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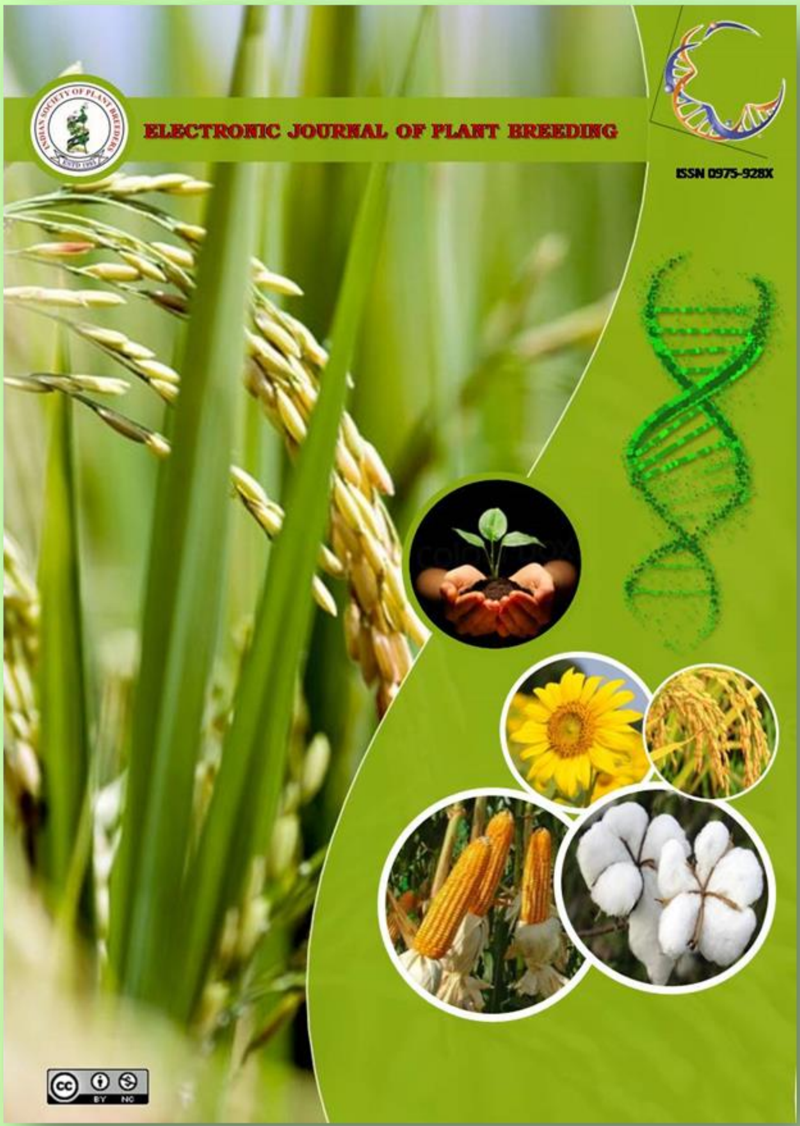


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**Research Article**

# Genetic architecture of morpho-physiological traits over environments in pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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**Abstract**
Thirty pearl millet accessions including inbreds and hybrids procured from ICRISAT, Hyderabad were evaluated during summer 2017 over three sowing dates. The wide range of phenotypic variation was noted in an individual and pooled environment for all fourteen qualitative and quantitative traits. Higher estimates of phenotypic coefficient of variation was observed over the genotypic coefficient of variation for the number of effective tillers per plant, grain yield per plant, number of total tillers per plant, harvest index, leaf area, test weight and seed setting on main tiller. The high GCV (%) and PCV (%) were obtained for most of the traits. High heritability was associated with high genetic advance (% mean) for plant height, dry fodder yield, earhead girth and length, leaf area, grain yield, test weight, harvest index and number of total tillers per plant suggesting additive gene action for inheritance and could be improved through selection. The trait grain yield was positively and highly significantly correlated with earhead girth, seed setting on main tiller, plant height, leaf area, dry fodder yield, test weight, number of total tillers per plant, number of effective tillers per plant and harvest index at genotypic, phenotypic and environmental levels. The path coefficient analysis concluded that the desirable ideotype for improving grain yield should possess maximum earhead girth, more number of effective tillers with moderate plant height and flowering time.

**Key words**
Association, genetic variability, heritability, genetic advance, pearl millet

## Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the staple food of the majority of the poor and small land holders, as well as feed and fodder for livestock in rain-fed regions of the country. Being world's sixth, it is India's fourth important cereal food crop after rice, wheat and maize. It is a cereal crop that thrives more in the arid and semi-arid tropical regions of Asia and Africa. It excels all other cereals being of C4 plant with high photosynthetic efficiency, high dry matter production capacity and is grown under the most adverse agro-climatic conditions where other crops like sorghum and maize fail to produce economic yields. The crop is rightly termed as "nutricereal" as it is a good source of energy, carbohydrate, protein, fat, ash, dietary fiber, iron and zinc (Satyavathi *et al*. 2017). Protogyny condition of the crop promotes cross pollination hence, the plant maintains heterozygous balance.

It is important to have information on the nature and magnitude of variability present in the population due to genetic and non-genetic causes. In this context, knowledge regarding genetic variability, heritability and genetic advance is quite useful for the formation of a systematic breeding strategy for improvement of yield in desired direction. Yield being a complex and polygenic character which depends on a number of components, is highly influenced by the environment. Therefore, study of the association of such quantitative and qualitative characters affecting the grain yield is of immense practical value for the plant breeder which helps in evolving effective selection indices for genetic improvement. However, this does not provide information of direct and indirect effects of the component characters towards dependent variable i.e. grain yield. This is possible by path analysis of Dewey and Lu (1959). Hence, the present study was formulated to assess the genetic parameters governing trait inheritance for suggesting desirable ideotype for rapid genetic improvement.

## Materials and Methods

The experimental material used in the present investigation comprised of 30 genotypes, including hybrids and advance lines of pearl millet procured from ICRISAT, Hyderabad. The experiment was laid out in randomized block design with two replications over three dates of sowing viz., 1st March (environment-I), 16th March (environment-II) and 31st March (environment-III) during the summer, 2017 at Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat. The spacing of 45 × 10-15 cm was maintained and all the recommended cultural practices were adopted to raise the crop. The observations were recorded on five randomly selected plants from each replication for twelve traits viz., plant height (cm), earhead length (cm), earhead girth (mm), number of total tillers per plant, number of effective tillers per plant, seed setting on main tiller (%), leaf area (cm2), dry fodder yield per plant (g), grain yield per plant (g), harvest index (%), test weight (g) and protein content (%), while two characters, namely, days to flowering and days to maturity were recorded on plot basis. Mean values of each observation of three replications of individual environment were subjected to standard statistical procedures viz., analysis of variance (Panse and Sukhatme, 1985), genotypic and phenotypic co-efficient of variations (Burton, 1952) and genetic advance (Johnson et al. 1955). The pooled data of three environment were also analysed for the statistical analysis. Correlation coefficients were determined by using the variance and covariance components as suggested by Al-Jibouri et al. (1958). The path analysis was carried out as per the procedure described by Dewey and Lu (1959).

**Results and Discussion**

The prime requirement of any study is the existence of variability of traits in the available population and in present study differences between accessions in three environments as well as pooled environment were highly significant for all the traits. The genotypes procured were belong to diverse origin. The significant genetic variations has been also reported by Kumari *et al*. (2013) and Vagadiya *et al*. (2013) in pearl millet. Prevalence of environment at different date of sowing differed from each other indicated by highly significant mean square due to environment for all the characters except dry fodder yield per plant and protein content (Table 1).

The erratic reaction of genotypes under varying environments was observed by significance of G × E interaction for most of the traits studied when tested against pooled error. These results are in agreement with earlier reports of Ramamoorthi *et al*. (1996) and Bikash *et al.* (2013b). Also, a perusal of Table 2 indicated that in general genotypes performed well in environment-I followed by environment-II whereas the lowest per se were recorded for almost all traits in environment-III. None of the genotype was consistent in their performance for any of the characters over varying environments. This indicated that genotypes differed in their performance for yield and other quantitative characters. The overall range of phenotypic variation in pooled analysis revealed highest for leaf area followed by plant height, dry fodder yield per plant, seed setting on main tiller, grain yield per plant, harvest index, days to flowering, earhead girth, days to maturity and earhead length. The same results were also found in individual environments. The wide range of phenotypic variation of various characters indicates the scope for genetic improvement in these characters through selection and other breeding approaches.

The phenotypic coefficient of variation depicted higher values than genotypic coefficient variation in individual and pooled environments for all the traits. The reason behind this might be differential environmental effects. The same was also reported by Govindaraj *et al.* (2011) and Mukh Ram *et al*. (2014). The GCV (%) was close to PCV (%) for the majority of traits indicating the low effect of the environment and greater role of genetic factors on the expression of the traits viz., days to flowering, days to maturity, plant height, earhead length and earhead girth. The results also revealed high GCV (%) and PCV (%) for dry fodder yield per plant followed by grain yield per plant, leaf area and plant height whereas moderate for earhead girth, earhead length and protein content. The pooled analysis (Table 2) revealed high GCV (%) and PCV (%) for dry fodder yield per plant followed by grain yield per plant, leaf area and plant height. The results were in accordance with Chaudhry *et al*. (2003) and Lakshmana *et al.* (2009) for plant height and grain yield per plant, Vidyadhar *et al*. (2007) and Vagadiya *et al.* (2013) for dry fodder yield per plant and grain yield per plant. The moderate genotypic and phenotypic coefficients of variation were observed in test weight, earhead girth, earhead length and protein content. Relatively low GCV (%) and PCV (%) were observed for days to flowering (9.51 and 10.17) and days to maturity (4.24 and 5.23), respectively. Sumathi *et al.* (2010) found the moderate and low GCV (%) and PCV (%) for earhead length and days to flowering, respectively.

The estimate of heritability was higher for all traits in individual environments except days to maturity in E3. In each individual and pooled over environment the expected genetic advance as per cent of mean was highest for dry fodder yield followed by grain yield except E3. In pooled, the high heritability was associated with high genetic advance (% mean) for plant height, dry fodder yield, earhead girth, leaf area, earhead length, grain yield, test weight, harvest index and number of total tillers per plant indicating greater efficiency of selection for improvement as they governed by additive gene action. These results were in agreement with the studies conducted by Varu *et al*. (2005) for earhead girth, earhead length and plant height, Bhoite *et al.* (2008) for earhead length, earhead girth, grain yield per plant, plant height and dry fodder yield per plant, Lakshmana *et al.* (2009) for earhead length, plant height, earhead girth, grain yield per plant and earhead length, Dhedhi *et al*. (2017) for plant height, harvest index, dry fodder yield per plant and grain yield per plant. High heritability coupled with high genetic advance as percentage of mean suggesting that these traits were governed by additive gene action and possibility of improving these characters through selection. High heritability was associated with moderate genetic advance (% mean) for days to flowering, protein content and seed setting on main tiller whereas days to maturity showed high heritability with lower genetic advance (% mean) revealed presence of non-additive gene action and influence of environment on the expression of these traits and thus, simple selection would be less effective for improvement of these characters.

In many cases, the genotypic correlation coefficients were higher than their phenotypic counterparts (Table 3) similar to the results of Chaudhry *et al.* (2003) and Bikash *et al*. (2013a)for plant height with earhead length, earhead length with earhead girth and grain yield per plant with earhead length. This pointed out the high degree of association between two variables at genotypic levels and its phenotype might deflect by environment. The character grain yield was positively and highly significantly correlated with earhead girth, seed setting on main tiller, plant height, leaf area, dry fodder yield per plant, test weight, number of total tillers per plant, number of effective tillers per plant and harvest index at genotypic, phenotypic and environmental levels, respectively, whereas earhead length, days to maturity and number of total tillers per plant significantly and positively correlated at genotypic and phenotypic levels, respectively. Highly significant and positive genotypic correlations were also observed for total number of tillers, number of effective tillers, earhead length, earhead girth and plant height by Vetriventhan and Nirmalkumari (2007), effective tillers per plant, plant height, earhead length, earhead girth and dry fodder yield by Singh et al. (2015). Significant and positive correlations depicted by Vidyadhar *et al.* (2007) for days to maturity, plant height, earhead girth and dry fodder yield per plant and for harvest index, earhead girth, effective tillers and dry fodder yield per plant by Bikash *et al.* (2013a). Hence, the above traits could be focused for improving grain yield in pearl millet. The trait, protein content presented as negatively and significantly correlated at genotypic and phenotypic levels.

Days to flowering was positively and highly significantly correlated with days to maturity, leaf area, and earhead girth at genotypic, phenotypic and environmental levels, respectively. Days to maturity was positively and significantly correlated at genotypic and phenotypic levels with number of effective tillers per plant, harvest index, seed setting on main tiller, leaf area, earhead girth and protein content. Plant height was highly significant and positively correlated with dry fodder yield per plant, leaf area, earhead girth, seed setting on main tiller, earhead length, test weight and number of total tillers per plant. Similar results were reported by Saraswati *et al.* (1993) for earhead girth and Sundari and Khan (1996) for dry fodder yield per plant. The number of total tillers per plant was positively and significantly correlated with earhead length, test weight, number of effective tiller, dry fodder yield per plant, seed setting on main tiller and leaf area. The number of effective tillers per plant was positively and significantly correlated with test weight, earhead length, harvest index, seed setting on main tiller and protein content at genotypic and phenotypic levels, respectively. The earhead length was positively and significantly correlated with dry fodder yield per plant, test weight, earhead girth, leaf area and seed setting on main tiller. Latha *et al.* (1998) also reported positive correlation between earhead length and earhead girth. The earhead girth was positively and significantly correlated with leaf area, seed setting on main tiller, test weight and dry fodder yield per plant. Seed setting on main tiller was positively and significantly correlated with leaf area, test weight, dry fodder yield per plant and harvest index. Leaf area was positively and significantly correlated with dry fodder yield per plant at genotypic, phenotypic and environmental levels, respectively. Dry fodder yield per plant was positively and significantly correlated with test weight at genotypic, phenotypic and environmental levels, respectively. Sundari and Khan (1996) also reported dry fodder yield per plant had highly significant and positive correlation for plant height and number of total tillers per plant. The positive correlation also found for grain yield per plant. Hence, identification of dual purpose genotypes from the evaluated germplasms could be possible.

Genotypic path coefficients were mainly analysed in order to identify the main grain yield components. The results of path analysis at genotypic level revealed that among all the characters earhead girth had highest positive direct effect on grain yield per plant followed by number of effective tillers per plant, plant height, days to flowering, dry fodder yield per plant and harvest index. Whereas, negative direct effects were recorded for days to maturity and number of total tillers per plant on grain yield per plant (Fig. 1). Similar results were reported by Salunke *et al*. (2006) for days to maturity and number of total tillers per plant, Choudhary *et al*. (2012) for plant height, number of effective tillers per plant, earhead girth, dry fodder yield per plant and harvest index, Singh *et al*. (2015) for days to flowering, plant height, earhead girth and harvest index and Talawar *et al.* (2017) for plant height and earhead girth.

From the present study of path analysis together with results of correlation, it is shown that earhead girth, plant height, number of effective tillers per plant, dry fodder yield per plant days to flowering and harvest index had significant positive correlation and high positive direct effects on grain yield. These component traits also exhibited positive inter associations with other characters and higher positive indirect effects on grain yield irrespective of management practices. Hence, these components may be given due importance in selection programme to improve the grain yield in pearl millet.

From the above discussion it was concluded that substantial genetic variability in the pearl millet accessions was present indicating that there is scope for genetic improvement through selection. It also revealed that dry fodder yield per plant, grain yield per plant, plant height and leaf area had high estimates of GCV (%) and PCV (%). These observations indicated that the variability could be exploited for successful isolation of desirable genotypes for the traits concerned. High heritability coupled with high genetic advance as percentage of mean was observed for plant height, dry fodder yield per plant, earhead girth, leaf area and grain yield per plant. Hence, these characters need to be given more importance while selecting the breeding lines as they are controlled by additive genes. The studies on correlation coefficients and path analysis indicated that the characters viz., earhead girth, number of effective tillers per plant, plant height and dry fodder yield per plant were the predominant yield contributing characters in pearl millet.

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**Table 1. Pooled analysis of variance (Mean square) over environments for fourteen traits in pearl millet**

| | | POOLED ENVIRONMENT | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sources of variation** | **d.f.** | **DF** | **DM** | **PH** | **TT** | **ET** | **EL** | **EG** | **SS** | **LA** | **FY** | **GY** | **HI** | **TW** | **PC** |
| Environment | 2 | 416.50** | 1208.17** | 561.98 ** | 2.24** | 2.24** | 24.08** | 63.19** | 2279.00** | 775493.40** | 31.23 | 702.74** | 379.3** | 12.87** | 0.78 |
| Genotype | 29 | 71.71 ** | 37.475** | 4227.97** | 1.59 ** | 0.19** | 23.58** | 66.85** | 262.96** | 963708.30** | 878.10** | 142.48** | 99.4 ** | 7.73** | 3.53** |
| G × E | 58 | 3.58 * | 5.10 | 75.85 * | 0.27 | 0.05** | 1.38 | 2.98 * | 53.60** | 62696.53** | 21.49 | 12.71** | 14.76** | 0.84 | 0.43 |
| Pooled Error | 87 | 0.37 | 1.56 | 16.52 | 0.05 | 0.01 | 0.38 | 0.64 | 2.76 | 6407.48 | 5.18 | 2.13 | 2.79 | 0.24 | 0.18 |

* and ** : Significant at 5 and 1 per cent levels of significance, respectively.
DF : Days to flowering, DM : Days to maturity, PH : Plant height (cm), TT : Number of total tillers per plant, ET : Number of effective tillers per plant, EL : Earhead length (cm), EG : Earhead girth (mm), SS : Seed setting on main tiller (%), LA : Leaf area ($cm^2$), FY : Dry fodder yield per plant (g), GY : Grain yield per plant (g), HI : Harvest index (%), TW : Test weight (%) and PC% : Protein content (%).

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**Table 2. *Per se*, range and genetic parameters for fourteen traits in individual and pooled over environment in pearl millet**

| Sr No. | Traits | Environ ments | Mean | Range | $\sigma^2g$ | $\sigma^2p$ | $\sigma^2e$ | GCV (%) | PCV (%) | $h^2$ (%) | GAM (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Days to flowering | $E_1$ | 54.79 | 47.00-68.00 | 31.62 | 32.61 | 0.99 | 10.27 | 10.42 | 97.00 | 20.82 |
| | | $E_2$ | 50.22 | 41.00-63.00 | 21.99 | 22.58 | 0.59 | 9.34 | 9.46 | 97.40 | 18.99 |
| | | $E_3$ | 47.40 | 41.00-58.00 | 24.15 | 24.80 | 0.65 | 10.37 | 10.51 | 97.40 | 21.08 |
| | | Pooled | 50.80 | 43.00-63.00 | 23.35 | 26.66 | 3.31 | 9.51 | 10.17 | 87.60 | 18.34 |
| **2** | Days to maturity | $E_1$ | 86.75 | 80.00-100.00 | 16.00 | 19.74 | 3.74 | 4.61 | 5.12 | 81.10 | 8.56 |
| | | $E_2$ | 78.75 | 73.00-89.00 | 23.18 | 25.95 | 2.76 | 6.11 | 6.47 | 89.40 | 11.91 |
| | | $E_3$ | 74.22 | 70.00-80.00 | 3.79 | 6.69 | 2.90 | 2.62 | 3.48 | 56.60 | 4.06 |
| | | Pooled | 79.91 | 74.33-89.66 | 11.50 | 17.46 | 5.96 | 4.24 | 5.23 | 65.90 | 7.09 |
| **3** | Plant height (cm) | $E_1$ | 162.07 | 85.80-228.20 | 1409.02 | 1447.32 | 38.30 | 23.16 | 23.48 | 97.40 | 47.07 |
| | | $E_2$ | 158.38 | 84.10- 214.80 | 1605.93 | 1637.00 | 31.07 | 25.30 | 25.55 | 98.10 | 51.63 |
| | | $E_3$ | 153.45 | 82.90-208.50 | 1315.18 | 1344.93 | 29.75 | 23.63 | 23.90 | 97.80 | 48.14 |
| | | Pooled | 157.97 | 84.26-208.50 | 1395.91 | 1476.42 | 80.51 | 23.65 | 24.32 | 94.50 | 47.38 |
| **4** | Number of total tillers per plant | $E_1$ | 4.18 | 2.20-6.10 | 0.96 | 1.07 | 0.11 | 23.41 | 24.78 | 89.30 | 45.56 |
| | | $E_2$ | 3.90 | 2.10-5.50 | 0.52 | 0.63 | 0.11 | 18.57 | 20.40 | 82.90 | 34.82 |
| | | $E_3$ | 3.63 | 1.70-5.40 | 0.51 | 0.60 | 0.09 | 19.70 | 21.40 | 84.80 | 37.36 |
| | | Pooled | 3.90 | 2.20-5.16 | 0.48 | 0.77 | 0.29 | 17.83 | 22.47 | 62.90 | 29.13 |
| **5** | Number of effective tillers per plant | $E_1$ | 1.85 | 1.00-2.90 | 0.16 | 0.21 | 0.05 | 21.67 | 24.84 | 76.10 | 38.93 |
| | | $E_2$ | 1.44 | 1.00-2.20 | 0.05 | 0.08 | 0.03 | 15.35 | 19.10 | 64.60 | 25.43 |
| | | $E_3$ | 1.33 | 1.00-2.00 | 0.05 | 0.07 | 0.03 | 16.12 | 20.10 | 64.30 | 26.64 |
| | | Pooled | 1.54 | 1.10-2.13 | 0.06 | 0.12 | 0.07 | 15.17 | 22.44 | 45.70 | 21.13 |
| **6** | Earhead length (cm) | $E_1$ | 20.40 | 16.10- 26.30 | 8.35 | 9.08 | 0.73 | 14.17 | 14.78 | 91.90 | 27.98 |
| | | $E_2$ | 18.87 | 14.00-24.80 | 9.07 | 9.79 | 0.72 | 15.96 | 16.58 | 92.70 | 31.65 |
| | | $E_3$ | 18.84 | 13.80-23.70 | 7.78 | 8.62 | 0.84 | 14.81 | 15.59 | 90.30 | 28.98 |
| | | Pooled | 19.37 | 15.10-24.93 | 7.60 | 9.17 | 1.56 | 14.23 | 15.63 | 82.90 | 26.70 |
| **7** | Earhead girth (mm) | $E_1$ | 27.99 | 19.36-39.74 | 29.20 | 30.48 | 1.26 | 19.30 | 19.72 | 95.80 | 38.93 |
| | | $E_2$ | 26.57 | 17.68- 34.66 | 21.76 | 22.99 | 1.23 | 17.56 | 18.05 | 94.60 | 35.19 |
| | | $E_3$ | 25.09 | 16.42-34.28 | 19.92 | 21.29 | 1.37 | 17.79 | 18.39 | 93.60 | 35.45 |
| | | Pooled | 26.55 | 17.99-35.45 | 21.76 | 24.92 | 3.16 | 17.57 | 18.80 | 87.30 | 33.82 |
| **8** | Seed setting on main tiller (%) | $E_1$ | 92.44 | 55.50-97.50 | 60.77 | 65.82 | 5.06 | 8.43 | 8.78 | 92.30 | 16.91 |
| | | $E_2$ | 89.45 | 54.30-95.90 | 85.35 | 90.89 | 5.55 | 10.33 | 10.66 | 93.90 | 20.62 |
| | | $E_3$ | 76.07 | 26.00-93.10 | 215.77 | 221.77 | 6.00 | 19.31 | 19.58 | 97.30 | 39.24 |
| | | Pooled | 85.99 | 53.50-95.10 | 79.95 | 126.16 | 46.21 | 10.40 | 13.06 | 63.40 | 17.05 |

*Table 2 Contd....*

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**Table 2 Contd....**

| Sr No. | Traits | Environments | Mean | Range | $\sigma^2g$ | $\sigma^2p$ | $\sigma^2e$ | GCV (%) | PCV (%) | $h^2$ (%) | GAM (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **9** | Leaf area ($cm^2$) | $E_1$ | 1726.64 | 895.07-2991.17 | 365771.20 | 381613.90 | 15842.73 | 35.03 | 35.77 | 95.80 | 70.64 |
| | | $E_2$ | 1584.45 | 550.12-2757.21 | 302089.40 | 314967.00 | 12877.61 | 34.69 | 35.42 | 95.90 | 69.98 |
| | | $E_3$ | 1405.78 | 492.07-2722.56 | 402019.30 | 411741.80 | 9722.49 | 45.10 | 45.65 | 97.60 | 91.81 |
| | | Pooled | 1572.29 | 733.47-2754.22 | 311595.20 | 369440.90 | 57845.79 | 35.50 | 38.66 | 84.30 | 67.17 |
| **10** | Dry fodder yield per plant (g) | $E_1$ | 34.89 | 8.50-79.00 | 366.15 | 377.90 | 11.75 | 54.85 | 55.72 | 96.90 | 111.23 |
| | | $E_2$ | 32.85 | 8.00-74.00 | 307.92 | 317.92 | 10.00 | 53.42 | 54.28 | 96.90 | 108.29 |
| | | $E_3$ | 33.72 | 7.50-70.50 | 231.47 | 240.83 | 9.36 | 45.12 | 46.03 | 96.10 | 91.13 |
| | | Pooled | 33.82 | 9.16-72.50 | 288.80 | 312.22 | 23.42 | 50.25 | 52.25 | 92.50 | 99.56 |
| **11** | Grain yield per plant (g) | $E_1$ | 22.75 | 7.60-41.53 | 74.10 | 80.99 | 6.88 | 37.83 | 39.55 | 91.50 | 74.56 |
| | | $E_2$ | 18.52 | 7.28-35.64 | 49.62 | 53.27 | 3.64 | 38.03 | 39.40 | 93.20 | 75.62 |
| | | $E_3$ | 13.10 | 3.78-26.57 | 37.80 | 40.06 | 2.26 | 46.94 | 48.32 | 94.40 | 93.93 |
| | | Pooled | 18.12 | 6.85-32.67 | 45.37 | 58.11 | 12.73 | 37.17 | 42.06 | 78.10 | 67.66 |
| **12** | Harvest index (%) | $E_1$ | 33.32 | 17.98-41.09 | 25.17 | 30.67 | 5.50 | 15.05 | 16.61 | 82.10 | 28.09 |
| | | $E_2$ | 30.13 | 18.17-42.42 | 37.42 | 43.36 | 5.93 | 20.30 | 21.85 | 86.30 | 38.86 |
| | | $E_3$ | 26.22 | 13.65-40.41 | 57.99 | 63.34 | 5.36 | 29.04 | 30.35 | 91.50 | 57.24 |
| | | Pooled | 29.89 | 18.28-39.67 | 30.62 | 45.79 | 15.17 | 18.51 | 22.64 | 66.90 | 31.18 |
| **13** | Test weight (g) | $E_1$ | 9.55 | 6.1-13.67 | 3.39 | 3.90 | 0.51 | 19.28 | 20.69 | 86.80 | 36.99 |
| | | $E_2$ | 8.66 | 4.93-12.46 | 2.06 | 2.52 | 0.46 | 16.55 | 18.32 | 81.60 | 30.80 |
| | | $E_3$ | 8.27 | 4.33-12.04 | 3.26 | 3.72 | 0.46 | 21.83 | 23.33 | 87.50 | 42.08 |
| | | Pooled | 8.83 | 5.41-12.09 | 2.42 | 3.38 | 0.97 | 17.61 | 20.83 | 71.40 | 30.65 |
| **14** | Protein content (%) | $E_1$ | 9.28 | 7.05-11.94 | 1.23 | 1.60 | 0.38 | 11.99 | 13.67 | 76.90 | 21.65 |
| | | $E_2$ | 9.22 | 6.56-11.50 | 1.27 | 1.65 | 0.38 | 12.20 | 13.93 | 76.80 | 22.02 |
| | | $E_3$ | 8.97 | 6.31-10.72 | 1.36 | 1.69 | 0.33 | 13.00 | 14.48 | 0.60 | 24.05 |
| | | Pooled | 9.16 | 7.15-11.15 | 1.08 | 1.65 | 0.56 | 11.37 | 14.02 | 65.80 | 18.99 |

Where,

$\sigma^2g$, $\sigma^2p$ and $\sigma^2e$ are the genotypic, phenotypic and environmental variance, respectively.

GCV % and PCV % are genotypic and phenotypic co-efficient of variance, respectively.

$h^2$ (%) and GAM are broad sense heritability and genetic advance expressed as per cent of mean, respectively.

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**Table 3. Genotypic ($r_g$), phenotypic ($r_p$) and environmental ($r_e$) correlation co-efficients among fourteen characters in pearl millet**

| Characters | | DM | PH | TT | ET | EL | EG | SS | LA | FY | HI | TW | PC | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $r_g$ | 0.9136** | -0.0987 | -0.1157 | 0.2795** | -0.0979 | 0.1481* | 0.4486** | 0.2187** | -0.1872* | 0.3607** | -0.0878 | 0.3591** | 0.1368 |
| **DF** | $r_p$ | 0.7834** | 0.0855 | 0.0737 | 0.1087 | 0.0091 | 0.2334** | 0.1478* | 0.4186** | 0.1597* | -0.1787* | -0.1035 | 0.1752* | 0.1404 |
| | $r_e$ | 0.6331** | 0.3990** | 0.1873 | -0.0574 | 0.1185 | 0.3050** | -0.2067** | 0.5620** | 0.6180** | -0.5870** | -0.1172 | 0.0365 | 0.1683* |
| | $r_g$ | | -0.0685 | 0.1400 | 0.5620** | 0.0880 | 0.2854** | 0.5558** | 0.2885** | -0.1550* | 0.5576** | 0.2165** | 0.2789** | 0.2962** |
| **DM** | $r_p$ | | -0.0248 | 0.1443 | 0.3580** | 0.0741 | 0.2771** | 0.2833** | 0.3380** | -0.0111 | 0.1477* | 0.0598 | 0.2070** | 0.2455** |
| | $r_e$ | | 0.0957 | 0.1876 | 0.0586 | 0.0543 | 0.3044** | -0.242** | 0.4689** | 0.3021** | -0.3395** | -0.1000 | 0.1493 | 0.0851 |
| | $r_g$ | | | 0.4268** | 0.0071 | 0.6760** | 0.7360** | 0.7105** | 0.8184** | 0.9296** | -0.0803 | 0.4909** | -0.559** | 0.8169** |
| **PH** | $r_p$ | | | 0.3343** | 0.0874 | 0.4940** | 0.4319** | 0.4863** | 0.5173** | 0.8248** | -0.1989** | 0.2724** | -0.234** | 0.7009** |
| | $r_e$ | | | 0.3379** | 0.2268** | 0.2175** | 0.0753 | 0.0580 | 0.3165** | 0.6094** | -0.3846** | 0.0898 | 0.1465* | 0.3294** |
| | $r_g$ | | | | 0.8038** | 0.9065** | 0.4742** | 0.4085** | 0.2988** | 0.5515** | 0.2322** | 0.8966** | -0.1169 | 0.6987** |
| **TT** | $r_p$ | | | | 0.5439** | 0.5310** | 0.1124 | 0.2293** | 0.2918** | 0.3796** | -0.0389 | 0.3113** | 0.1840* | 0.3889** |
| | $r_e$ | | | | 0.4222** | 0.3380** | -0.0595 | 0.1291 | 0.2895** | 0.3032** | -0.1590 | 0.0841 | 0.3217** | 0.1921 |
| | $r_g$ | | | | | 0.5699** | 0.1909* | 0.3244** | 0.0592 | 0.0785 | 0.5673** | 0.7276** | 0.1606* | 0.4501** |
| **ET** | $r_p$ | | | | | 0.4442** | 0.1170 | 0.1725* | 0.1070 | 0.0668 | 0.2444** | 0.2881** | 0.1667* | 0.3408** |
| | $r_e$ | | | | | 0.3178** | 0.0580 | -0.0028 | 0.1409 | 0.0532 | 0.0082 | 0.0090 | 0.1734 | 0.1859* |
| | $r_g$ | | | | | | 0.6705** | 0.4841** | 0.5857** | 0.8552** | 0.0314 | 0.7924** | -0.256** | 0.8179** |
| **EL** | $r_p$ | | | | | | 0.1653* | 0.2191** | 0.3599** | 0.4787** | -0.0556 | 0.2415** | -0.0038 | 0.5226** |
| | $r_e$ | | | | | | -0.2623** | -0.1046 | 0.2255** | -0.0247 | -0.1246 | -0.1284 | 0.1972** | 0.0023 |
| | $r_g$ | | | | | | | 0.8554** | 0.9153** | 0.6332** | 0.2851** | 0.6495** | -0.567** | 0.8595** |
| **EG** | $r_p$ | | | | | | | 0.4037** | 0.4940** | 0.4846** | 0.1268 | 0.5005** | -0.155* | 0.6758** |
| | $r_e$ | | | | | | | -0.0268 | 0.2748** | 0.3507** | 0.0280 | 0.4224** | 0.1078 | 0.5368** |
| | $r_g$ | | | | | | | | 0.8396** | 0.5423** | 0.4183** | 0.6754** | -0.240** | 0.8500** |
| **SS** | $r_p$ | | | | | | | | 0.3053** | 0.3389** | 0.4131** | 0.3682** | -0.199** | 0.6692** |
| | $r_e$ | | | | | | | | -0.0802 | 0.0202 | 0.4286** | 0.1513 | -0.171 | 0.3072** |
| | $r_g$ | | | | | | | | | 0.6434** | 0.2398** | 0.586** | -0.654** | 0.8052** |
| **LA** | $r_p$ | | | | | | | | | 0.4931** | -0.1537* | 0.0366 | -0.1877* | 0.4602** |
| | $r_e$ | | | | | | | | | 0.4237** | -0.3467** | -0.200** | 0.0438 | 0.1872* |
| | $r_g$ | | | | | | | | | | -0.2759** | 0.5342** | -0.331** | 0.7608** |
| **FY** | $r_p$ | | | | | | | | | | -0.4141** | 0.3524** | -0.0937 | 0.6505** |
| | $r_e$ | | | | | | | | | | -0.5843** | 0.2307** | 0.1421 | 0.4029** |
| | $r_g$ | | | | | | | | | | | 0.3535** | -0.392** | 0.3873** |
| **HI** | $r_p$ | | | | | | | | | | | 0.2764** | -0.214** | 0.3346** |
| | $r_e$ | | | | | | | | | | | 0.2382** | -0.1100 | 0.3473** |
| | $r_g$ | | | | | | | | | | | | -0.243** | 0.7130** |
| **TW** | $r_p$ | | | | | | | | | | | | 0.0798 | 0.5452** |
| | $r_e$ | | | | | | | | | | | | 0.2466** | 0.5073** |
| | $r_g$ | | | | | | | | | | | | | -0.5150** |
| **PC** | $r_p$ | | | | | | | | | | | | | -0.2290** |
| | $r_e$ | | | | | | | | | | | | | 0.1397 |

* and ** : Significant at 5 and 1 per cent levels of significance, respectively.

DF : Days to flowering, DM : Days to maturity, PH : Plant height (cm), TT : Number of total tillers per plant, ET : Number of effective tillers per plant, EL : Earhead length (cm), EG : Earhead girth (mm), SS : Seed setting on main tiller (%), LA : Leaf area ($cm^2$), FY : Dry fodder yield per plant (g), GY : Grain yield per plant (g), HI : Harvest index (%), TW : Test weight (%) and PC% : Protein content (%).

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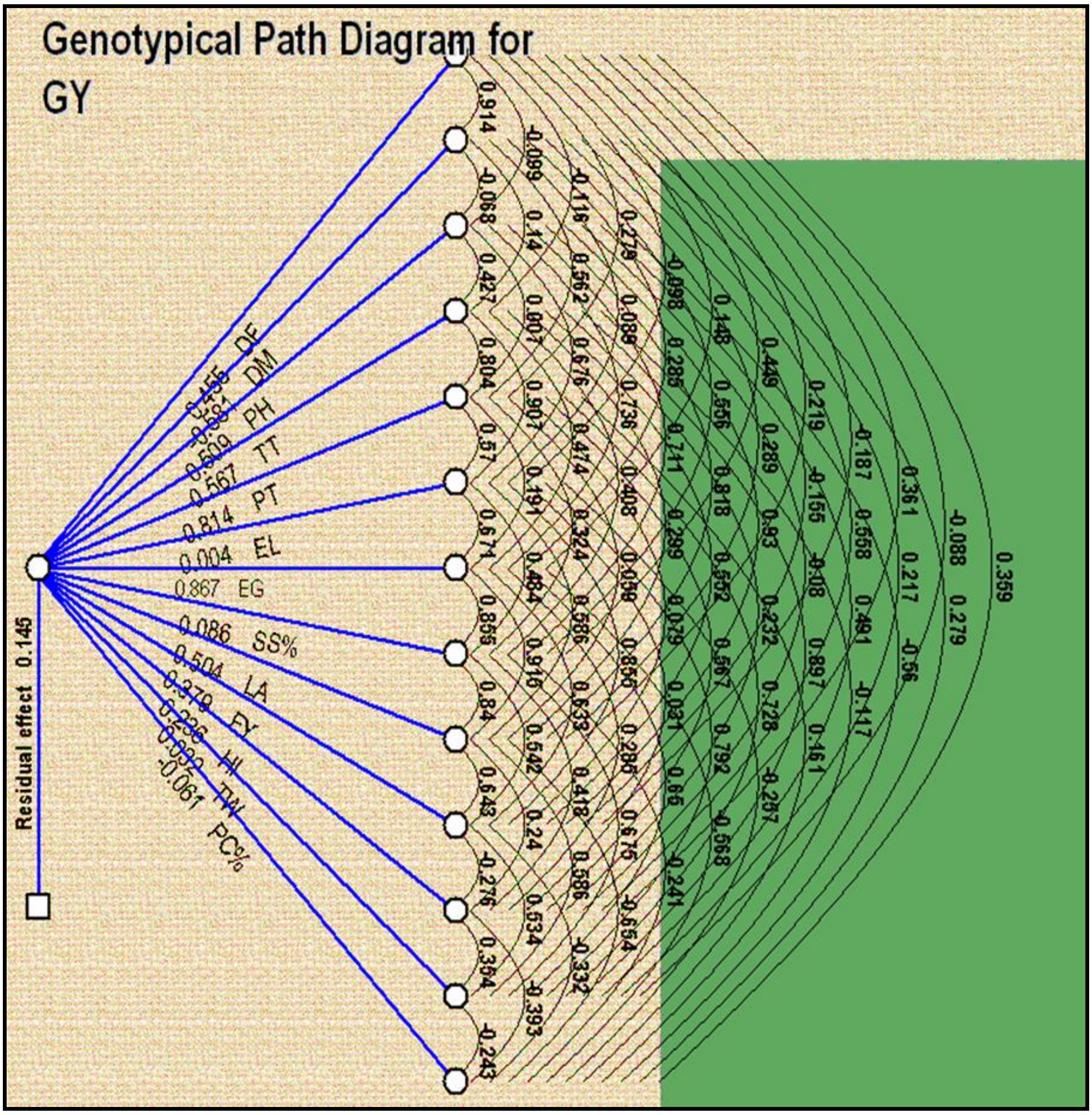


**Fig. 1. Genotypic path diagram for grain yield per plant**

Where,

| | | | | | |
|---|---|---|---|---|---|
| DF | = | Days to flowering | DM | = | Days to maturity |
| PH | = | Plant height (cm) | TT | = | Number of total tillers per plant |
| EL | = | Earhead length (cm) | PT | = | Number of effective tillers per plant |
| EG | = | Earhead girth (mm) | SS | = | Seed setting on main tiller (%) |
| LA | = | Leaf area ($cm^2$) | HI | = | Harvest index (%) |
| TW | = | Test weight (g) | PC | = | Protein content (%) |
| FY | = | Dry fodder yield per plant (g) | GY | = | Grain yield per plant (g) |

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