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Research Article

Genetic variability and association analysis in barnyard millet mutants

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Abstract
The present study was carried out using 40 mutants along with two check varieties CO(Kv)2 and MDU1 during Kharif 2019. Sixteen characters were studied and out of which only 11 traits showed significant variation. Correlation and path analysis were done for 11 traits viz., number of basal tillers, days to fifty percent flowering, flag leaf length, panicle length, plant height, number of racemes, number of productive tillers, number of leaves in main tiller, average leaves in side tiller, single ear head weight and single plant yield. Among the eleven biometrical traits, high heritability was recorded by traits such as number of basal tillers, days to fifty percent flowering, flag leaf length, plant height, number of racemes, number of productive tillers, number of leaves in main tiller, single ear head weight and single plant yield. Correlation studies showed that number of productive tillers, single ear head weight and plant height possess significant positive correlation with yield at both genotypic and phenotypic level. Path analysis showed that traits like number of basal tillers, single ear head weight and panicle length had high direct effect on yield. Thus, selection of these traits would be rewarding for yield improvement in barnyard millet.

Keywords
Barnyard millet, variability, genetic parameters, correlation, path analysis.

INTRODUCTION
In general, small millets' productivity is lower than other cereal crops but they possess wider adaptability to various biotic and abiotic stresses. It made them as an climate resilient crop (Gupta et al., 2011). Among small millets, barnyard millet is grown as substitute for rice in harsh climatic regions which are unsuitable for rice cultivation (Yabuno, 1987). Millets contain high nutritive value hence popularly known to be Nutri-cereal making them a potential food and fodder (Prakash and Vanniarajan, 2015). Barnyard millet contains high protein (11.1%-13.9%) (Monteiro et al., 1988), high carbohydrate (65%) (Sood et al., 2015) high calcium (23.16 mg/100g) and high Fe content (6.91 mg/100g) (Verma et al., 2015).

Diversity in barnyard millet is eroding fast due to change in social, cultural and economic status of farming community. Creation of variation by conventional breeding in small millets is difficult due to their small floret size (Muduli and Misra, 2007). Mutation breeding is the best alternative approach to small floret sized crops to create variation and improve specific defect of elite cultivar without much alteration in original nature of parent (Mehra, 1963). The present study was carried out using different barnyard millet mutants to estimate correlation, direct and indirect effect of various traits by means of path analysis.

MATERIALS AND METHODS
The present study was carried out to assess correlation and path analysis in barnyard millet in M₄ generation mutants. The study was carried out during Kharif 2019 at Sugarcane Research Station, Tamil Nadu Agricultural University, Melalathur, Vellore. The seeds obtained from Agricultural College and Research Institute, Madurai comprising of 40 mutants of the variety CO(Kv)² (Table 1) generated by different doses of Gamma, ethyl methyl sulphonate (EMS) and their combinations viz., Gamma-900Gy(9Nos); 800Gy(4Nos); 700Gy(2Nos); EMS-60mM(6Nos); 70mM(6Nos); 80mM(7Nos); EMS+Gamma-70mM+700Gy(1No); 70mM+800Gy(3Nos); 70mM+900Gy(2Nos) with two check varieties CO(Kv)².
and MDU 1. These genotypes were raised as M₅ generation in RBD with two replications. Each mutant was sown in three rows with 45 x 15 cm spacing. All the recommended package of cultivation practice was adopted.

The observation was recorded for 16 biometrical traits viz., number of basal tillers, days to fifty percent flowering, flag leaf length (cm), flag leaf width (cm), peduncle length (cm), panicle length (cm), length lower raceme (cm), plant height (cm), number of raceme, stem girth (cm), number of productive tillers, number of leaves in main tiller, average leaves in side tiller, single ear head weight (g), 1000 grain weight (g) and single plant yield (g). For every mutant, five plants were selected randomly per replication and used to record the biometrical data except days to fifty percent flowering which was recorded on a plot basis.

The data was subjected to analysis of variance (ANOVA) as per Panse and Sukhatme (1967). Out of sixteen traits studied only 11 traits showed significant variation which are subjected for further statistical analyses. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were calculated using formula of Sivasubramanian and Madhavamenon (1973). Heritability in broad sense and genetic advance as percent of mean were calculated using the method of Johnson et al. (1955). Path analysis was carried out using GENRES version 3.11 software.

Table 1. List of 40 mutants derived from CO(Kv)2

| Mutant lines | Treatment details | Mutagen          |
|--------------|-------------------|------------------|
| M1           | Gamma ray - 900 Gy| Gamma ray        |
| M2           | EMS - 70mM + Gamma ray 700 Gy | EMS - Gamma ray |
| M3           | EMS - 60 mM       | EMS              |
| M4           | EMS - 70mM + Gamma ray 800 Gy | EMS - Gamma ray |
| M5           | EMS - 70mM + Gamma ray 800 Gy | EMS - Gamma ray |
| M6           | EMS - 70mM + Gamma ray 800 Gy | EMS - Gamma ray |
| M7           | EMS - 70 mM       | EMS              |
| M8           | EMS - 70 mM       | EMS              |
| M9           | EMS - 80 mM       | EMS              |
| M10          | Gamma ray - 900 Gy| Gamma ray        |
| M11          | Gamma ray - 900 Gy| Gamma ray        |
| M12          | Gamma ray - 800 Gy| Gamma ray        |
| M13          | Gamma ray - 800 Gy| Gamma ray        |
| M14          | Gamma ray - 800 Gy| Gamma ray        |
| M15          | Gamma ray - 800 Gy| Gamma ray        |
| M16          | EMS - 80 mM       | EMS              |
| M17          | EMS - 70 mM       | EMS              |
| M18          | EMS - 70 mM       | EMS              |
| M19          | EMS - 70 mM       | EMS              |
| M20          | Gamma ray - 900 Gy| Gamma ray        |
| M21          | Gamma ray - 700 Gy| Gamma ray        |
| M22          | EMS - 80 mM       | EMS              |
| M23          | EMS - 80 mM       | EMS              |
| M24          | Gamma ray - 700 Gy| Gamma ray        |
| M25          | EMS - 70 mM       | EMS              |
| M26          | Gamma ray - 900 Gy| Gamma ray        |
| M27          | Gamma ray - 900 Gy| Gamma ray        |
| M28          | Gamma ray - 900 Gy| Gamma ray        |
| M29          | Gamma ray - 900 Gy| Gamma ray        |
| M30          | Gamma ray - 900 Gy| Gamma ray        |
| M31          | EMS - 60 mM       | EMS              |
| M32          | EMS - 60 mM       | EMS              |
| M33          | EMS - 60 mM       | EMS              |
| M34          | EMS - 80 mM       | EMS              |
| M35          | EMS - 80 mM       | EMS              |
| M36          | EMS - 70mM + Gamma ray 900 Gy | EMS - Gamma ray |
| M37          | EMS - 70mM + Gamma ray 900 Gy | EMS - Gamma ray |
| M38          | EMS - 60 mM       | EMS              |
| M39          | EMS - 60 mM       | EMS              |
| M40          | EMS - 80 mM       | EMS              |
RESULTS AND DISCUSSION

The analysis of variance (ANOVA) showed significant difference for 11 traits out of 16 biometrical traits observed (Table 2). The 11 traits showing significant differences are number of basal tillers, days to fifty percent flowering, flag leaf length, panicle length, plant height, number of raceme, number of productive tillers, number of leaves in main tiller, average leaves in side tiller, single ear head weight and single plant yield. Similar results for traits such as days to fifty percent, flag leaf length, panicle length, plant height, number of raceme, number of productive tillers and single plant yield were reported by (Arunachalam and Vanniarajan, 2012; Kumari et al., 2019). Since the mutants derived from a single parent CO(Kv)2 and the study was carried at M4 generation there was no significance observed for five traits viz., flag leaf width, peduncle length, length of lower raceme, stem girth and 1000 grain weight (Table 2). Wide range of variability was recorded for traits such as flag leaf length (20.42-33.67), number of basal tillers (7.50-15.50), days to fifty percent flowering (64.00-76.25), panicle length (15.53-21.95), plant height (103.00-157.83), number of raceme (33.06-52.00), number of productive tiller (2.83-8.00), number of leaves in main tiller (9.50-20.67), average leaves in side tiller (4.94-11.73) single ear head weight (5.54-13.59) and single plant yield (25.43-67.95) (Table 3). Similar results for traits like plant height, panicle length, days to fifty percent flowering, single plant yield were reported by Trivedi et al. (2017). While reports for traits like flag leaf length, number productive tillers, number of leaves in main tiller was similar to Joshi, 2013.

The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all 11 traits. The range of heritability for different traits under study was ranged between 43.73% and 97.60%. High heritability (H2) were recorded for nine traits viz., number of basal tillers (71.42), days to fifty percent flowering (93.61), flag leaf length (75.21), plant height (87.31), number of raceme (93.61), days to fifty percent flowering, flag leaf length, plant height. While low GAM was recorded for panicle length. High H2 and high GAM were recorded for traits viz., number of basal tillers, number of racemes, number productive tillers, number of leaves in main tiller, average number of leaves in side tiller, single ear head weight and single plant yield. Similar results were reported for single plant yield and number of productive tillers by (Arunachalam and Vanniarajan, 2012, Sood et al., 2015). Moderate GAM was recorded for three traits namely days to fifty percent flowering, flag leaf length, plant height. While low GAM was recorded for panicle length. High H2 and high GAM were recorded for traits viz., number of basal tillers, number of racemes, number productive tillers, number of leaves in main tiller, single ear head weight and single plant yield indicating additive gene effect and selection for these traits are highly effective. While moderate H2 and low GAM were recorded for panicle length indicating non-additive gene action and selection for such trait may not be rewarding (Table 3).

The genetic advance as percent mean (GAM) for 11 traits ranged from 9.06% to 49.74% showed the effectiveness of phenotypic selection alone. While heritability along with GAM gives clear-cut idea about level of genetic enhancement attained through phenotypic selection. High GAM was recorded for seven traits namely number of basal tillers, number of racemes, number of productive tillers, number of leaves in main tiller, average number of leaves in side tiller, single ear head weight and single plant yield. Similar results were reported for single plant yield and number of productive tillers by (Arunachalam and Vanniarajan, 2012, Sood et al., 2015). Moderate GAM was recorded for three traits namely days to fifty percent flowering, flag leaf length, plant height. While low GAM was recorded for panicle length. High H2 and high GAM were recorded for traits viz., number of basal tillers, number of racemes, number productive tillers, number of leaves in main tiller, single ear head weight and single plant yield indicating additive gene effect and selection for these traits are highly effective. While moderate H2 and low GAM were recorded for panicle length indicating non-additive gene action and selection for such trait may not be rewarding (Table 3).

Table 2. ANOVA for 16 biometrical traits in barnyard millet mutants

| Source of variation | df | NBT | DFF | FLL | FLW | PEL | PAL | LLR | PH | NR | SG | NPT | NLM | ALS | SE | 1000GW | SPY |
|---------------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|-----|
| Replication         |    | 1   | 1193| 270 | 844 | 30897| 0.009| 2.191| 56.545| 0.201| 1.348| 0.541| 2.279| 4.703| 0.010| 12.625 |
| Treatment           |    | 41  | 6.354**| 26.677**| 17.881**| 0.358**| 0.987**| 4.522**| 0.362**| 282.717**| 39.667**| 0.304**| 0.504**| 2.845**| 0.022**| 230.929** |
| Error               |    | 41  | 1.059| 0.881| 2.539| 0.145| 0.634| 1.770| 0.120| 19.148| 0.494| 0.094| 0.494| 0.821| 0.607| 0.982| 0.054 | 2.810 |

*NS-non significance
**,** significance at 5% and 1% respectively

Yield is a polygenic trait so by selecting traits that are highly correlated with yield is the indirect way to improve the yield. The traits such as number of productive tillers, average leaves in side tiller, flag leaf length and single ear head weight may be rewarding for genetic gain.
and single ear head weight possess highly significant positive correlation with yield. In finger millet, similar results were reported by Sapkal et al., (2019); Keerthana et al., (2019). While days to fifty percent flowering possess significant but negative correlation with yield at both genotypic and phenotypic level (Table 4 & 5). Studies on traits association among the yield attributing components showed significant positive correlation between flag leaf length with panicle length and number of productive tillers; panicle length with number of productive tillers; plant height with number of productive tillers; number of leaves in main tiller with average leaves in side tiller at genotypic level (Table 4).

Table 3. Estimation of genetic parameters for 11 biometric traits in barnyard millet mutants

| S. No | Character | Range | GCV  | PCV  | Heritability (%) | Genetic advance as percent of mean |
|-------|-----------|-------|------|------|------------------|-----------------------------------|
| 1     | NBT       | 7.50-15.50 | 15.32 | 18.13 | 71.42            | 26.67                             |
| 2     | DFF       | 64.00-76.25 | 5.02  | 5.19  | 93.61            | 10.00                             |
| 3     | FLL       | 20.42-33.67 | 10.73 | 12.38 | 75.21            | 19.17                             |
| 4     | PAL       | 15.53-21.95 | 6.65  | 10.06 | 43.73            | 9.06                              |
| 5     | PH        | 103.00-157.83 | 9.15  | 9.79  | 87.31            | 17.61                             |
| 6     | NR        | 33.06-52.00 | 10.03 | 10.16 | 97.47            | 20.40                             |
| 7     | NPT       | 2.83-8.00  | 23.00 | 27.07 | 72.16            | 40.25                             |
| 8     | NLM       | 9.50-20.67 | 16.18 | 17.81 | 82.46            | 30.26                             |
| 9     | ALS       | 4.94-11.73 | 13.33 | 17.58 | 57.44            | 20.81                             |
| 10    | SE Wgt    | 5.54-13.59 | 17.28 | 20.10 | 73.96            | 30.62                             |
| 11    | SPY       | 25.43-67.95 | 24.44 | 24.74 | 97.60            | 49.74                             |

NBT - number of basal tillers; DFF - days to fifty percent flowering; FLL - flag leaf length (cm); PAL - panicle length (cm); PH - plant height (cm); NR - number of raceme; NPT - number of productive tillers; NLM - number of leaves in main tiller; ALS - average number of leaves in side tiller; SE wgt - single ear head weight (g); SPY - single plant yield (g).

Table 4. Genotypic correlation coefficient matrix for 11 biometric traits

| S. No | Character | NBT | DFF | FLL | PAL | PH | NR | NPT | NLM | ALS | SE wgt | SPY |
|-------|-----------|-----|-----|-----|-----|----|----|-----|-----|-----|--------|-----|
| 1     | NBT       | 1   | -0.043 | -0.171 | 0.131 | -0.146 | 0.177 | -0.172 | -0.383* | -0.377* | 0.01   |
| 2     | DFF       | 1   | -0.498** | -0.768** | -0.046 | -0.095 | -0.753** | -0.021 | 0.013 | -0.108 | -0.487** |
| 3     | FLL       | 1   | 0.545** | -0.086 | -0.107 | 0.381* | -0.135 | 0.042 | 0.045 | 0.233 |
| 4     | PAL       | 1   | 0.156 | 0.108 | 0.586** | -0.144 | -0.339* | -0.167 | 0.365* |
| 5     | PH        | 1   | -0.249 | 0.342* | 0.174 | 0.069 | 0.81 | 0.345* |
| 6     | NR        | 1   | 0.128 | 0.291 | 0.084 | 0.44 | 0.178 |
| 7     | NPT       | 1   | 0.058 | 0.009 | 0.221 | 0.660** |
| 8     | NLM       | 1   | 0.691** | 0.299 | 0.145 |
| 9     | ALS       | 1   | 0.241 | 0.157 |
| 10    | SE wgt    | 1   | 0.624** |
| 11    | SPY       | 1   |       |

*, ** indicates significance at 5% and 1% respectively

NBT - number of basal tillers; DFF - days to fifty percent flowering; FLL - flag leaf length (cm); PAL - panicle length (cm); PH - plant height (cm); NR - number of raceme; NPT - number of productive tillers; NLM - number of leaves in main tiller; ALS - average number of leaves in side tiller; SE wgt - single ear head weight (g); SPY - single plant yield (g).
### Table 5. Phenotypic correlation coefficient matrix for 11 biometric traits

| S. No | Character | NBT  | DFF  | FLL  | PAL  | PH   | NR   | NPT  | NLM  | ALS  | SE wgt | SPY  |
|-------|-----------|------|------|------|------|------|------|------|------|------|--------|------|
| 1     | NBT       | 1    | 0.131| -0.044| -0.024| 0.187| -0.141| 0.173| -0.168| -0.301| -0.255| 0.005  |
| 2     | DFF       | 1    | -0.456**| -0.555**| -0.079| -0.09| -0.614**| 0.002| -0.002| -0.124| -0.023| 0.135  | 0.203 |
| 3     | FLL       | 1    | 0.501**| 0.056| 0.266| 0.072| -0.012| 0.002| 0.053| -0.109| 0.072  | 0.023  | 0.173 |
| 4     | PAL       | 1    | 0.136| 0.07 | 0.324*| -0.056| 0.232| -0.168| 0.153| 0.254| 0.005  | 0.002  | 0.002 |
| 5     | PH        | 1    | 0.131| -0.044| -0.024| 0.187| -0.141| 0.173| -0.168| -0.301| -0.255| 0.005  |
| 6     | NR        | 1    | 0.103| 0.058| 0.118| 0.023| 0.135| 0.203| 0.158| 0.561**| 0.294  | 0.147  | 0.002 |
| 7     | NPT       | 1    | 0.058| 0.118| 0.023| 0.135| 0.203| 0.158| 0.561**| 0.294  | 0.147  | 0.002 |
| 8     | ALS       | 1    | 0.155| 0.002| 0.002| 0.017| 0.002| 0.017| 0.002| 0.017| 0.002  | 0.017  | 0.017 |
| 9     | SE wgt    | 1    | 0.537**| 0.624**| 0.316| 0.010| 0.010| 0.010| 0.010| 0.010| 0.010  | 0.010  | 0.010 |
| 10    | SPY       | 1    | 0.537**| 0.624**| 0.316| 0.010| 0.010| 0.010| 0.010| 0.010| 0.010  | 0.010  | 0.010 |

*; ** indicates significance at 5% and 1% respectively

NBT - number of basal tillers; DFF - days to fifty percent flowering; FLL - flag leaf length (cm); PAL - panicle length (cm); PH - plant height (cm); NR - number of raceme; NPT - number of productive tillers; NLM - number of leaves in main tiller; ALS - average number of leaves in side tiller; SE wgt - single ear head weight (g); SPY - single plant yield (g).

Path coefficient analysis Dewey and Lu (1959) was done to know direct and indirect contribution of various independent characters on a dependent character. Traits such as number of basal tillers, panicle length, plant height, number of productive tillers, average leaves in side tiller and single ear head weight possess positive direct effect on single plant yield. Similar results for single ear head weight was reported by (Mohan and Maloo, 2006; Nirmalakumari and Vetriventhan, 2010; Prakash and vanniarajan, 2015; Renganathan et al., 2017). While traits such as days to fifty percent flowering, flag leaf length, number of racemes, number of leaves in main tiller possess negative direct effect on single plant yield. Among the various traits experimented, high positive direct effect was contributed by single ear head weight (0.949), while low positive direct effect was contributed by number of productive tillers (0.049). Based on the scales suggested by Lenka and Misra (1973), the calculated coefficient was categorized into negligible (0.00-0.009), low (0.10-0.19), moderate (0.20-0.29), high (0.30-1.00) and very high (>1.00). Among the different biometrical studied, the direct effect by number of productive tillers was negligible. This was in accordance with the findings of (Arunachalam and Vanniarajan, 2012) while the direct effect of traits such as flag leaf length, plant height, number of raceme and number of leaves in main tillers are moderate; traits such as number of basal tillers, panicle length, average leaves in side tiller and single ear head weight possess high direct effect respectively (Table 6).

### Table 6. Path analysis for 11 biometric traits in barnyard millet mutants

| S. No | Character | NBT  | DFF  | FLL  | PAL  | PH   | NR   | NPT  | NLM  | ALS  | SE wgt | SPY  |
|-------|-----------|------|------|------|------|------|------|------|------|------|--------|------|
| 1     | NBT       | 0.310| -0.003| 0.010| 0.114| 0.029| 0.031| 0.009| 0.041| -0.173| -0.358  | 0.010 |
| 2     | DFF       | 0.043| -0.223| 0.121| -0.509| -0.010| 0.020| -0.037| 0.005| 0.006  | -0.103  | 0.487**|
| 3     | FLL       | -0.013| 0.012| -0.243| 0.361| -0.019| 0.023| 0.019| 0.032| 0.019  | 0.043   | 0.233 |
| 4     | PAL       | 0.053| 0.018| -0.132| 0.663| 0.035| -0.023| 0.029| 0.034| -0.153  | -0.158  | 0.365* |
| 5     | PH        | 0.041| 0.001| 0.021| 0.104| 0.221| 0.053| 0.017| 0.041| 0.031   | -0.185  | 0.345* |
| 6     | NR        | -0.045| 0.002| 0.026| 0.072| -0.055| -0.214| 0.006| -0.069| 0.038   | 0.418   | 0.178 |
| 7     | NPT       | 0.055| 0.017| -0.092| 0.390| 0.076| -0.027| 0.049| -0.014| -0.004  | 0.210   | 0.660**|
| 8     | NLM       | -0.053| 0.000| 0.033| -0.096| -0.038| -0.062| 0.003| -0.237| 0.311   | 0.284   | 0.145 |
| 9     | ALS       | -0.119| 0.000| -0.010| -0.225| 0.015| -0.018| 0.000| -0.164| 0.450   | 0.229   | 0.157 |
| 10    | SE wgt    | -0.117| 0.003| -0.011| -0.110| -0.043| -0.094| 0.011| -0.071| 0.109   | 0.949   | 0.624**|

RESIDUAL EFFECT=0.3169807

*; ** indicates significance at 5% and 1% respectively

NBT - number of basal tillers; DFF - days to fifty percent flowering; FLL - flag leaf length (cm); PAL - panicle length (cm); PH - plant height (cm); NR - number of raceme; NPT - number of productive tillers; NLM - number of leaves in main tiller; ALS - average number of leaves in side tiller; SE wgt - single ear head weight (g); SPY - single plant yield (g).
The correlation studies showed that traits such as number of productive tillers, single ear head weight, panicle length and plant height are significant and positively associated with single plant yield. Path analysis revealed that the traits viz., number of productive tillers, single ear head weight, panicle length and plant height possess positive direct effect. The number of productive tillers had negligible direct effect on yield. Based on association studies among 11 traits, it is noticed that selection by single ear head weight, panicle length and plant height could help in improvement of the single plant yield.

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