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Studies on character association and path analysis in restorer lines of pearl millet [*Pennisetum glaucum* (L.) R. Br.] for yield contributing characters

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Abstract
Thirty-two pearl millet restorer lines were studied to determine the interrelationship between yield and yield components and other quantitative traits, including plant height, days to flowering, days to maturity, number of effective tillers, ear head length, ear head girth, ear head weight, dry fodder yield per plant and grain yield per plant. The path analysis and phenotypic and genotypic correlation coefficients were worked out. The results from present study revealed significant and positive association of grain yield per plant with number of effective tiller per plant (r_g=0.345, r_p=0.200) earhead girth (r_g=0.503, r_p=0.352), earhead weight (r_g=0.479, r_p=0.481) and dry fodder yield per plant (r_g=0.747, r_p=0.601). Among them, earhead girth was also found to be positive significantly associated with earhead weight (r_g=0.380, r_p=0.295) and dry fodder yield per plant (r_g=0.468, r_p=0.431). Hence, selection criteria for these traits should be considered important for the improvement in grain yield per plant. While, negative and significant association of grain yield per plant with days to flowering (r_g= -0.610, r_p= -0.218) and days to maturity (r_g= -0.356, r_p= -0.313) was observed which are inversely proportional to grain yield per plant indicating that delayed flowering and maturity in pearl millet leads to reduction in grain yield per plant. Path analysis indicated Positive and highest direct effect for dry fodder yield per plant while, low and positive indirect effects of number of effective tiller, earhead girth and earhead weight through dry fodder yield per plant was observed which denoted significant contribution of the traits on grain yield per plant. Thus, these characters can be used as selection criteria for yield improvement of pearl millet.

Keywords: Pearl millet, restorers, correlation coefficients, path analysis

Introduction
Pearl millet is a warm season crop cultivated for grain and fodder purpose. Globally, pearl millet ranks sixth among cereal grains after wheat, rice, maize, barley and sorghum. It is cultivated over an area of 34 million ha worldwide with yield of 31 million tonnes (Patil *et al*., 2020) [16]. India is the largest producer of pearl millet in world having 6.93 million ha area under the crop with an average production of 8.61 million tonnes and productivity of 1243 kg per ha (Anonymous, 2019) [4]. Pearl millet being a C_4 crop, possess high photosynthetic efficiency along with dry-matter production (Yadav and Rai, 2013) [22]. This property makes pearl millet a highly desirable crop for farmers under adverse agro-climatic conditions where most of the cereals are likely to fail to provide economic yields. Pearl millet is a good source of energy, carbohydrate, protein, fat, ash, dietary fiber, iron, and zinc (Kumari, 2019) [11] as well as it is gluten-free and the only grain that retains its alkaline properties after being cooked which is ideal for people with gluten allergy (Irén Léder, 2004) [13].
Correlation coefficient expresses the association between the two variables by estimating the covariance components between different types of observations. The cause and effect, interrelationship between two variables cannot be estimated from simple correlation coefficient analysis. Therefore, the correlation among the different character combinations can be utilized to construct the path coefficient analysis as suggested by Wright (1921) [21] and used by Dewey and Lu (1959) [8] in plants. Genotypic correlation coefficients of eight variables with seed yield per plant were used to estimate the path analysis for the direct effects of various independent characters on seed yield per plant.
Among many phases in pearl millet improvement in India, current phase from 1996 onwards of hybrid development has put a much greater emphasis on genetic diversification of both seed and pollinator parents (Yadav and Rai, 2013) [22]. Hybrid breeding has shown progressive yield enhancement in pearl millet especially in India (Yadav and Rai, 2013 [22]; Kumara *et al*., 2014 [10]).

For exploiting hybrid vigour in pearl millet, three-line system (A, B and R line) of hybrid development is used. Among this three lines, A and B lines are genetically similar. Thus, variability present in the restorer lines should be exploited for enhanced hybrid vigour.

The inflorescence of pearl millet permits many breeding techniques to be used ranging from various types of population improvement to strict pedigree selection. Higher yield being a very complex trait and influenced by many component traits, the correlation of this traits along with direct and indirect effect of them on grain yield per plant is important in enhancing the yields. Therefore, the present investigation was carried out to study yield contributing characters and understanding character association among these characters of restorer lines in pearl millet.

Materials and Method

The present investigation was undertaken at Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during Summer - 2020. The research material comprised of 32 Restorer lines which were raised in a Randomized Block Design (RBD) with four replications and spacing 45 × 15 cm. Observations were recorded for 9 agro-morphological traits by tagging five competitive plants randomly per entry in a replication. Observations were recorded for plant height (cm), days to flowering, days to maturity, number of effective tiller per plant, earhead length (cm), earhead girth (mm), earhead weight (g), grain yield per plant (g) and dry fodder yield per plant (g). All the statistical analysis was done by SPAR ver 2.0 (Ahuja *et al*. 2008) [2]. Thirty-two genotypes used for study were: 15001 R, 15035 R, 15056 R, 15061 R, 15063 R, 15208 R, 15214 R, 15240 R, 15298 R, 15367 R, 15388 R, 15403 R, 15451 R, 15550 R, 15611 R, 15636 R, 15697 R, 15713 R, 15725 R, 15743 R, 15787 R, 15851 R, 16088 R, 16110 R, 16317 R, 16713 R, 17548 R, 18120 R, 18123 R, 18140 R, 18196 R, 18511 R.

The parameters genotypic (r_g) and phenotypic (r_p) correlation coefficient were calculated as under by adopting the procedure explained by Al-jibouri *et al.* (1958) [3]. The correlation among the different character combinations was utilized to construct the path coefficient analysis as suggested by Dewey and Lu (1959) [8]. in plants. Genotypic correlation coefficients of eight variables with grain yield per plant were used to estimate the path analysis for the direct effects of various independent characters on grain yield per plant. Scales for path coefficients was suggested by Lenka and Mishra, 1973 [14]. As (0.00-0.09)- Negligible, (0.10-0.19)- Low, (0.20-0.29)- Moderate, (0.30-1.00)- High, (>1.00)- Very high.

Results and Discussion

Correlation coefficient analysis

Through correlation coefficient analysis it was found that genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients for all the characters studied (Table.1). Correlation coefficient studies reveals about the yield contributing characters, their quality and correlation with grain yield and among themselves. The information obtained from correlation coefficients along with direct and indirect effect of component characters would prove efficient in selection of elite genotypes from given diverse genetic populations.

Plant height was positive and significantly correlated at genotypic level (r_g=0.399, r_p=0.353) with earhead length. Days to flowering had positive and highly significant correlation with days to maturity (r_g=0.661, r_p=0.340) at both genotypic and phenotypic level while it exhibited negative and highly significant association with earhead weight (r_g= -0.436, r_p= -0.287) dry fodder yield per plant (r_g= -0.370, r_p= -0.179) and grain yield per plant (r_g= -0.610, r_p= -0.218) at both genotypic and phenotypic level. Days to maturity had negative and significant correlation with grain yield per plant (r_g= -0.356, r_p= -0.313) at both genotypic and phenotypic level.

Number of effective tiller per plant had positive and significant correlation with grain yield per plant (r_g=0.345, r_p=0.200) at both genotypic and phenotypic level which was in accordance with Beniwal *et al*. (2020) [5] and Kumar *et al*. (2020) [12]. Number of effective tiller per plant had negative and highly significant correlation with earhead weight (r_p= -0.197) at phenotypic level only. Present study reported negative and significant correlation of earhead length with earhead girth (r_p= -0.225) at phenotypic level. Positive and highly significant correlation was recorded between earhead girth with grain yield per plant (r_g=0.503, r_p=0.352), dry fodder yield per plant (r_g=0.468, r_p=0.431) and ear head weight (r_g=0.431, r_p=0.295) at both genotypic and phenotypic levels. Earhead weight showed positive and highly significant correlation with grain yield per plant (r_g=0.479, r_p=0.481) at both genotypic and phenotypic level and with dry fodder yield per plant (r_p=0.296) at phenotypic level. Similar results of earhead weight with grain yield per plant were reported by Vagadiya *et al*., 2010 [20]. Dry fodder yield per plant exhibited positive and highly significant correlation with grain yield per plant (r_g=0.747, r_p=0.601) at both genotypic and phenotypic level (Bhasker *et al*., 2017) [6].

The results from present study revealed significant and positive association of grain yield per plant with number of effective tiller per plant, earhead girth, earhead weight and dry fodder yield per plant. Among them, earhead girth was also found to be positive significant associated with earhead weight and dry fodder yield per plant. Hence, selection criteria for these traits should be considered important for the improvement in grain yield per plant.

Table 1: Genotypic and phenotypic correlation coefficients among nine characters

Character		PH	DF	DM	NET	EHL	EHG	EHW	DFYPP	GYPP
PH	r_g	1.000	-0.309	0.184	-0.205	0.399*	0.185	0.195	0.122	-0.070
	r_p	1.000	-0.150	0.143	-0.127	0.353**	0.167	0.152	0.114	-0.056
DF	r_g		1.000	0.661*	-0.165	-0.170	-0.157	-0.436*	-0.370*	-0.610**
	r_p		1.000	0.340**	0.143	-0.005	-0.113	-0.287**	-0.179*	-0.218**
DM	r_g			1.000	0.085	0.150	-0.137	-0.257	-0.064	-0.356*
	r_p			1.000	0.078	0.124	-0.117	-0.197*	-0.039	-0.313**
NET	r_g				1.000	0.040	0.062	-0.328	0.287	0.345*
	r_p				1.000	0.062	-0.011	-0.395**	0.160	0.200*

EHL	r_g					1.000	-0.304	0.049	-0.143	-0.249
	r_p					1.000	-0.225*	0.036	-0.103	-0.139
EHG	r_g						1.000	0.431*	0.468**	0.503**
	r_p						1.000	0.295**	0.431**	0.352**
EHW	r_g							1.000	0.317	0.479**
	r_p							1.000	0.296**	0.481**
DFYPP	r_g								1.000	0.747**
	r_p								1.000	0.601**
GYPP	r_g									1.000
	r_p									1.000

Where,
PH: Plant Height, DF: Days to Flowering, DM: Days to Maturity, NET: Number of Effective tiller per plant, EHL: Earhead length, EHG: Earhead girth, EHW: Earhead Weight, GYPP: Grain Yield Per Plant, DFYPP: Dry Fodder Yield Per Plant.
*,** - Significance at 5 and 1 per cent probability level

While, negative and significant association of grain yield per plant with days to flowering and days to maturity at both genotypic and phenotypic level was observed which lays emphasis on the mutual correlation between days to flowering and days to maturity which are inversely proportional to grain yield per plant which indicated that delayed flowering and maturity in pearl millet leads to reduction in grain yield per plant.

Path analysis

In present study, path coefficient analysis was carried out at genotypic path for all the characters under study. The direct and indirect effects of these independent variables on grain yield per plant are presented in Table 2. Positive and high direct effect was recorded for dry fodder yield per plant which was in accordance with previous studies by Beniwal *et al.* 2020 [5], Patil *et al*., 2018) [15], Bhasker *et al*., 2017) [6]. Low and positive indirect effects of number of effective tiller (0.103), earhead girth (0.169) and earhead weight (0.114) through dry fodder yield per plant was observed which denoted significant contribution of the trait on grain yield per plant. Days to flowering (-0.693) showed negative high direct effect with negative significant correlation with grain yield per plant which denoted inverse relationship between the two characters. Similar findings were reported by Ezeaku *et al.* (2015) [9]. Days to maturity (0.281) and earhead girth (0.228) exhibited moderate and positive direct effect on grain yield per plant. Positive direct effect along with negative genotypic correlation for days to maturity with grain yield per plant would be due to negative indirect effect of days to maturity via other component traits earhead length, earhead girth, earhead weight and dry fodder yield per plant. Plant height exhibited moderate indirect effect via days to flowering (0.214) and days to flowering reported low indirect effect via days to maturity (0.186).

High negative direct effect of plant height (-0.380) on grain yield per plant was also reported by Beniwal *et al.* (2020) [5] and Bhasker *et al.* (2017) [6]. Negative and non-significant genotypic correlation was observed between plant height and grain yield per plant. This is in accordance with the previous findings of Beniwal *et al.* (2020) [5]. Negative direct effect along with non-significant correlation points towards the fact that selection for the character plant height would not give specific genetic improvement in grain yield.

In present study, number of effective tiller per plant (0.066) had observed positive significant genotypic correlation and positive direct effect on grain yield per plant. This was supported by Abuali *et al.* (2012) [1] and Patil *et al.* (2018) [15]. Negative direct effects of earhead length (-0.146) on grain yield per plant was also reported by Sumanth *et al.* (2014) [19], Ezeaku *et al.* (2015) [9], Rasitha *et al.* (2019) [17], Kumar *et al.* (2020) [12]. Earhead weight (0.151) reported low and positive direct effect on grain yield per plant. Present study points towards the fact that selection for dry fodder yield per plant per plant would express significant genotypic correlation along with positive and direct effect on grain yield per plant imparting genetic improvement.

Table 2: Path coefficient analysis showing direct and indirect effects of various traits on grain yield per plant

Character	PH	DF	DM	NET	EHL	EHG	EHW	DFYPP	GYPP
PH	-0.380	0.214	0.052	-0.014	-0.058	0.042	0.029	0.044	-0.070
DF	0.117	-0.693	0.186	-0.011	0.025	-0.036	-0.066	-0.133	-0.610**
DM	-0.070	-0.458	0.281	0.006	-0.022	-0.031	-0.039	-0.023	-0.356*
NET	0.078	0.114	0.024	0.066	-0.006	0.014	-0.049	0.103	0.345*
EHL	-0.151	0.118	0.042	0.003	-0.146	-0.069	0.007	-0.052	-0.249
EHG	-0.070	0.109	-0.039	0.004	0.045	0.228	0.057	0.169	0.503**
EHW	-0.074	0.302	-0.072	-0.022	-0.007	0.087	0.151	0.114	0.479**
DFYPP	-0.046	0.256	-0.018	0.019	0.021	0.107	0.048	0.360	0.747**

Where,
PH: Plant Height, DF: Days to Flowering, DM: Days to Maturity, NET: Number of Effective tiller per plant, EHL: Earhead length, EHG: Earhead girth, EHW: Earhead Weight, GYPP: Grain Yield Per Plant, DFYPP: Dry Fodder Yield Per Plant, Residual effect = 0.0299
Note: Bold diagonal values indicate direct effect

Similar results of the highest positive direct effect of dry fodder yield per plant on grain yield per plant along with highest negative direct effect values of plant height and days to flowering on grain yield per plant found to be in accordance with by Beniwal *et al.* (2020) [5], Bhasker *et al.* (2017) [6].

Positive and highly significant genotypic correlation between earhead girth and grain yield per plant was found in present

study. The high positive indirect effect of ear head girth via dry fodder yield per plant was observed. Thus, direct selection for high earhead girth may give satisfactory enhancement in grain yield per plant. These findings were in accordance with Patil *et al*. (2018) [15]. Dry fodder yield per plant recorded positive and highly significant genotypic correlation with grain yield per plant along with high and positive direct effect on grain yield per plant. It exhibited positive and low indirect effects through traits *viz*; number of effective tiller per plant, earhead girth and earhead weight.

The observed residual effect of 0.0299 indicated that the chosen characters were adequate and good enough for path coefficient analysis in this study. Path analysis measures direct and indirect contribution of each independent variable on the dependent variable say grain yield per plant in present study. The path analysis revealed that days to maturity, number of effective tiller per plant, earhead girth, earhead weight, dry fodder yield per plant showed positive direct effect on grain yield per plant indicating their appreciable contribution in enhancing the grain yield per plant. The direct effect of dry fodder yield per plant was of high magnitude. The high and desirable genotypic correlation of other characters with grain yield per plant was also due to high indirect effect through this character. Among these traits, high and positive indirect effect on grain yield per plant was observed through number of effective tiller per plant, earhead girth and earhead weight.

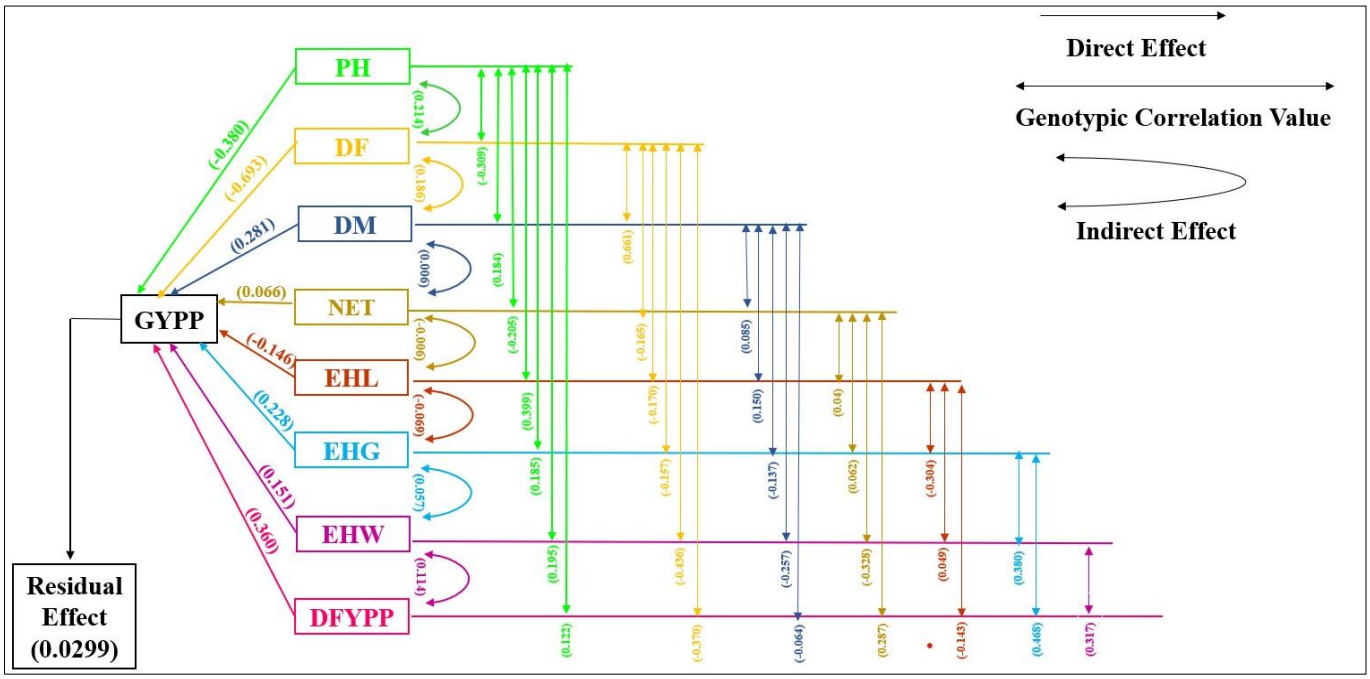

Fig: Diagrammatic representation of genotypic path analysis in pearl millet

Conclusions

The results from character association and path analysis study from present investigation revealed positive significant association of grain yield per plant with number of effective tiller per plant, earhead girth, earhead weight and dry fodder yield per plant. Among them, earhead girth was also found to be positive significant associated with earhead weight and dry fodder yield per plant. Also, the characters number of effective tiller per plant, earhead girth, earhead weight, dry fodder yield per plant showed positive direct effect on grain yield per plant indicating their appreciable contribution in enhancing the grain yield per plant. Therefore, breeding program done in effective manner based on these traits could be beneficial for improvement in grain yield.

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