genetically divergent clusters already identified (10), offers a coherent and efficient route to grain yield improvement in sorghum under the agro-climatic conditions of Saikheda.

Conclusion

Correlation analysis of eleven quantitative traits in twenty-two sorghum genotypes showed that harvest index, biological yield per plant, panicle length and panicle width were strongly and signifi-

cantly associated with grain yield at both the genotypic and phenotypic level. In contrast, the vegetative and phenological traits bore, at best, a weak relationship with yield. Path coefficient analysis clarified that this simple picture concealed an important distinction: only harvest index and biological yield per plant exerted a genuine, large, and mutually consistent direct effect on grain yield at both levels, making them the most dependable traits for direct or indirect selection. Panicle length and, in particular, panicle width, despite their high correlation with yield, acted mainly indirectly, through harvest index and biological yield, on account of their own strong mutual correlation, and should therefore be used in combination with these two traits within a selection index rather than selected for in isolation. The vegetative traits possessed small, largely inconsequential direct effects that were consistently offset by a negative indirect path through harvest index, cautioning against selection for mere vegetative vigour. With the residual effect negligible at both levels, these ten traits may be considered a sufficient and well-chosen basis for future selection work on this material, and, read alongside the divergence pattern already established for these genotypes, they provide sorghum breeders with a practical, trait-based selection index, harvest index and biological yield per plant as primary criteria, supported by panicle dimensions, for genetic improvement of grain yield in sorghum.

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Authors' contributions

All authors contributed equally.

Compliance with ethical standards

Conflict of interest: The authors declare no conflicts of interest.

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References

- Naoura G, Sawadogo N, Atchouze EA, Emendack Y, Hassan MA, Reoungal D, *et al.* Assessment of agro-morphological variability of dry-season sorghum cultivars in Chad as novel sources of drought tolerance. *Scientific Reports*. 2019;9:18261.
- Gebre W, Mekbib F, Tirfessa A, Bekele A. Genetic diversity, association, and path coefficient analyses of sorghum [*Sorghum bicolor* (L.) Moench] genotypes. *Scientifica*. 2024;2024:1611869.
- Al-Jibouri HA, Miller PA, Robinson HF. Genotypic and environmental variances and covariances in an upland cotton cross of interspecific origin. *Agronomy Journal*. 1958;50(10):633-636.
- Wright S. Correlation and causation. *Journal of Agricultural Research*. 1921;20:557-585.
- Dewey DR, Lu KH. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agronomy Journal*. 1959;51(9):515-518.
- Angadi KS, Somu G. Genetic variability and association studies in grain sorghum (*Sorghum bicolor* L. Moench). *Plant Archives*. 2025;25(1):73-78.
- Mohammedi Begum, More AW, Aquibullah Khan, Lagad SL. Correlation coefficients and path analysis for grain yield and yield contributing traits in brown midrib sorghum [*Sorghum bicolor* (L.) Moench]. *Plant Archives*. 2024;24(Special Issue GABELS):519-523.
- Sujatha K, Akshay HV, Maheshwaramma S, Rani CS, Anuradha C, Kumar CVS. Correlation and path coefficient analysis for yield and contributing traits in yellow sorghum (*Sorghum bicolor* (L.) Moench). *International Journal of Bioresource and Stress Management*. 2025;16(12):01-10.
- Rao S, Singh L, Janghel DK, Roy D, Yadav KK. Integrated correlation and path coefficient analysis of yield contributing traits in sorghum (*Sorghum bicolor* L. Moench). *Plant Archives*. 2026;26(Supplement 2):1484-1491.
- Meshram VV, Sapkal D, Pandey G, Rathod M, Sarda A. Exploiting genetic variability and D2 statistics for divergence-based classification of genotypes in sorghum [*Sorghum bicolor* (L.) Moench]. *Int J Res Agron*. 2026;9(8):1366-1372.
- Singh RK, Chaudhary BD. *Biometrical Methods in Quantitative Genetic Analysis*. New Delhi: Kalyani Publishers; 1977.
- Olivoto T, Lúcio ADC. metan: an R package for multi-environment trial analysis. *Methods in Ecology and Evolution*. 2020;11(6):783-789.
- Kumari J, Maxton A. Genetic variability and trait association in 20 diverse genotypes of greengram (*Vigna radiata* L.) under field conditions. *Environment Conservation Journal*. 2025;26(3):976-983.
- Vivek K, Rabiya J, Gawande AB, Sandeep N, Vaidurya PS. Assessing genetic diversity in the 3K mini-core collection of rice (*Oryza sativa* L.) using standardised Euclidean distance and Ward's hierarchical clustering. *Plant Science Today*. 2026.
- Kumari J, Kumar V, Masih SA, Maxton A. Effect of phytohormonal seed priming with indole acetic acid and salicylic acid on yield and yield component traits in green gram. *Plant Archives*. 2025;25(2).
- Yadav M, Kumari J, Gantait A, Kumar V, Maxton A. Assessment of Genetic Diversity for Yield Component Traits and Grain Yield of Blackgram [*Vigna mungo* (L.) Hepper]. *J. Exp. Agric. Int*. 2024;46(9):426-33.
- Yadav KK, Kumari J, Mamatha A, Kumar V, Gantait A, Maxton A. Study of Genetic Variability and Path Analysis for Yield in Greengram (*Vigna radiata* L. Wilczek). *J. Exp. Agric. Int*. 2024;46(9):130-41.
- Noru RSR, Thomas B, Maraskole SK, S VP, Panotra N, Rajesh J, *et al.* Participatory Plant Breeding: A Pathway to Sustainable and Resilient Agriculture. *J. Adv. Biol. Biotechnol*. 2024;27(8):1293-306.
- Koushal S, Mankar AA, Anbarasan S, Kumar V, Kumari J, Nagarjuna S, Jahan R, Kishan KR, Satapathy SN. Mechanism and methodologies of seed priming: enhancing germination and crop resilience. *Plant Cell Biotechnology and Molecular Biology*. 2024;25(11-12):185-94.

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