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INTEGRATED CORRELATION AND PATH COEFFICIENT ANALYSIS OF YIELD CONTRIBUTING TRAITS IN SORGHUM (*Sorghum bicolor* L. Moench)

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ABSTRACT

An investigation was carried out to study the association among yield and yield contributing traits in sorghum (*Sorghum bicolor* L. Moench) genotypes through correlation and path coefficient analysis. Twenty-eight sorghum genotypes were evaluated in a Randomized Block Design (RBD) with three replications. Observations were recorded on sixteen quantitative traits including flowering, maturity, plant height, leaf traits, panicle traits, grain yield, biological yield, dry fodder yield, harvest index, and 1000-seed weight. Genotypic and phenotypic correlation analyses revealed that grain yield per plant had strong positive association with harvest index, panicle width, panicle breadth, number of grains per panicle, and leaf width. Harvest index exhibited the highest positive correlation with grain yield at both genotypic (0.9125) and phenotypic (0.9135) levels. In contrast, plant height, biological yield, dry fodder yield, and panicle length showed significant negative association with grain yield. Path coefficient analysis indicated that harvest index exerted the highest positive direct effect on grain yield followed by panicle width, panicle breadth, and 1000-seed weight. The study suggested that traits such as harvest index, panicle width, panicle breadth, and number of grains per panicle are important selection criteria for improving grain yield in sorghum. Therefore, emphasis on these traits during selection and hybridization programs may help in developing high yielding sorghum genotypes suitable for semi-arid conditions.

***Keywords*:** Sorghum; correlation; path analysis; grain yield; harvest index; panicle traits.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is one of the most important cereal crops cultivated in tropical and subtropical regions of the world for food, feed, fodder, and industrial purposes. The crop is highly valued for its adaptability to drought, high temperature, and low fertility soils, making it an important climate-resilient cereal for semi-arid regions (Reddy *et al.*, 2013). Globally, sorghum ranks fifth among cereal crops after wheat, rice, maize, and barley in terms of importance and utilization. According to the Food and Agriculture Organization (FAO, 2024), sorghum is cultivated on approximately 42 million hectares worldwide with an annual production of about 64 million tonnes and an average productivity of nearly 1.52 t ha^{-1}. The crop plays a crucial role in ensuring food and fodder security, particularly in Africa and Asia where climatic instability limits the cultivation of other cereals.

India is one of the major sorghum-growing countries and contributes substantially to global sorghum production. Sorghum, commonly known as jowar, is cultivated mainly in Maharashtra, Karnataka, Madhya Pradesh, Rajasthan, Telangana, and Haryana under rainfed and low-input conditions. As per the Directorate of Economics and Statistics (DES, 2024), sorghum in India occupied an area of about 3.97 million hectares with a production of approximately 4.40 million tonnes and an average productivity of 1.16 t ha^{-1} during 2023–24. Besides being an important source of food and fodder, sorghum grains are rich in carbohydrates, proteins, dietary fiber, minerals, and antioxidants, which enhance their nutritional and industrial value (Kumar & Prasad, 2019).

Grain yield in sorghum is a complex quantitative trait governed by several interrelated characters and strongly influenced by environmental factors. Consequently, direct selection based only on grain yield is often ineffective because of its low heritability and complex inheritance pattern (Johnson *et al.,* 1955). Correlation analysis provides information regarding the magnitude and direction of association among traits and helps breeders in identifying characters that influence yield either directly or indirectly (Falconer & Mackay, 1996). However, simple correlation analysis does not explain the exact contribution of each trait toward grain yield.

To overcome this limitation, path coefficient analysis developed by Sewall Wright (1921) has been widely used in plant breeding studies to partition correlation coefficients into direct and indirect effects. This technique provides a clear understanding of the cause-and-effect relationship among traits and helps in identifying reliable selection criteria for crop improvement programs (Dewey & Lu, 1959). Several researchers have reported the importance of harvest index, panicle width, panicle breadth, number of grains per panicle, and seed weight as important yield contributing traits in sorghum (Mahajan *et al.,* 2020; Sharma *et al.,* 2021; Singh *et al.*, 2020).

Therefore, integrated studies involving both correlation and path coefficient analyses are highly useful for understanding the complex relationship among characters and formulating effective breeding strategies. Keeping these facts in view, the present investigation was undertaken to study the genotypic and phenotypic correlation along with path coefficient analysis among yield and yield contributing traits in sorghum genotypes in order to identify important characters for grain yield improvement.

Materials and Methods

Experimental Site, Materials and Design

The present study was conducted during the Kharif 2025 season at the Agriculture Farm of G D Goenka University, located in Sohna, Gurugram, Haryana (28.26° N latitude and 77.06° E longitude). The experimental site falls under the semi-arid agro-climatic zone of Southern Haryana, suitable for sorghum cultivation under irrigated and rain fed conditions. Twenty eight genotypes were sown in RBD with three replication having proper spacing of 45×15cm. The experiment was lay out on 28 June 2025 and harvested on 29 October 2025. Seeds were treated with PSB biofertilizer before sowing, and a recommended fertilizer dose of 80:40:40 kg N: P_2O_5 : K_2O per hectare was applied. Standard agronomic and intercultural practices were followed uniformly throughout the crop season.

Observations Recorded

Data were recorded on sixteen quantitative traits from five randomly selected competitive plants in each genotype and replication. The observations included days to 50% flowering, days to maturity, plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), panicle length (cm), panicle breadth (cm), panicle weight (g), number of grains per panicle, dry fodder yield per plant (g), 1000-seed weight (g), number of primary branches per panicle, harvest index (%), biological yield per plant (g), and grain yield per plant (g).

Statistical Analysis

The recorded data were subjected to statistical analysis using R Studio software with the “variability” package developed by Popat *et al.* (2020) along with the online statistical platform Agri Analyze developed by Popat *et al.* (2024) for agricultural research data analysis. Analysis of variance (ANOVA) for all traits was carried out according to the procedure suggested by Panse and Sukhatme (1985) for Randomized Block Design (RBD).

Genotypic and phenotypic correlation coefficients among different characters were estimated using the methodology proposed by Al-Jibouri *et al.* (1958). The correlation coefficients were computed to determine the magnitude and direction of association among yield and yield contributing traits at both genotypic and phenotypic levels. The significance of correlation coefficients was tested using the t-test suggested by Panse and Sukhatme (1985):

Path coefficient analysis was carried out to partition the correlation coefficients into direct and indirect effects following the method proposed by Sewall Wright (1921) and later elaborated by Dewey and Lu (1959). Grain yield per plant was considered as the dependent variable, whereas the remaining characters were treated as independent variables. The magnitude of path coefficients was classified according to the scale suggested by Lenka and Mishra (1973), where values greater than 1.0 were considered very high, 0.30–0.99 as high, 0.20–0.29 as moderate, 0.10–0.19 as low, and 0.00–0.09 as negligible.

Result and Discussion

Genotypic Correlation (Table:1)

The genotypic correlation analysis among sixteen quantitative traits in sorghum genotypes revealed significant associations among yield and its contributing characters, indicating their importance in grain yield improvement. Days to 50% flowering (DFF) showed significant positive correlation with days to maturity (DM) (r = 0.723), plant height (PH) (r = 0.357), number of leaves (NL) (r = 0.416), panicle length (PL) (r = 0.462), dry fodder yield (DFY) (r = 0.473), and number of primary branches (NPB) (r = 0.410), while it was negatively associated with panicle width (PW) (r = −0.540), number of grains per panicle (NGP) (r = −0.575), harvest index (HI) (r = −0.523), and grain yield (GY) (r = −0.526). Similar results were reported by Reddy *et al*. (2017) and Arunkumar *et al*. (2018).

Days to maturity exhibited positive association with PH (r = 0.449), leaf length (LL) (r = 0.364), DFY (r = 0.546), and biological yield (BY) (r = 0.363), whereas significant negative correlation was observed with NGP (r = −0.656), HI (r = −0.543), and GY (r = −0.570), supporting the findings of Patel *et al*. (2020) and Jain and Patel (2019). Plant height showed strong positive correlation with NL (r = 0.755), PL (r = 0.763), DFY (r = 0.836), NPB (r = 0.786), and BY (r = 0.719), while negative association was recorded with PW (r = −0.780), HI (r = −0.843), and GY (r = −0.790), which corroborates the reports of Sharma *et al*. (2021) and Meena *et al*. (2020).

Number of leaves, leaf length, and DFY were positively associated with BY but negatively correlated with GY, indicating that vegetative traits mainly contributed toward biomass production rather than economic yield. Leaf width (LW), panicle width/breadth (PW/PB), and NGP exhibited positive association with HI and GY, suggesting their direct role in enhancing yield potential. Similar observations were reported by Singh *et al*. (2019), Chavan *et al*. (2022), Kumar *et al*. (2019), Verma *et al*. (2021), and Rathod *et al*. (2018).

Among all the traits, HI, PW, NGP, and PB exhibited the strongest positive correlation with grain yield. Grain yield showed highly significant positive correlation with HI (r = 0.912), NGP (r = 0.874), PW (r = 0.866), and PB (r = 0.798). These findings are in agreement with Ali *et al*. (2020) and Johnson *et al*. (1955), indicating that these traits may serve as reliable selection indices for improving grain yield in sorghum breeding programs.

Phenotypic Correlation (Table:2)

The phenotypic correlation analysis among sixteen quantitative traits in sorghum genotypes revealed significant interrelationships among yield and yield contributing characters, indicating the effectiveness of these traits for selection in breeding programs. Days to 50% flowering (DFF) exhibited a significant positive correlation with days to maturity (DM) (r = 0.723), plant height (PH) (r = 0.355), number of leaves (NL) (r = 0.416), leaf length (LL) (r = 0.320), panicle length (PL) (r = 0.462), dry fodder yield (DFY) (r = 0.472), number of primary branches (NPB) (r = 0.406), and biological yield (BY) (r = 0.323). However, DFF showed significant negative association with panicle width (PW) (r = −0.545), number of grains per panicle (NGP) (r = −0.578), harvest index (HI) (r = −0.524), and grain yield (GY) (r = −0.524). Similar findings were reported by Reddy *et al.* (2017), Sharma *et al.* (2021), and Arunkumar *et al.* (2018), who observed that delayed flowering and maturity reduced grain productivity in sorghum.

Days to maturity exhibited significant positive association with plant height (PH), leaf length (LL), panicle length (PL), dry fodder yield (DFY), number of primary branches (NPB), and biological yield (BY), while negative correlation was observed with panicle width (PW), number of grains per panicle (NGP), harvest index (HI), and grain yield (GY). These findings are in agreement with Patel *et al.* (2020) and Jain and Patel (2019), who reported that late maturing genotypes accumulate greater biomass but lower grain yield.

Plant height showed strong positive correlation with number of leaves (NL), LL, PL, DFY, NPB, and BY, whereas negative association was recorded with panicle breadth (PB), PW, NGP, HI, and GY. Similar observations were reported by Meena *et al.* (2020) and Verma *et al.* (2021), suggesting that taller plants contribute more toward vegetative growth and fodder production than grain yield.

NL and LL exhibited positive association with DFY and BY but negative correlation with HI and GY. Similar findings were reported by Singh *et al.* (2019) and Chavan *et al.* (2022), indicating that vegetative traits are more closely related to biomass accumulation than economic yield.

Leaf width exhibited positive association with PB, PW, NGP, HI, and GY, suggesting its importance in photosynthetic efficiency and grain production, as also reported by Kumar *et al.* (2019). Panicle breadth also showed strong positive association with HI and GY, confirming the importance of panicle traits in improving grain yield, as reported by Rathod *et al.* (2018) and Ali *et al.* (2020).

Among all the traits studied, harvest index (HI), panicle width (PW), and number of grains per panicle (NGP) exhibited the strongest positive association with grain yield. Grain yield showed highly significant positive correlation with HI (r = 0.913), NGP (r = 0.877), PW (r = 0.870), PB (r = 0.800), and LW (r = 0.589). Similar findings were reported by Johnson *et al.* (1955), Sharma *et al.* (2021), and Patel *et al.* (2020), who concluded that harvest index and grain number are the most important yield determining characters in cereal crops. Therefore, these traits may serve as reliable selection criteria for the development of high yielding sorghum genotypes.

Genotypic path coefficient analysis (Table:3)

The genotypic path coefficient analysis revealed the magnitude and direction of direct and indirect effects of different traits on grain yield in sorghum genotypes. Path analysis partitions the correlation coefficients into direct and indirect effects and helps in identifying the true relationship between yield and its component traits. In the present investigation, harvest index (HI) exhibited the highest positive direct effect on grain yield (0.4323), followed by panicle width (PW) (0.1587), panicle breadth (PB) (0.1296), and thousand seed weight (TSW) (0.1038). Similar findings were reported by Mohammed *et al.* (2020), Rani *et al.* (2021), and Deshmukh *et al.* (2018), who identified harvest index and panicle traits as major contributors to grain yield in sorghum.

Harvest index exhibited strong positive indirect effects through panicle width (0.3843), number of grains per panicle (0.3895), and panicle breadth (0.3558), resulting in a highly significant positive association with grain yield (r = 0.9125). These findings indicate the importance of efficient assimilate partitioning toward economic yield, as also reported by Kumar and Prasad (2019).

Panicle width exerted a high positive direct effect (0.1587) on grain yield and contributed positively through panicle breadth, number of grains per panicle, and harvest index, resulting in a strong positive genotypic correlation with grain yield (r = 0.8658). Similar findings were reported by Singh *et al.* (2020) and Bhat *et al.* (2019), emphasizing the importance of panicle architecture traits in sorghum breeding.

Panicle breadth also showed a substantial positive direct effect (0.1296) along with favorable indirect effects through panicle width, number of grains per panicle, and harvest index, leading to a strong positive association with grain yield (r = 0.7983). Similar observations were reported by Yadav *et al.* (2018).

Number of grains per panicle exhibited a negative direct effect (−0.0921) but maintained a highly positive correlation with grain yield (r = 0.8739) due to indirect effects through panicle width, harvest index, and panicle breadth, supporting the findings of Patel and Chauhan (2021).

Dry fodder yield, plant height, number of leaves, leaf length, and panicle length showed negative direct effects on grain yield, indicating that excessive vegetative growth reduces reproductive efficiency, as reported by Sandeep *et al.* (2017), Rao *et al.* (2022), and Elangovan *et al.* (2019). Thousand seed weight showed a moderate positive direct effect on grain yield.

Phenotypic path coefficient analysis (Table:4)

The phenotypic path coefficient analysis revealed that harvest index (HI), panicle width (PW), panicle breadth (PB), and thousand seed weight (TSW) exerted positive direct effects on grain yield, indicating their importance as effective selection criteria in sorghum improvement programs. Similar findings were reported by Mahajan *et al.* (2020), Tirkey *et al.* (2021), and Prakash *et al.* (2019).

Among all the traits, harvest index exhibited the highest positive direct effect (0.4485) on grain yield along with strong positive indirect effects through panicle width, number of grains per panicle (NGP), and panicle breadth, resulting in a highly significant positive association with grain yield (r = 0.9135). Similar observations were made by Naik *et al.* (2018), emphasizing the importance of efficient assimilate partitioning in enhancing grain productivity.

Panicle width and panicle breadth also showed considerable positive direct and indirect effects on grain yield, suggesting that panicle architecture traits contribute significantly toward sink capacity and grain filling. Similar results were reported by Ganesamurthy *et al.* (2022), Chauhan *et al.* (2020), and Rukhsar *et al.* (2019).

Although number of grains per panicle exhibited a negative direct effect, it maintained a strong positive correlation with grain yield due to favorable indirect effects through PW, PB, and HI. Similar findings were reported by Khandelwal *et al.* (2021).

Dry fodder yield, plant height, number of leaves, leaf length, and panicle length exhibited negative direct effects on grain yield, indicating that excessive vegetative growth adversely affects reproductive efficiency and grain production. Similar observations were reported by Mofokeng *et al.* (2017), Adewale *et al.* (2020), and Birhanu and Tesfaye (2021). Thousand seed weight showed a moderate positive contribution toward grain yield, as also observed by Dube *et al.* (2018).

Integrated Correlation and Path Analysis

Integrated correlation and path coefficient analysis revealed that harvest index (HI), panicle width (PW), panicle breadth (PB), number of grains per panicle (NGP), leaf width (LW), and thousand seed weight (TSW) were important yield contributing traits in sorghum. Grain yield exhibited strong positive association with HI, PW, PB, and NGP at both genotypic and phenotypic levels. Among these, harvest index showed the highest positive correlation and direct effect on grain yield, indicating the importance of efficient assimilate partitioning toward economic yield. Similar findings were reported by Mahajan *et al.* (2020), Naik *et al.* (2018), and Kumar and Prasad (2019).

Panicle width and panicle breadth also exhibited strong positive direct effects and correlations with grain yield, suggesting that panicle architecture traits play a major role in grain filling and sink capacity. Similar observations were reported by Singh *et al.* (2020), Ganesamurthy *et al.* (2022), and Yadav *et al.* (2018). Although number of grains per panicle showed a negative direct effect, it maintained a strong positive association with grain yield through indirect effects via harvest index and panicle traits, as reported by Patel and Chauhan (2021) and Khandelwal *et al.* (2021).

Conversely, plant height, number of leaves, leaf length, panicle length, dry fodder yield, and biological yield exhibited negative direct effects on grain yield, indicating that excessive vegetative growth adversely affects reproductive efficiency. Similar findings were reported by Mofokeng *et al.* (2017), Adewale *et al.* (2020), and Rao *et al.* (2022). Leaf width and thousand seed weight contributed moderately toward grain productivity, corroborating the findings of Dube *et al.* (2018) and Prakash *et al.* (2019).

Conclusion

The present investigation revealed significant associations among grain yield and its contributing traits in sorghum genotypes at both genotypic and phenotypic levels. Correlation and path coefficient analyses indicated that harvest index, panicle width, panicle breadth, and number of grains per panicle were the most important traits contributing positively toward grain yield. These traits also exhibited high direct and indirect effects, suggesting their effectiveness as reliable selection criteria in sorghum improvement programs. Conversely, traits associated with excessive vegetative growth such as plant height, biological yield, and dry fodder yield showed negative association with grain yield. Therefore, emphasis on harvest index and panicle-related traits during selection and hybridization programs may help in developing high yielding sorghum genotypes suitable for semi-arid conditions.

Table 1: Genotypic Correlation Matrix

Trait	DFF	DM	PH	NL	LL	LW	PL	PB	PW	NGP	DFY	TSW	NPB	HI	BY	GY
DFF	1.000	0.723*	0.357*	0.416*	0.320*	-0.269*	0.462*	-0.397*	-0.540*	-0.575*	0.473*	0.105*	0.410*	-0.523*	0.318*	-0.526*
DM		1.000	0.449*	0.397*	0.364*	-0.325*	0.441*	-0.393*	-0.541*	-0.656*	0.546*	0.086*	0.462*	-0.543*	0.363*	-0.570*
PH			1.000	0.755*	0.689*	-0.430*	0.763*	-0.764*	-0.780*	-0.751*	0.836*	-0.074*	0.786*	-0.843*	0.719*	-0.790*
NL				1.000	0.688*	-0.484*	0.720*	-0.719*	-0.758*	-0.747*	0.797*	-0.024*	0.804*	-0.794*	0.722*	-0.763*
LL					1.000	-0.381*	0.593*	-0.498*	-0.638*	-0.599*	0.774*	0.025*	0.637*	-0.700*	0.633*	-0.632*
LW						1.000	-0.613*	0.585*	0.616*	0.579*	-0.524*	0.146*	-0.569*	0.605*	-0.423*	0.584*
PL							1.000	-0.747*	-0.729*	-0.765*	0.745*	0.034*	0.792*	-0.787*	0.610*	-0.760*
PB								1.000	0.766*	0.726*	-0.712*	0.099*	-0.779*	0.823*	-0.582*	0.798*
PW									1.000	0.859*	-0.804*	0.147*	-0.806*	0.889*	-0.629*	0.866*
NGP										1.000	-0.810*	0.072*	-0.842*	0.901*	-0.702*	0.874*
DFY											1.000	-0.064*	0.835*	-0.871*	0.749*	-0.786*
TSW												1.000*	-0.074	0.111	-0.001	0.169
NPB													1.000	-0.874*	0.730*	-0.831*
HI														1.000	-0.724*	0.912*
BY															1.000	-0.693*

Footnote: The asterisk (*) indicates that the specific correlation is statistically significant at the 0.05 level.

Table 2: Phenotypic Correlation Matrix

Trait	DFF	DM	PH	NL	LL	LW	PL	PB	PW	NGP	DFY	TSW	NPB	HI	BY	GY
DFF	1.000	0.723*	0.355*	0.416*	0.320*	-0.269*	0.462*	-0.396*	-0.545*	-0.578*	0.472*	0.110*	0.406*	-0.524*	0.323*	-0.524*
DM		1.000	0.448*	0.397*	0.366*	-0.330*	0.442*	-0.391*	-0.544*	-0.658*	0.545*	0.088*	0.461*	-0.543*	0.365*	-0.569*
PH			1.000	0.757*	0.693*	-0.439*	0.765*	-0.763*	-0.785*	-0.754*	0.835*	-0.073*	0.788*	-0.844*	0.723*	-0.790*
NL				1.000	0.689*	-0.488*	0.720*	-0.722*	-0.759*	-0.748*	0.798*	-0.023*	0.808*	-0.795*	0.724*	-0.764*
LL					1.000	-0.375*	0.593*	-0.505*	-0.640*	-0.601*	0.778*	0.029*	0.638*	-0.702*	0.638*	-0.634*
LW						1.000	-0.617*	0.601*	0.623*	0.588*	-0.533*	0.140*	-0.569*	0.614*	-0.436*	0.589*

Trait	DFF	DM	PH	NL	LL	LW	PL	PB	PW	NGP	DFY	TSW	NPB	HI	BY	GY
PL							1.000	-0.751*	-0.730*	-0.766*	0.746*	0.036*	0.796*	-0.787*	0.612*	-0.760*
PB								1.000	0.774*	0.730*	-0.711*	0.098*	-0.783*	0.825*	-0.586*	0.800*
PW									1.000	0.859*	-0.808*	0.149*	-0.816*	0.890*	-0.629*	0.870*
NGP										1.000	-0.813*	0.073*	-0.851*	0.901*	-0.702*	0.877*
DFY											1.000	-0.064*	0.839*	-0.872*	0.751*	-0.786*
TSW												1.000*	-0.068	0.111	-0.004	0.166
NPB													1.000	-0.879*	0.742*	-0.832*
HI														1.000	-0.725*	0.913*
BY															1.000	-0.698*

Footnote: The asterisk (*) indicates that the specific correlation is statistically significant at the 0.05 level.

Table 3: Genotypic Path Matrix

Trait	DFF	DM	PH	NL	LL	LW	PL	PB	PW	NGP	DFY	TSW	NPB	HI	BY	GY
DFF	**-0.0044**	-0.0032	-0.0016	-0.0018	-0.0014	0.0012	-0.0020	0.0018	0.0024	0.0025	-0.0021	-0.0005	-0.0018	0.0023	-0.0014	-0.5262*
DM	-0.0917	**-0.1268**	-0.0570	-0.0503	-0.0461	0.0412	-0.0559	0.0498	0.0685	0.0832	-0.0692	-0.0109	-0.0585	0.0689	-0.0460	-0.5695*
PH	-0.0045	-0.0056	**-0.0125**	-0.0095	-0.0086	0.0054	-0.0096	0.0096	0.0098	0.0094	-0.0105	0.0009	-0.0099	0.0106	-0.0090	-0.7898*
NL	-0.0194	-0.0185	-0.0351	**-0.0466**	-0.0320	0.0225	-0.0335	0.0335	0.0353	0.0348	-0.0371	0.0011	-0.0374	0.0370	-0.0336	-0.7628*
LL	-0.0207	-0.0235	-0.0446	-0.0445	**-0.0647**	0.0247	-0.0384	0.0322	0.0413	0.0387	-0.0501	-0.0016	-0.0412	0.0453	-0.0409	-0.6325*
LW	0.0045	0.0055	0.0072	0.0081	0.0064	**-0.0168**	0.0103	-0.0098	-0.0104	-0.0097	0.0088	-0.0025	0.0096	-0.0102	0.0071	0.5844*
PL	-0.0328	-0.0313	-0.0542	-0.0511	-0.0421	0.0436	**-0.0710**	0.0530	0.0518	0.0543	-0.0529	-0.0024	-0.0563	0.0559	-0.0433	-0.7599*
PB	-0.0514	-0.0509	-0.0990	-0.0932	-0.0646	0.0757	-0.0968	**0.1296**	0.0993	0.0941	-0.0922	0.0128	-0.1010	0.1066	-0.0755	0.7983*
PW	-0.0858	-0.0858	-0.1237	-0.1202	-0.1013	0.0977	-0.1157	0.1216	**0.1587**	0.1363	-0.1276	0.0233	-0.1279	0.1410	-0.0998	0.8658*
NGP	-0.0653	-0.0745	-0.0853	-0.0848	-0.0680	0.0658	-0.0869	0.0825	0.0976	**0.1136**	-0.0921	0.0081	-0.0957	0.1023	-0.0797	0.8739*
DFY	0.1159	0.1339	0.2049	0.1953	0.1898	-0.1284	0.1826	-0.1745	-0.1972	-0.1987	**0.2452**	-0.0158	0.2048	-0.2136	0.1835	-0.7860*
TSW	0.0109	0.0089	-0.0077	-0.0025	0.0026	0.0151	0.0035	0.0102	0.0153	0.0074	-0.0067	**0.1038**	-0.0077	0.0115	-0.0001	0.1689
NPB	-0.0240	-0.0270	-0.0460	-0.0471	-0.0373	0.0333	-0.0464	0.0456	0.0472	0.0493	-0.0489	0.0044	**-0.0586**	0.0512	-0.0427	-0.8312*
HI	-0.2262	-0.2349	-0.3643	-0.3435	-0.3026	0.2616	-0.3401	0.3558	0.3843	0.3895	-0.3767	0.0480	-0.3777	**0.4323**	-0.3130	0.9125*
BY	-0.0314	-0.0358	-0.0709	-0.0712	-0.0624	0.0418	-0.0601	0.0574	0.0620	0.0692	-0.0738	0.0001	-0.0720	0.0714	**-0.0986**	-0.6931*

Footnote: Diagonal values (Bold) are direct effect values and remaining values are indirect effect values.

Table 4: Phenotypic Path Matrix

Trait	DFF	DM	PH	NL	LL	LW	PL	PB	PW	NGP	DFY	TSW	NPB	HI	BY	GY
DFF	**0.0156**	0.0113	0.0055	0.0065	0.0050	-0.0042	0.0072	-0.0062	-0.0085	-0.0090	0.0073	0.0017	0.0063	-0.0082	0.0050	-0.5244*
DM	-0.0932	**-0.1290**	-0.0578	-0.0512	-0.0472	0.0426	-0.0570	0.0505	0.0701	0.0849	-0.0704	-0.0113	-0.0595	0.0701	-0.0471	-0.5689*
PH	0.0048	0.0061	**0.0135**	0.0102	0.0094	-0.0059	0.0103	-0.0103	-0.0106	-0.0102	0.0113	-0.0010	0.0106	-0.0114	0.0098	-0.7898*
NL	-0.0211	-0.0201	-0.0383	**-0.0506**	-0.0349	0.0247	-0.0365	0.0366	0.0384	0.0379	-0.0404	0.0012	-0.0409	0.0402	-0.0366	-0.7636*
LL	-0.0182	-0.0209	-0.0395	-0.0393	**-0.0570**	0.0214	-0.0338	0.0288	0.0365	0.0343	-0.0444	-0.0016	-0.0364	0.0400	-0.0364	-0.6336*
LW	0.0085	0.0105	0.0139	0.0155	0.0119	**-0.0317**	0.0196	-0.0191	-0.0198	-0.0187	0.0169	-0.0044	0.0181	-0.0195	0.0138	0.5892*
PL	-0.0413	-0.0394	-0.0683	-0.0643	-0.0529	0.0551	**-0.0893**	0.0670	0.0652	0.0684	-0.0666	-0.0032	-0.0710	0.0703	-0.0546	-0.7605*
PB	-0.0506	-0.0500	-0.0976	-0.0924	-0.0646	0.0769	-0.0960	**0.1279**	0.0989	0.0934	-0.0909	0.0126	-0.1002	0.1055	-0.0750	0.7997*
PW	-0.1032	-0.1029	-0.1486	-0.1435	-0.1211	0.1180	-0.1382	0.1464	**0.1892**	0.1625	-0.1529	0.0281	-0.1544	0.1685	-0.1191	0.8702*
NGP	-0.0725	-0.0826	-0.0946	-0.0938	-0.0754	0.0738	-0.0961	0.0916	0.1078	**0.1255**	-0.1020	0.0092	-0.1068	0.1131	-0.0880	0.8769*
DFY	0.1137	0.1314	0.2012	0.1922	0.1874	-0.1285	0.1798	-0.1713	-0.1947	-0.1957	**0.2408**	-0.0154	0.2020	-0.2100	0.1810	-0.7862*
TSW	0.0109	0.0087	-0.0072	-0.0023	0.0028	0.0139	0.0036	0.0098	0.0148	0.0073	-0.0063	**0.0993**	-0.0068	0.0110	-0.0004	0.1664
NPB	-0.0057	-0.0064	-0.0110	-0.0113	-0.0089	0.0079	-0.0111	0.0109	0.0114	0.0119	-0.0117	0.0009	**-0.0139**	0.0122	-0.0103	-0.8318*
HI	-0.2351	-0.2437	-0.3784	-0.3564	-0.3150	0.2754	-0.3531	0.3700	0.3994	0.4043	-0.3910	0.0498	-0.3941	**0.4485**	-0.3253	0.9135*
BY	-0.0370	-0.0418	-0.0828	-0.0829	-0.0731	0.0499	-0.0701	0.0671	0.0721	0.0803	-0.0860	0.0005	-0.0849	0.0830	**-0.1145**	-0.6978*

Footnote: Diagonal values (Bold) are direct effect values and remaining values are indirect effect values.

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