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Character Associations and Path Coefficient Analysis for Grain Yield and Yield Contributing Traits in Pearl Millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract: The present investigation was conducted on forty genotypes of pearl millet to estimate the nature and magnitude of genetic variability, correlation and path analysis for different yield and its contributing traits. The analysis of variance revealed significant variability among genotypes for all the traits studied. The phenotypic coefficient of variation (PCV) was greater than genotypic coefficient of variation (GCV), which reflected the influence of environmental factor on the traits. High PCV and GCV were observed for plant height followed by 1000-grain weight and grain yield per plant. The plant height showed highest heritability coupled with high genetic advance as per cent of mean, due to the additive gene effects. While other yield traits like panicle diameter, effective tillers per plant, 1000-grain weight, grain yield per plant, days to maturity and panicle length have moderate value of heritability and genetic gain. The association analysis revealed that grain yield per plant had significant positive correlations with plant height, 1000 grain weight, biological yield per plant and harvest index both at genotypic and phenotypic level. Path analysis revealed that the biological yield per plant, 1000-grain weight, harvest index, plant height and days to maturity showed higher compensation due to uprising positive direct effect as well as showed positive correlation with grain yield per plant. Hence, the present study emphasizes on these traits in future crop improvement programme in pearl millet.

Key words: Genetic variability, additive gene effects, association analysis, harvest index, pearl millet.

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Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is tropical C4 small grained cereal crop having a very high photosynthetic efficiency and dry matter production capacity within a short life cycle and has large genome size of 2352 Mbp (Bennett, 2000). It belongs to family *Poaceae* and sub-family *Panicoideae*. It is believed to have originated in West Africa (Vavilov, 1950) from where it spreaded into India and other countries. It is a cross pollinated crop of protogynous nature. Pearl millet provides a nutritionally superior staple food to millions of poor rural families in drought prone arid and semi-arid regions all over the world. The grains of pearl millet are also used as feed for poultry and birds, while green and dry fodders are used for feeding the dairy cattle (Yadav and Rai, 2013). It tolerates low soil pH rangeing from 4.0 to 7.5 better than sorghum (Myers, 2002). It also possesses unique genetic predisposition to withstand environmental stress and produce appreciable yield even when grown on marginal lands. *Pennisetum glaucum* is usually grown in low fertility soils, which receive annual rainfall of 150-750 mm. In terms of area and production, pearl millet occupies the fourth rank in India after wheat, rice and maize. It is cultivated on about 24.2 mha with a production of 16.3 mt in more than 30 countries of five continents *viz*., Asia, Africa, North America, South America and Australia. In India, pearl millet is cultivated on about 6.93 mha area and produced 8.61 mt with the average productivity of 1243 kg ha^{-1} (Anonymous, 2019).

The identification of good and potential breeding lines having higher grain yield along with lesser days to maturity and high tillering ability is essential for development of the better hybrids in pearl millet. Genetic improvement of quantitative traits in any crop can be achieved through a clear understanding of the nature and amount of variability present in the breeding materials. The estimates of variability are very useful for identification of suitable selection strategy for developing high yielding genotypes. Knowledge of genetic parameters would be useful to develop appropriate breeding programme and selection process. The correlation and path coefficient analysis is also useful to determine character associations for selection of the better parents in a hybridization programme to further improve the crop improvement in pearl millet. Keeping the above facts in view, the proposed study was undertaken.

Materials and Methods

The experimental material for the present investigation consisted of 40 genotypes of diverse origin obtained from Rajasthan Agriculture Research Institute (RARI), Durgapura, Jaipur. All of them were evaluated during *Kharif* season 2019 of Research farm, S.K.N. College of Agriculture, Jobner-Jaipur, Rajasthan. The trial was arranged in randomized block design with 3 replications. In each replication, every genotype consisted of single row each of 4 m length with 45 cm of row spacing. Plant to plant distance was maintained at 10 cm through thinning/ transplanting at 3 leaf stage. All recommended package of practices were followed to raise a good and healthy plantlet. Observations were recorded on five randomly selected plants from each genotype in each replication avoiding border plants for all the traits except days to 50% flowering and days to maturity which were recorded on whole plot basis. The mean value of five plants for each trait was computed and recorded as plot mean value for days to 50% flowering, days to maturity, plant height (cm), number of productive tillers per plant, panicle length (cm), panicle diameter (cm), 1000 grain weight (g), biological yield per plant (g), harvest index (%) and grain yield per plant (g). Statistical analysis of data was carried out for each character as described by Panse and Sukhatme (1967). Genotypic and phenotypic coefficients of variation were estimated as suggested by Burton and de Vane (1953). Heritability in broad sense was calculated as suggested by Hanson *et al*. (1956). Estimates of appropriate components were substituted for the parameters to predict expected genetic gain and subsequently, the genotypic and phenotypic correlation coefficients were calculated (Johnson *et al*., 1955). Path coefficient analysis was carried out using Dewey and Lu (1959) methodology.

Results and Discussion

A successful breeding strategy for varietal development depends mainly on the nature and magnitude of variability in a population that provides the opportunity of selection to evolve a genotype having desirable traits. The analysis of variance reflects the existence of high and significant genetic variability among the genotypes of pearl millet (Table 1). The estimates of range and parameters of variability viz., phenotypic and genotypic coefficient of variability (GCV and PCV, respectively) along with heritability (h^2bs) in broad sense and expected genetic advance as per cent of mean for different traits are presented (Table 2).

Table 1. Analysis of variance for yield and yield related characters in pearl millet

Source of Variation	df	Days to 50% flowering	Days to maturity	Plant height	Effective tiller	Panicle length	Panicle diameter	1000 grain wt	Biological yield plant^{-1}	Harvest index	Grain yield plant^{-1}
Replication	2	0.499	3.265	18.426	0.001	13.017	0.002	0.220	24.863	37.327	0.144
Treatment	39	8.854**	107.926**	1943.717**	0.064**	16.702**	0.094*	2.145**	66.835*	64.924*	13.102*
Error	78	1.689	4.367	42.643	0.007	7.775	0.009	0.630	14.55	41.606	3.889

*, ** Significant at 5 % & 1 % level of significance, respectively

Table 2. Variability parameters for yield and yield contributing traits

Characters	Range	Heritability	GCV	PCV	GA	GA% Mean
Days to 50% flowering	45.33-54.33	58.57	3.11	4.07	2.43	4.91
Days to maturity	71.00-90.00	88.77	7.12	7.56	11.40	13.82
Plant height	75.45-165.51	93.69	20.21	20.87	50.19	40.29
Effective tillers per plant	1.34-1.90	72.87	8.86	10.38	0.24	15.58
Panicle length	10.18-19.56	27.67	10.53	20.02	1.86	11.41
Panicle diameter	1.33-2.11	76.16	10.26	11.76	0.30	18.46
1000 grain wt	4.24-7.52	44.47	13.71	20.56	0.97	18.83
Biological yield plant^{-1}	30.20-46.45	54.50	11.04	14.95	6.34	16.78
Harvest index	32.30-51.33	15.74	7.03	17.73	2.27	5.75
Grain yield plant^{-1}	12.06-22.11	44.12	11.83	17.81	2.39	16.19

In this study, magnitudes of phenotypic variance obtained were greater than the corresponding genotypic variance for all the characters which indicated significant impact of environment on the genotypes under trial as was also reported earlier (Dubey and Manga, 2005; Govindraj *et al.,* 2011; Nehra *et al.,* 2017; Kumawat *et al.,* 2019). High to moderate PCV along with GCV were observed for plant height (20.87%, 20.20%), 1000 grain weight (20.56%, 13.71%), panicle length (20.01%, 10.53%), grain yield per plant (17.81%, 11.83%), biological yield per yield plant (14.95%, 11.03%) and panicle diameter (11.76%, 10.20%). Harvest index (17.73%, 7.03%), and effective tillers per plant (10.38%, 8.86%) represented moderate PCV with lower GCV. High PCV and GCV were observed for the plant height trait which is less influenced by the environmental factors in expression of genes related to it. The results are in accordance with Singh and Singh (2016) and Sharma *et al.* (2018).

The magnitude of heritability in broad sense reveals the reliability with which a genotype can be recognized by its phenotype expression. A very high heritability was observed for both plant height (93.69%) and days to maturity (88.77%) traits. Earlier reports of many research workers also found similar results for plant height (Manga *et al.,* 1985; Nagar *et al.,* 2006 and Vinodhana *et al.,* 2013) in pearl millet, while high to moderate for panicle diameter (76.16%), effective tillers per plant (72.87%), days to 50% flowering (58.57%), biological yield per plant (54.50%), 1000 grain weight (44.47%) and grain yield per plant (44.12%). These results are in accordance with those of Borkhataria *et al.* (2005) and Bhasker *et al.* (2017).

The high expected genetic advance is expressed as percentage of mean and is used to relate genetic advance for different traits. A significantly high value of genetic advance was observed for plant height (40.29%). The value was, however, moderate for most of the other phenotypic traits i.e. 1000 grain weight (18.83%), panicle diameter (18.45%), biological yield per plant (16.78%), grain yield per plant (16.18%), effective tillers per plant (15.58%), days to maturity (13.82%) and panicle length (11.41%). Similar findings in pearl millet were earlier reported by Nagar *et al.* (2006). High estimate of heritability coupled with moderate to high genetic gain were detected for plant height, 1000-grain weight, panicle diameter, biological yield per plant and number of effective tillers per plant. Hence, it is noteworthy to emphasize on these traits

Table 3. Estimation of Genotypic (G) and Phenotypic (P) correlation coefficient among yield and yield related traits

Characters		Days to maturity	Plant height	Effective tillers	Panicle length	Panicle diameter	1000 grain wt	Biological yield (per plant)	Harvest index	Grain yield (per plant)
Days to 50% flowering	r_g	0.105	-0.056	-0.046	-0.005	-0.092	-0.021	-0.270**	0.239**	-0.111
	r_p	0.069	-0.060	0.030	0.000	-0.079	0.081	-0.077	0.164	0.081
Days to maturity	r_g		-0.035	0.319**	0.219*	0.079	0.048	-0.014	0.086	0.078
	r_p		-0.03	0.250**	0.141	0.028	0.034	-0.022	0.085	0.083
Plant height	r_g			0.100	0.723**	-0.014	0.379**	0.792**	-0.605**	0.417**
	r_p			0.074	0.369**	0.005	0.236**	0.542**	-0.255**	0.230*
Effective tillers	r_g				-0.007	0.151	-0.055	-0.06	0.190*	0.034
	r_p				0.017	0.063	-0.033	-0.006	0.028	0.019
Panicle length	r_g					0.117	0.199*	0.541**	-0.612**	0.201*
	r_p					0.022	0.142	0.285**	-0.127	0.141
Panicle diameter	r_g						-0.234**	0.021	-0.015	0.001
	r_p						-0.111	0.003	-0.047	-0.042
1000 grain weight	r_g							0.751**	0.349**	0.962**
	r_p							0.381**	0.485**	0.837**
Biological yield per plant	r_g								-0.336**	0.789**
	r_p								-0.435**	0.445**
Harvest index	r_g									0.310**
	r_p									0.600**

*, ** Significant at 5 % & 1 % level of significance, respectively

while selecting a genotype in pearl millet for future crop improvement programme.

Knowledge of genetic associations of yield and its contributing characters are of economic worth in formulating the breeding programme. The correlations between yield and component characters estimated at genotypic and phenotypic levels are presented in Table 3. The magnitude of genotypic correlation coefficient was higher than the corresponding values of phenotypic correlation coefficient, which revealed low environmental effects on the character expression. Results showed that grain yield per plant had positive and significant genotypic and phenotypic correlation with plant height, 1000-grain weight, biological yield per plant and harvest index. Similar associations of grain yield with other yield contributing traits were also observed by Kapoor (2020). Among different pairs of yield and yield contributing traits, it was observed that days to 50% flowering exhibited positive correlation with harvest index, days to maturity, effective tillers per plant (phenotypic level), 1000-grain weight (phenotypic level) and grain yield per plant (phenotypic level). Likewise, days to maturity also showed positive correlation with effective tillers per plant, panicle length, panicle diameter, 1000 grain weight and grain yield per plant. Similar results are reported by Sharma *et al.*, (2018) that days to flowering showed highly significant and positive correlation with plant height, days to maturity, earhead length, earhead girth and seed density traits. Plant height too displayed a positive and significant association with panicle length, 1000-grain weight, biological yield per plant, effective tillers per plant, panicle diameter and grain yield per plant both at genotypic and phenotypic level. The results are akin with Sharma *et al*. (2018) and Kumawat *et al.* (2019). Positive correlation of number of productive tillers per plant was observed with harvest index, panicle length, panicle diameter and grain yield per plant both at genotypic and phenotypic level which are in close harmony with Manga (2002) and Nehra *et al*. (2017) observed that number of productive tillers per plant showed significant positive correlation with days to 50% flowering, number of nodes per plant, spike length, plant height, 1000 grain weight, dry fodder yield per plant, green fodder yield per plant and grain yield per plant and Sharma *et al.* (2018) also reported positive and significant association with earhead length,

Table 4. Direct and indirect effects of different characters on grain yield at genotypic (g) and phenotypic (p) level

Characters		Days to 50% flowering	Days to maturity	Plant height	Effective tillers	Panicle length	Panicle diameter	1000 grain wt	Biological yield plant^{-1}	Harvest index	Grain yield plant^{-1}
Days to 50% flowering	g	-0.05623	0.00497	-0.00690	0.00093	0.00025	-0.01199	-0.01193	-0.10222	0.07260	-0.111
	p	-0.01398	0.00145	-0.00015	-0.00009	0.00000	-0.00052	0.00754	-0.06151	0.14829	0.081
Days to maturity	g	-0.00590	0.04737	-0.00438	-0.00644	-0.01002	0.01033	0.02663	-0.00544	0.02601	0.078
	p	-0.00096	0.02112	-0.00007	-0.00077	0.00156	0.00018	0.00312	-0.01783	0.07713	0.083
Plant height	g	0.00315	-0.00168	0.12339	-0.00203	-0.03312	-0.00177	0.21194	0.30043	-0.18358	0.417**
	p	0.00084	-0.00063	0.00252	-0.00023	0.00407	0.00004	0.02191	0.43235	-0.23119	0.230*
Effective tillers	g	0.00259	0.01509	0.01237	-0.02020	0.00033	0.01967	-0.03062	-0.02260	0.05762	0.034
	p	-0.00042	0.00528	0.00019	-0.00308	0.00018	0.00041	-0.00311	-0.00502	0.02505	0.019
Panicle length	g	0.00031	0.01036	0.08926	0.00015	-0.04578	0.01530	0.11157	0.20517	-0.18573	0.201*
	p	0.00000	0.00298	0.00093	-0.00005	0.01104	0.00014	0.01324	0.22741	-0.11485	0.141
Panicle diameter	g	0.00517	0.00375	-0.00168	-0.00305	-0.00537	0.13039	-0.13113	0.00781	-0.00441	0.001
	p	0.00111	0.00059	0.00001	-0.00019	0.00024	0.00659	-0.01035	0.00213	-0.04221	-0.042
1000 grain weight	g	0.00120	0.00225	0.04674	0.00111	-0.00913	-0.03056	0.55950	0.28470	0.10598	0.962**
	p	-0.00113	0.00071	0.00059	0.00010	0.00157	-0.00073	0.09297	0.30404	0.43927	0.837**
Biological yield per plant	g	0.01516	-0.00068	0.09775	0.00120	-0.02477	0.00268	0.42004	0.37923	-0.10202	0.789**
	p	0.00108	-0.00047	0.00136	0.00002	0.00315	0.00002	0.03541	0.79818	-0.39404	0.445**
Harvest index	g	-0.01346	0.00406	-0.07467	-0.00384	0.02803	-0.00190	0.19546	-0.12754	0.30336	0.310**
	p	-0.00229	0.00180	-0.00064	-0.00009	-0.0014	-0.00031	0.04512	-0.34751	0.90506	0.600**

Residual effect: 0.01727, 0.0219, at genotypic and phenotypic level, respectively

earhead girth, seed size and seed density traits Panicle length showed positive and significant correlation with 1000-grain weight, grain yield per plant, biological yield and panicle diameter correspondingly panicle diameter also showed positive with biological yield and grain yield per plant both at genotypic and phenotypic level which are great agreement with Talawar *et al.* (2017) and Kumawat *et al.* (2019). Grain weight showed positive and significant relationship with biological yield per plant, harvest index and grain yield per plant at both genotypic and phenotypic level. These results are at close proximity with Bikash *et al.* (2013). The biological yield per plant exhibited positively and significant correlated with grain yield per plant which is comparable with Sharma *et al*. (2018) and Kumar *et al*. (2019). Harvest index displayed positive and significant association with grain yield per plant at both genotypic and phenotypic level which are approximating with Abuali *et al.* (2012) and Choudhary *et al.* (2012).

Path coefficient analysis helps in separating the direct effect of a component characters on grain yield from indirect effect via other traits. The genotypic and phenotypic correlation coefficients of grain yield with its contributing characters were partitioned into direct and indirect effects through path coefficient analysis are presented in table 4. Path coefficient showed highest positive direct effect on grain yield per plant for harvest index followed by biological yield per plant and 1000 grain weight both at genotypic and phenotypic level, while panicle diameter, plant height, days to 50% flowering, days to maturity and panicle length showed high direct effect at only genotypic level. Plant height displayed a significant positive association with grain yield, which was due to direct effect at genotypic level as well as positive indirect effects via biological yield per plant and 1000 grain weight while harvest index gave high negative indirect effect both at genotypic and phenotypic level which alike to Yadav *et al.,* (1993), Manga (2002), Choudhary *et al*. (2012) and Ezeaku *et al*. (2015). 1000 grain weight displayed highly significant positive association with grain yield; it gave high direct effect along with high positive indirect via biological yield and harvest index at genotypic and phenotypic level which parallel with Rasitha *et al.* (2019). The biological yield per plant directly associated with grain yield per plant, results indicated that biological yield gave high direct effect and it also gave high positive indirect effect via 1000 grain weight, plant height and panicle length. Harvest index had high negative indirect effect via biological yield per plant while positive indirect effect via 1000 grain weight at both genotypic and phenotypic level, these results were parallel to study conducted by Choudhary *et al*. (2012) reported that fodder yield per plant, harvest index and number of nodes per plant with grain yield and their inter-associations. Path analysis revealed that the biological yield per plant, 1000-grain weight, harvest index, plant height and days to maturity showed higher compensation due to high positive direct effect as well as showed positive correlation with grain yield per plant. Hence, their large direct effect on grain yield maximum emphasis in selection for improvement of grain yield in future pearl millet improvement programme.

Conclusions

Our study indicated the presence of high genetic variability for various traits in different genotypes of pearl millet. High PCV and GCV were recorded for plant height followed by test weight and grain yield per plant. Out of ten characters studied plant height showed maximum heritability coupled with high genetic advance as per cent of mean as, these traits might be under the control of additive gene effects. Present investigation brought out that yield component traits like plant height, 1000 grain weight, panicle length, harvest index and biological yield per plant were positively associated with grain yield per plant and simultaneously all the yield component traits showed inter correlation with each other and contributed towards grain yield directly or through other traits. Correlation co-efficient indicated only the general associations between any two traits without tracing any possible causes of such associations. The same is correlated with path analysis. As grain yield is a complex character, for genetic improvement, an understanding of association relationship within its contributing traits is needed to develop high yield novel genotypes.

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