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INTER RELATIONSHIPS AMONG YIELD AND YIELD-CONTRIBUTING TRAITS IN LITTLE MILLET (*Panicum sumatrense* L.) GENOTYPES

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ABSTRACT

The experiment was conducted in Kharif 2025-26 season in Randomized Block Design with three replications using 30 different little millet genotypes. Data on 12 yield-contributing traits were recorded. Phenotypic correlation and path coefficient analysis were investigated using the 30 little millet genotypes. Grain yield per plant showed highly significant and positive correlation with biological yield per plant (g) (0.685**), 1000 seed weight (g) (0.559**), Harvest index (%) (0.389**), No. of productive tiller per plant (0.377**), panicle length (cm) (0.318**) while flag leaf length (cm) (0.222*) shows significant and positive correlation. However, it shows negative correlation with days to 50% flowering. Rest characters were non-significant. Path coefficient analysis indicated that, days to 50 % flowering, flag leaf length, peduncle length, panicle length, productive tiller, plant height, 1000 seed weight, biological yield and harvest index had a positive direct effect on grain yield per plant, while negative direct effect was found for days to maturity and flag leaf width. While genotypic correlation analysis revealed that Grain yield per plant showed highly significant and positive correlation with days to maturity (0.682**), flag leaf length (cm) (0.335**), panicle length (cm) (0.506**), No. of productive tiller per plant (0.602**), 1000 seed weight (g) (0.639**), biological yield per plant (g) (0.815**), Harvest index (%) (0.324**).

Key words: Phenotypic correlation, Genotypic correlation, Path coefficient analysis, Little millet.

Introduction

Little millet (*Panicum sumatrense* L.) is one of the most important millet. It belongs to the family poaceae. Little Millet is nutritious small millet known for its very rich nutrient composition and health benefits. Per 100 g of raw grain, it provides about 329–341 kcal of energy, 67–68 g carbohydrates, 7–8 g protein, and 4–5 g fat rich in essential minerals such as iron (8–10 mg), phosphorus (220–230 mg), magnesium (90–100 mg), calcium (15–20 mg), and potassium (200–220 mg). Despite its agronomic and nutritional advantages, little millet remains under-researched and underutilized, resulting in low productivity levels. The lack of high-yielding, region - specific varieties and limited exploitation of available genetic diversity are major constraints to its improvement. In this investigation, correlation coefficient analysis is employed to assess the inter relationships among various traits, thereby identifying the key components on which selection can be focused to enhance yield. The phenotypic level effects, both direct and indirect, of the analyzed character on grain yield indicates how one trait is linked with each other.

Materials and methods

Experimental Site and Material

The experiment was conducted during the Kharif season of 2025-26 in the Research field of Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India. The experimental material consisted of 30 diverse little millet genotypes including improved varieties and

Table 1: List of Genotypes.

Entry No.	Genotypes	Entry No.	Genotypes
1	IPmr 700	16	IPmr 1032
2	IPmr 722	17	IPmr 1035
3	IPmr 857	18	IPmr 1038
4	IPmr 865	19	IPmr 1042
5	IPmr 868	20	IPmr 1047
6	IPmr 880	21	IPmr 1050
7	IPmr 885	22	IPmr 1053
8	IPmr 990	23	IPmr 1057
9	IPmr 991	24	IPmr 1058
10	IPmr 1002	25	IPmr 1059
11	IPmr 1003	26	BL 6 (Check)
12	IPmr 1006	27	GNV 3 (Check)
13	IPmr 1014	28	GPUL 6 (Check)
14	IPmr 1015	29	GV 2 (Check)
15	IPmr 1020	30	Phule Ekadashi (Check)

advanced breeding lines collected from BAU, Sabour (Table 1).

Experimental Design and Observations

This experiment was laid out in a Randomized Block Design (RBD) with three replications. Each genotype was sown in plot size of 5.4 m^2 area with plant to plant spacing 10 × 10 cm. Recommended agronomic practices were followed to maintain healthy growth of the crop. Five competitive plants were selected at random from each replication for 12 quantitative characters (Days to 50 % Flowering, Days to maturity, Plant height (cm), Number of Productive tillers per plant, Flag leaf length (cm), Flag leaf width (cm), Panicle length (cm), Peduncle length (cm), 1000 seed weight (g), Grain yield per plant (g), Biological Yield (g), Harvest index (HI) were recorded.

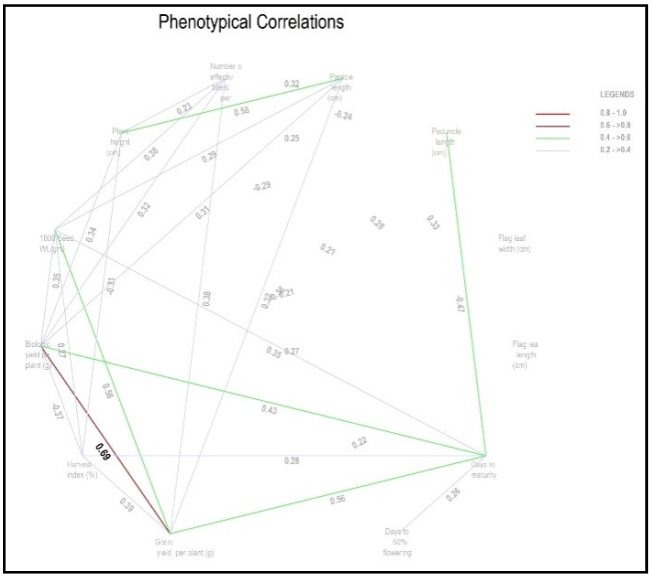


Fig. 1: Phenotypic Correlation coefficients for 12 characters in 30 little.

Statistical Analysis

The mean data were analysed using Indostat 9.2 software. The correlation coefficient is a statistical measure that quantifies the strength and direction of the relationship between two or more variables. This was determined at the phenotypic level utilizing the formulas suggested by Falconer (1981). Path coefficient analysis, initially proposed by Wright (1921) and further developed by Dewey and Lu (1959), was utilized to determine the direct and indirect contributions of different traits to yield.

Results and Discussion

Phenotypic correlation

- **Correlation of grain yield per plant with other characters:**

Grain yield per plant showed highly significant and

Table 2: Cluster mean of 12 characters for 30 little millet genotypes.

CA	DFF	DM	FLL	FLW	PDL	PL	PT	PH	TW	BY	HI	GY
DF	**1**	0.263*	-0.001	-0.174	-0.039	-0.016	0.052	-0.133	0.046	0.019	-0.130	-0.094
DM		**1**	-0.092	0.074	-0.466**	-0.058	0.088	-0.118	0.352**	0.432**	0.278**	0.158
FLL			**1**	0.178	-0.062	0.335**	0.277**	0.214*	0.189	0.265*	-0.118	0.222*
FLW				**1**	-0.056	-0.141	0.027	0.059	0.062	0.212*	-0.092	0.121
PDL					**1**	0.1665	-0.241*	0.247*	-0.287**	-0.1315	-0.362**	0.125
PL						**1**	0.323**	0.576**	0.287**	0.312**	-0.089	0.318**
NPT							**1**	0.226*	0.384**	0.317**	0.045	0.377**
PH								**1**	0.127	0.340**	-0.312**	0.191**
SW									**1**	0.351**	0.269*	0.559**
BYP										**1**	-0.369**	0.685**
HI											**1**	0.389**

CA: Characters; DFF: Days to 50% flowering; DM: Days to maturity; FLL: Flag leaf length (cm); FLW: Flag leaf width(cm); PDL: Peduncle length(cm); PL: Panicle length(cm); PT: Number of productive tillers/plant; PH: Plant height(cm); TW: 1000 Seed Wt.(gm); BY: Biological yield per plant (g); HI: Harvest index (%); GY: Grain yield per plant (g)

Table 3: Phenotypic path coefficient for grain yield and its attributing traits in 30 little millet genotypes.

CA	DFF	DM	FLL	FLW	PDL	PL	PT	PH	TW	BY	HI	PC
DF	**0.0202**	0.0053	0.0000	-0.0035	-0.0008	-0.0003	0.0011	-0.0027	0.0009	0.0004	-0.0026	-0.094
DM	-0.0186	**-0.0706**	0.0065	-0.0052	0.0329	0.0041	-0.0062	0.0083	-0.0248	-0.0305	-0.0196	0.158
FLL	0.0000	-0.0027	**0.0296**	0.0052	-0.0018	0.0099	0.0082	0.0063	0.0056	0.0078	-0.0035	0.222*
FLW	0.0016	-0.0007	-0.0016	**-0.0091**	0.0005	0.0013	-0.0002	-0.0005	-0.0006	-0.0019	0.0008	0.121
PDL	-0.0007	-0.0080	-0.0011	-0.0010	**0.0171**	0.0028	-0.0041	0.0042	-0.0049	-0.0022	-0.0062	0.125
PL	-0.0003	-0.0009	0.0052	-0.0022	0.0026	**0.0156**	0.0050	0.0090	0.0045	0.0049	-0.0014	0.318**
NPT	0.0004	0.0007	0.0021	0.0002	-0.0019	0.0025	**0.0077**	0.0017	0.0030	0.0024	0.0003	0.377**
PH	-0.0111	-0.0099	0.0180	0.0049	0.0207	0.0483	0.0190	**0.0839**	0.0106	0.0285	-0.0261	0.191**
SW	0.0004	0.0034	0.0018	0.0006	-0.0028	0.0028	0.0038	0.0012	**0.0098**	0.0034	0.0026	0.559**
BYP	0.0180	0.0185	0.2566	0.2048	-0.1273	0.3018	0.3066	0.3296	0.3393	**0.9681**	-0.3569	0.685**
HI	-0.1042	0.2233	-0.0948	-0.0736	-0.2905	-0.0711	0.0358	-0.2500	0.2160	-0.2957	**0.8020**	0.389**

CA: Characters; DFF: Days to 50% flowering; DM: Days to maturity; FLL: Flag leaf length (cm); FLW: Flag leaf width(cm); PDL: Peduncle length(cm); PL: Panicle length(cm); PT: Number of productive tillers/plant; PH: Plant height(cm); TW: 1000 Seed Wt.(gm); BY: Biological yield per plant (g); HI: Harvest index (%); PC: Phenotypic correlation with GY
RESIDUAL EFFECT = 0.192

positive correlation with biological yield per plant (g) (0.685**), 1000 seed weight (g) (0.559**), Harvest index (%) (0.389**), No. of productive tiller per plant (0.377**), panicle length (cm) (0.318**) while flag leaf length (cm) (0.222*) shows significant and positive correlation. However, it shows negative correlation with days to 50% flowering. Rest characters were non-significant. It has been represented in Table 2 and Fig. 1. Similar findings were reported by Shinde *et al.,* (2018), Venkataratnam *et al.* (2019), Nagar *et al.,* (2020), Sneha *et al.,* (2019), Gopikrishnan *et al.,* (2021), Narasimhulu *et al.,* (2023), Nehru *et al.,* (2024), and Benjamin *et al.,* (2026).

- **Character association among other characters:**

Days to 50% flowering showed significant positive correlation with days to maturity (0.263*). Days to maturity showed significantly positive correlation with thousand seed weight (g) (0.352**), biological yield per plant (g) (0.432**), harvest index (%)(0.278**). Flag leaf length showed highly significantly positive correlation with panicle length (cm) (0.335**) and number of productive tillers per plant (0.277**). Flag leaf width showed significant positive correlation with biological yield per plant (g) (0.212*). Peduncle length showed significant positive correlation with plant height (cm) (0.247*). Panicle length showed significantly positive correlation with number of productive tillers per plant (0.323**), plant height (cm) (0.576**), 1000 seed weight (g) (0.287**), biological yield per plant (g) (0.312**), grain yield per plant (g) (0.318**). Productive tiller per plant showed highly significantly positive correlation with 1000 seed weight (g) (0.384**), biological yield (g) (0.317**) and grain yield per plant (g) (0.377**). Plant height (cm) (0.226*) showed significantly positive correlation. 1000 seed weight (g) showed highly significantly positive correlation with biological yield (g) (0.351**) and grain yield per plant (g) (0.559**).Biological yield per plant showed significantly highly positive correlation with grain yield per plant (g) (0.685**).

Genotypic correlation

- **Correlation of grain yield per plant with other characters:**

Grain yield per plant showed highly significant and positive correlation with days to maturity (0.682**), flag leaf length (cm) (0.335**), panicle length (cm) (0.506**), No. of productive tiller per plant (0.602**), 1000 seed weight (g) (0.639**), biological yield per plant (g) (0.815**), Harvest index (%)(0.324**). However, only

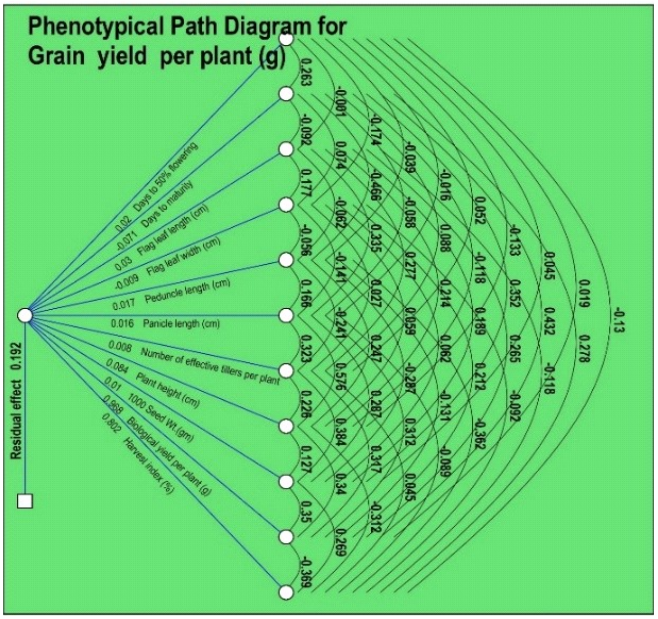


Fig. 2: Phenotypic Path for 12 characters in 30 little millet genotypes.

Table 4: Genotypic Correlation coefficients for 12 characters in 30 little millet genotypes.

CA	DFF	DM	FLL	FLW	PEL	PL	PT	PH	TW	BY	HI	GY
DF	**1**	0.147	-0.139	-0.498**	0.165	-0.016	-0.070	-0.617	0.129	-0.068	-0.067	-0.156
DM		**1**	-0.136	0.171	-0.686**	-0.123	0.024	-0.221*	0.383**	0.471**	0.477	0.682**
FLL			**1**	0.652**	-0.249*	0.621**	0.730**	0.273**	0.288**	0.372**	-0.140	0.335**
FLW				**1**	-0.676**	0.230*	0.285**	0.643**	0.078	0.423**	-0.427**	0.123
PDL					**1**	0.328**	-0.210*	0.662**	-0.417**	-0.204*	-0.588**	0.077
PL						**1**	0.737**	0.691**	0.509**	0.547	-0.181	0.506**
NPT							**1**	0.397**	0.557**	0.446**	0.171	0.602**
PH								**1**	0.173	0.582**	-0.519**	-0.232*
SW									**1**	0.408**	0.355**	0.639**
BYP										**1**	-0.267*	0.815**
HI											**1**	0.324**

CA: Characters; DFF: Days to 50% flowering; DM: Days to maturity; FLL: Flag leaf length (cm); FLW: Flag leaf width(cm); PEL: Peduncle length(cm); PL: Panicle length(cm); PT: Number of productive tillers per plant; PH: Plant height(cm); TW: 1000 Seed Wt.(gm); BY: Biological yield per plant (g); HI: Harvest index (%); GY: Grain yield per plant (g)

significant & negative association with plant height (cm) (-0.232*). Rest characters were non-significant. It has been represented in Table 4 and Fig. 3.

- **Character association among other characters:**

Days to 50% flowering showed highly significant negative correlation with flag leaf width (cm) (-498**). Days to maturity showed significantly positively correlation with thousand seed weight (g) (0.383**), biological yield per plant (g) (0.471**), grain yield per plant (g) (0.682**). Flag leaf length showed significantly positively correlation with flag leaf width (cm) (0.652**), panicle length (cm) (0.621**), number of productive tillers per plant (0.730**), plant height (cm) (0.273**), 1000 seed weight (g) (0.288**), biological yield per plant (g) (0.372**) and grain yield per plant (g) (0.335**). Peduncle length showed significant negative correlation (-0.249*). Flag leaf width showed significantly positively correlation with number of productive tillers per plant (0.285**), plant height (cm) (0.643**), biological yield per plant (g) (0.423**).Peduncle length showed significantly positively correlation with panicle length (cm) (0.328**), plant height (cm) (0.662**).Panicle length showed significantly positively correlation with number of productive tillers per plant (0.737**), plant height (cm) (0.691**), 1000 seed weight (g) (0.509**), and grain yield per plant (g) (0.506**). Productive tiller per plant showed significantly positively correlation with plant height (cm) (0.397**), 1000 seed weight (g) (0.557**), biological yield (g) (0.446**) and grain yield per plant (g) (0.602**).For plant height, biological weight per plant (g) (0.582**) have highly significant positive correlation.1000 seed weight (g) showed significantly positively correlation with biological yield (g) (0.408**) harvest index (%)(0.355**) and grain yield per plant (g) (0.639**). For biological yield, harvest index (%) (0.815**) is significantly highly positively correlated. Harvest index (%) (0.324**) showed significantly positive correlation with grain yield per plant.

Path coefficient analysis

- **Phenotypic Path analysis:**

Path coefficient analysis indicated that, days to 50 % flowering, flag leaf length, peduncle length, panicle length, productive tiller, plant height, 1000 seed weight, biological yield and harvest index had a positive direct effect on grain yield per plant, while negative direct effect was found for days to maturity and flag leaf width. It has been represented in Table 3 and Fig. 2. Similar findings were reported by Sasamala *et al.,* (2011), Negi *et al.,* (2016), and Nehru *et al.,* (2024).

Genotypic path coefficient analysis revealed substantial variation in the direct and indirect effects of

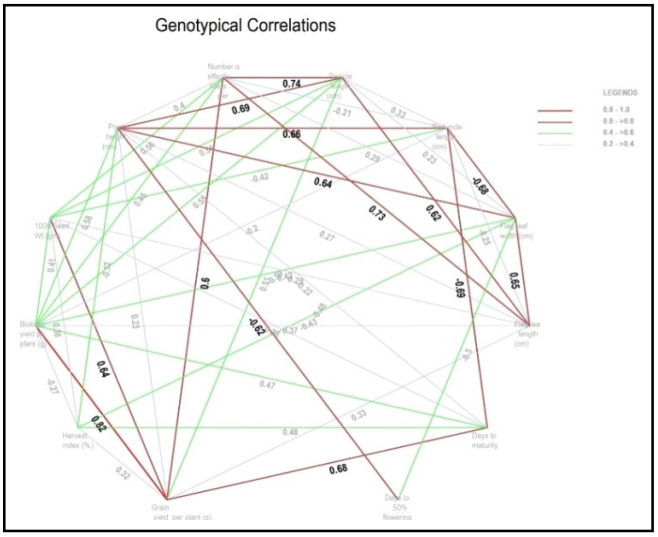


Fig. 3: Genotypic Correlation coefficients for 12 characters in 30 little millet genotypes.

Table 5: Genotypic Path for 12 characters in 30 little millet genotypes.

CA	DFF	DM	FLL	FLW	PEL	PL	PT	PH	TW	BYP	HI	GC
DF	**0.0834**	0.0122	-0.0116	-0.0415	0.0138	-0.0013	-0.0058	-0.0514	0.0107	-0.0057	-0.0056	-0.156
DM	-0.0071	**-0.0484**	0.0066	-0.0083	0.0332	0.0060	-0.0012	0.0107	-0.0185	-0.0228	-0.0231	0.682**
FLL	-0.0409	-0.0399	**0.2937**	0.1914	-0.0731	0.1824	0.2144	0.0801	0.0844	0.1091	-0.0412	0.335**
FLW	0.0143	-0.0049	-0.0187	**-0.0287**	0.0194	-0.0066	-0.0082	-0.0185	-0.0023	-0.0121	0.0123	0.123
PDL	0.0341	-0.1414	-0.0513	-0.1393	**0.2061**	0.0676	-0.0434	0.1364	-0.0860	-0.0421	-0.1211	0.077
PL	0.0049	0.0390	-0.1967	-0.0729	-0.1039	**-0.3167**	-0.2332	-0.2187	-0.1613	-0.1732	0.0573	0.506**
NPT	0.0045	-0.0016	-0.0471	-0.0184	0.0136	-0.0475	**-0.0646**	-0.0256	-0.0359	-0.0288	-0.0110	0.602**
PH	-0.1352	-0.0485	0.0598	0.1410	0.1450	0.1514	0.0870	**0.2191**	0.0379	0.1274	-0.1137	-0.232*
SW	0.0121	0.0360	0.0271	0.0074	-0.0393	0.0480	0.0524	0.0163	**0.0942**	0.0385	0.0335	0.639**
BYP	-0.0713	0.4908	0.3874	0.4409	-0.2130	0.5705	0.4651	0.6064	0.4259	**1.0428**	-0.2787	0.815**
HI	-0.0543	0.3890	-0.1142	-0.3482	-0.4789	-0.1475	0.1391	-0.4227	0.2895	-0.2178	**0.8149**	0.324**

CA: Characters; DFF: Days to 50% flowering; DM: Days to maturity; FLL: Flag leaf length (cm); FLW: Flag leaf width(cm); PEL: Peduncle length(cm); PL: Panicle length(cm); PT: Number of productive tillers per plant; PH: Plant height(cm); TW: 1000 Seed Wt.(gm); BY: Biological yield per plant (g); HI: Harvest index (%); GC: Genotypic correlation with GY
RESIDUAL EFFECT = 0.0453

yield-associated traits on grain yield per plant. Days to 50% flowering showed a positive direct effect on grain yield and positive indirect effects through days to maturity, productive tillers per plant, 1000-seed weight and biological yield. Days to maturity, however, exhibited a negative direct effect, although its indirect contribution through flag leaf length, peduncle length and plant height was positive. Flag leaf length, peduncle length and panicle length recorded positive direct effects on grain yield and also contributed positively through several component traits. Flag leaf width showed a negative direct effect but positive indirect effects through days to 50% flowering, peduncle length, panicle length and harvest index.

Among the yield-contributing traits, productive tillers per plant, plant height, 1000-seed weight and biological yield exhibited positive direct effects on grain yield, along with predominantly positive indirect effects through other component traits. Productive tillers per plant showed positive indirect effects through most of the studied traits, except peduncle length, which showed a negative indirect effect. Plant height, 1000-seed weight and biological yield also demonstrated positive indirect contributions through several yield-related traits. Harvest index exhibited a positive direct effect and positive indirect effects through days to maturity, productive tillers and 1000-seed weight. Overall, the predominance of positive direct effects for productive tillers, plant height, 1000-seed weight, biological yield, panicle length, peduncle length and flag leaf length indicates their important association with grain yield. These traits may therefore serve as useful selection criteria for improving grain yield in breeding programmes.

- **Genotypic Path analysis:**

Genotypic path coefficient analysis was conducted to determine the direct and indirect effects of characters related to yield on grain yield (GY) in 30 genotypes of little millet. Results showed that biological yield (BY) had the highest positive direct effect on grain yield (1.0428) followed by flag leaf length (FLL) (0.2937), plant height (PH) (0.2191) and panicle exertion length (PEL) (0.2061). However, panicle length (PL) showed the highest negative direct effect (-0.3167) followed by productive tillers (PT) (-0.0646), days to maturity (DM) (-0.0484) and flag leaf width (FLW) (-0.0287). Thus, the strong positive genotypic correlation of BY with GY (0.815*) was greatly supported by its high positive direct effect which indicates that biological yield is one of the important determinants of grain yield in little millet. Similarly, FLL showed a positive direct effect and significant positive correlation with GY (0.335*), suggesting its potential contribution to yield improvement (Table 5 and Fig. 4).

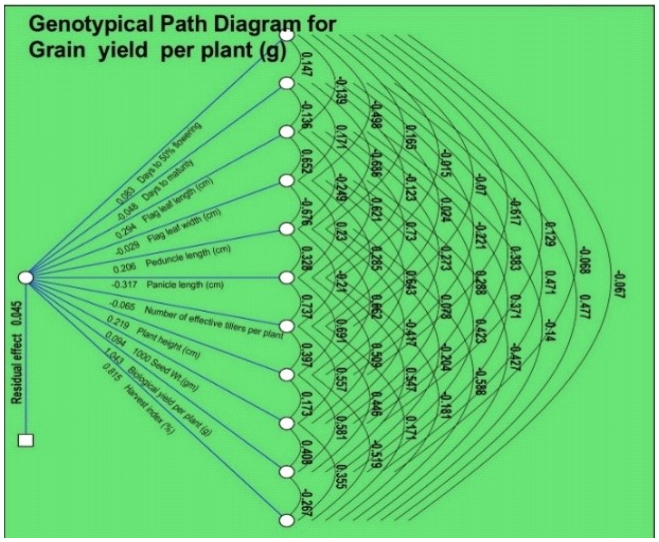


Fig. 4: Genotypic Path for 12 characters in 30 little millet genotypes.

Other traits namely DM (0.682), test weight (TW) (0.639*), PT (0.602) and PL (0.506) had significant positive genotypic correlations with grain yield. But the positive association of DM, PT and TW with GY observed was despite their small direct effects, indicating that their correlation with grain yield was highly influenced by indirect effects through other characters especially biological yield. Plant height had positive direct effect but was negatively correlated with GY (-0.232) indicating that its net association with yield was diminished by adverse indirect effects via other traits. Harvest index (HI) also had a positive direct effect (0.8149) and a significant positive correlation with GY (0.324**) showing a significant contribution to yield via both direct and indirect pathways. The residual effect of 0.0453 indicated that the characters used in the analysis accounted for a large proportion of the genotypic variation in grain yield. The overall path analysis revealed that biological yield and harvest index along with FLL and PH could be considered as important yield associated traits for selection in little millet breeding programs. In contrast, the indirect effects of other characters should be carefully considered in the course of selection.

Conclusion

In conclusion, the significant positive correlations of grain yield with biological yield, 1000-seed weight, and number of productive tillers indicate that these traits are important contributors to grain yield in little millet. Path coefficient analysis further confirmed their potential as effective selection criteria. Therefore, direct selection for these traits can be effectively employed to improve grain yield and productivity of little millet genotypes, thereby facilitating faster genetic improvement and enhancing the efficiency of future breeding programmes.

Author Contributions

This manuscript is the part of my M Sc. thesis and works was done under the supervision of Dr. Ranju Kumari, Dr. Anand Kumar and other advisory team.

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