Biological Forum – An International Journal **14(3): 474-479(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Association and Genetic variability Studies for Yield Contributing Traits in Barnyard Millet (*Echinochloa frumentacea* (Roxb.) Link) Mutants

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(Received 17 May 2022, Accepted 12 July, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Barnyard millet is a climate-resilient crop and have high nutrient content and antioxidant effects hence it considered to be a functional food crop. It is used as one of the substitutes for conventional cereal crops. The present study was conducted to study the genetic variability, correlation and path analysis for the yield contributing characters in barnyard millet mutants. Twenty-five mutants along with check-MDU 1 were studied for 12 biometrical traits. Analysis of variance showed significant for all the characters. High PCV and GCV indicates less influence of environmental effect. The correlation studies showed that there was significant positive correlation observed for plant height, number of tillers, number of productive tillers, number of racemes, single ear head weight, and thousand-grain weight. A positive direct effect was noticed in the path analysis for the traits such as number of productive tillers, number of racemes, days to maturity, single ear head weight and thousand-grain weight on the yield. Selection criteria based on these traits would be helpful for increasing the yield.

Keywords: Barnyard millet, genetic variability, correlation and path analysis.

INTRODUCTION

Barnyard millet, which was a food and feed crop of semi-arid tropics is considered important in the era of extreme climate unpredictability because of its value for drought tolerance and biotic stress resistance. Owing to these qualities, barnyard millet is an excellent supplemental crop for subsistence farmers and a contingency crop during monsoon breakdowns. And furthermore, it has been exploited in the rehabilitation of soils with sodicity, arsenic, and cadmium concerns (Anuradha *et al.,* 2020). With an area of 0.146 million hectares, production of 0.151 million tonnes, and productivity of 1034 kg/ha stated for the previous three years, India was reported to be the world's leading producer of barnyard millet (Renganathan *et al*., 2020). Being a short duration crop, it would be beneficial for the introduction of cultivars with extra-early maturity (60–75 days) and large yields which might aid farmers in reducing the impact of the ongoing climatic fluctuations. A genetic gain estimate is a cornerstone of each crop breeding strategy in order to evaluate its successes and drawbacks and to set up long term breeding efforts. It is necessary to have a solid grasp of the target environment with a population that exhibits substantial genetic diversity in order to increase selection efficiency and genetic progress in challenging conditions.

Finding novel sources of genetic variability for advantageous traits, such that a combination of alleles results in offspring with improved performance, is essential to the advancement of plant breeding.The objective of the present study is to identify the determinants that influence variability and trait association of barnyard millet mutants in order to improve the crop yield for succeeding generations.

MATERIALS AND METHODS

The experiment was conducted at Agricultural College and Research Institute, Madurai during *Rabi* season 2021. Sodium Azide(SA) and Ethyl Methane Sulphonate (EMS) were used as chemical mutagens in varying concentrations to generate 25 mutants of the MDU 1 variety for the experiment. Three replications were used in Randomized Block Design experiment with the mutants and the check variety MDU 1 grown as an M_5 generation. The plants were raised with a row-to-row spacing of 30 cm and a plant-to-plant spacing of 15 cm employing the suggested crop management actions for the crop's effective growth. Five plants were randomly chosen from each replication for the observations, observations were recorded.

The observations were recorded for 12 biometrical traits, considering the characters such as plant height (cm), number of tillers, number of productive tillers, days to 50% flowering, flag leaf length (cm), flag leaf breadth (cm), number of racemes, length of lower raceme (cm), days to maturity, single ear head weight (g), thousand-grain weight (g) and single plant yield (g). Except for days to 50% blooming, which was recorded on a plot basis, five plants were randomly chosen each replication for each mutant and used to record the biometrical data.

Following Burton's approach (1952), phenotypic and genotypic coefficients of variation were calculated, and their interpretation was predicated based on Sivasubramanian and Madhavamenon's categorization (1973). Computation of Heritability was carried out following the procedure stated by Lush (1940) and the genetic advance as a percentage of the mean was examined referring to Johnson *et al.* (1955a). Correlation and path co-efficient were analyzed employing the methods proposed by Johnson *et al.* (1955b); Dewey and Lu (1959), respectively. The data was subjected to R software for analysis.

RESULTS AND DISCUSSION

Analysis of variance: The quantitative characters exhibit continuous variation, which there-in imposesthe need for selection. The continuous variation is analyzed by the ANOVA which splits the total variation into different components, which gives the basis for the test of significance. The analysis of variance (ANOVA) revealed the significance for all the studied characters (Table 1). It represents the presence of sufficient variation in the studied traits. Similar findings were concluded by Arunachalam and Vanniarajan (2012) in barnyard millet; Lule *et al*. (2012) in barnyard millet and Keerthana *et al*. (2019) in finger millet. A wide range of variability was noticed for the characters such as plant height (98.12 – 145.2), days to 50% flowering (58.33 – 68), flag leaf length (26.06 – 33), flag leaf breadth (2.34 – 3.84), number of tillers (4.8 – 8.8), number of productive tillers (3.2 – 6), number of racemes (45.4 – 72.8), length of lower raceme (2.24 – 4.08), single ear head weight (7.58 – 15.20), days to maturity (88 – 97.2), thousand-grain weight (2.22 – 5.78) and single plant yield (30.18 – 62.66) which were identical to the results of Nirubana *et al*. (2021) in Kodo millet; Upadhyaya *et al*. (2014) in barnyard millet; Emrey *et al*. (2022) in finger millet.

Measures of variability: The phenotypic coefficient of variation was slightlygreater than the genotypic coefficient of variation which indicates the less environmental effect in association with the traits at the level of genotype. The estimates of variability studies were represented in Table 2. The high PCV and GCV were observed for the traits such as thousand-grain weight and single plant yield which represents the presence of a large amount of variation in the mutants. Subramanian *et al*. (2020) reported similar findings for the single plant yield but in contradiction to the trait of thousand-grain weight in barnyard millet. Wanna Soe *et al*. (2022) also concluded the same outcomes for plant yield in finger millet.

Table 1: ANOVA for 12 quantitative traits in 25 mutants in M5 generations.

Source of Variation	df	MEAN SUM OF SQUARES											
		PH	NOT	NPT	DFF	FLL	FLB	NOR	LLR	DTM	SEHW	TGW	SPY
Replication	2	0.2067	0.2659	0.0085	0.3762	0.9423	0.0037	1.5625	0.0022	3.875	0.1622	0.005	3.5721
Treatment	25	438.925**	3.2956**	1.418**	24.997**	8.7463**	0.3055**	127.7258**	0.7606**	20.8633**	9.1453**	2.146**	393.4754**
Error	50	9.0867	0.0331	0.0156	2.8214	0.8747	0.0070	2.1452	0.0058	5.5108	0.0596	0.0096	0.9050

* Significant at 5% level ** Significant at 1% level.

PH - Plant Height(cm); NOT - Number of Tillers; NPT - Number of Productive Tillers; DFF - Days to 50% Flowering; FLL - Flag Leaf Length(cm); FLB - Flag Leaf Breadth(cm); NOR -Number of Raceme; LLR - Length of Lower Raceme(cm); DTM - Days To Maturity; SEHW - Single Ear Head Weight(g); TGW - Thousand-grain Weight(g); SPY - Single Plant Yield(g).

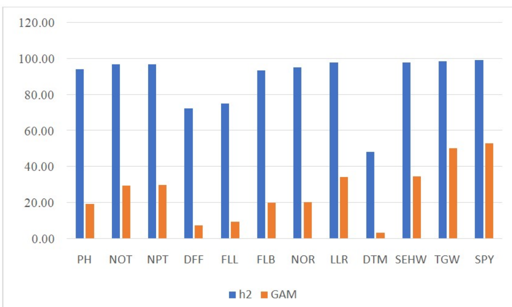
Table 2: Genetic parameters for variability studies for yield and yield contributing traits in 25 mutants in M5 generations.

Character	Mean	Range	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
PH	123.44	98.12 - 145.2	10.00	9.70	94.04	19.37
NOT	7.15	4.8 - 8.8	14.81	14.59	97.05	29.61
NPT	4.61	3.2 - 6	15.06	14.82	96.76	30.03
DFF	63.16	58.33 - 68	5.06	4.31	72.39	7.55
FLL	29.92	26.06 - 33	6.25	5.41	74.99	9.66
FLB	3.14	2.34 - 3.84	10.40	10.06	93.46	20.03
NOR	63.73	45.4 - 72.8	10.41	10.15	95.13	20.40
LLR	2.97	2.24 - 4.08	17.10	16.91	97.75	34.44
DTM	93.25	88 - 97.2	3.50	2.43	48.13	3.47
SEHW	10.25	7.58 - 15.20	17.15	16.98	98.07	34.65
TGW	3.42	2.22 - 5.78	24.81	24.65	98.68	50.44
SPY	44.36	30.18 - 62.66	25.88	25.79	99.31	52.94

PH - Plant Height(cm); NOT – Number of Tillers; NPT - Number of Productive Tillers; DFF - Days to 50% Flowering; FLL - Flag Leaf Length(cm); FLB - Flag Leaf Breadth(cm); NOR -Number of Raceme; LLR - Length of Lower Raceme(cm); DTM - Days to Maturity; SEHW - Single Ear Head Weight(g); TGW - Thousand-grain Weight(g); SPY - Single Plant Yield(g).

The medium PCV and GCV were noticed for flag leaf breadth, number of tillers, number of productive tillers, number ofracemes, length of lower raceme, and single ear head weight which indicates the availability of considerable amount of variation present in the studied characters of the genotypes. Similar conclusions were revealed by Vikram *et al*. (2020) for number of tillers; Subramanian *et al*. (2020) for the character of number of productive tillers; Reganathan *et al*. (2018) for number of racemes and single ear head weight in barnyard millet; Subramanian *et al*. (2020) in barnyard millet for flag leaf breadth. The low PCV and GCV were identified in the characters such as plant height, days to 50% flowering, flag leaf length, and days to maturity. This revealed that the selection of these characters would not effective for the genetic improvement program. Similar outcomes were obtained by Renganathan *et al*. (2018); Arya *et al*. (2018) in barnyard millet; Dhanalakshmi *et al.* (2019) in barnyard millet and Anuradha *et al*. (2020) in little millet.

Heritability in combination with genetic advance helps to depict the genetic improvement underphenotypic selection. The estimates of h^2 and GAM were represented graphically in Fig. 1.



PH - Plant Height(cm); NOT – Number of Tillers; NPT - Number of Productive Tillers; DFF - Days to 50% Flowering; FLL - Flag Leaf Length(cm); FLB - Flag Leaf Breadth(cm); NOR -Number of Raceme; LLR - Length of Lower Raceme(cm); DTM - Days to Maturity; SEHW - Single Ear Head Weight(g); TGW - Thousand-grain Weight(g); SPY - Single Plant Yield(g).

Fig. 1. Heritability and Genetic Advance as percent of Mean for 12 biometrical traits in 25 mutants in M_5 generations.

The heritability varied between 48.13% to 99.31%. The high heritability was recorded for eleven characters such as plant height (94.04%), number of tillers (97.04%), number of productive tillers (96.76%), days to 50% flowering (72.39%), flag leaf length (74.99%), flag leaf breadth (93.45%), number of racemes (95.12%), length of lower raceme (97.75%), single ear head weight (98.07%), thousand-grain weight (98.67%) and single plant yield (99.31%). Similar reports were produced by Vikram *et al.* (2020) in barnyard millet for all traits; Ranjana *et al*. (2020) in barnyard millet for lower raceme and thousand-grain weight; Lule *et al.* (2012) in finger millet and WannaSoe *et al*. (2022) in finger millet for days to 50% flowering; Dhanalakshmi *et al*. (2019) in barnyard millet for plant height, flag leaf length, flag leaf width, lower raceme length, and yield; Renganathan *et al*. (2018) for number of racemes, single ear head weight and plant yield in barnyard millet. The high heritability indicates the additive gene action of the character. The moderate heritability was observed for the days to maturity (48.13%) with similar findings reported by Arya *et al*. (2018) in barnyard millet. Thousand-grain weight and single plant yield showed the high h^2 and high GCV which indicates the genotypic reaction.

The genetic advance as percent of the mean (GAM) ranged from 3.46% - 52.94% for the 12 characters. High GAM was identified for eight characters *viz*, number of tillers, number of productive tillers, flag leaf breadth, number of racemes, length of lower raceme, single ear head weight, thousand-grain weight and single plant yield. The findings were identical with Vikram *et al*. (2020) for number of tillers, number of productive tillers, single ear head weight and single plant yield; Keerthana *et al*. (2019) in finger millet for number of racemes; Ranjana *et al*. (2020) for flag leaf breadth, lower raceme length and thousand-grain weight. The character plant height showed a medium level of GAM identical to the findings of Arya *et al.* (2018) in barnyard millet; Emrey *et al*. (2022) in finger millet. Low GAM was noticed for days to 50% flowering, flag leaf length and days to maturitythese results were in accordance with the reports submitted by for days to maturity in finger millet mutants; Anuradha *et al*. (2020) in little millet for flag leaf length. The characters with both high heritability and high GAM reveal the predominant action of additive gene which could be useful for selecting the desirable mutantsfor further generations. Low heritability with low genetic advance concludes that the trait is highly dominated by environmental effects and the selection would be ineffective.

Correlation studies: Yield is a quantitative trait that is controlled by several genes. Correlation studies help to identify the relationship between yield and yield contributing traits. We can improve the yield, by the indirect selection of independent attributes which influence the yield. Correlation coefficients for studied traits were presented in Tables 3 & 4. Among the examined traits, characteristics such as plant height, number of tillers,number of productive tillers, number of racemes, single ear head weight, and thousand-grain weight were highly significant and positively correlated with single plant yield (Table 3). Similar results were reported by Monika *et al.* (2021) for all traits in barnyard millet; Prabhu *et al*. (2020) for plant height, number of racemes and single ear head weight; Kumar *et al*. (2014) in finger millet for number of tillers, and number of productive tillers; Nandhini *et al*. (2020) in barnyard millet for number of tillers and plant height;Nirubana *et al*. (2021) in Kodo millet for plant height and number of productive tillers and thousand-grain weight in finger millet. This suggested that a positive correlation for plant yield with the other contributing traits inferred that all these traits might simultaneously enhance the yield and also inferred that increase in any one of the positively associated characters would lead to improvement of other independent characters. Hence, indirect selection of the above traits aids in determining the high-yielding mutants in the population. The flag leaf length and length of lower racemewere found to be non-significant but positively correlated for the single plant yield. Similar results were produced by Chavan *et al*. (2020)

for raceme length in finger millet and Vikram *et al*. (2020) for flag leaf length in barnyard millet. Among the 12 characters, plant height, number of tillers, number of productive tillers, number of racemes, single ear head weight showed highly significant and positively correlated with yield in both genotypic and phenotypic correlation (Table 3 & 4).

Association studies on the studied characters, the independent characters showed highly significant and positive intercorrelated between plant height with number of tillers, number of productive tillers, flag leaf breadth, number of racemes, days to maturity, single ear head weight, and thousand-grain weight with same reports inferred by Renganathan *et al*. (2017) for all traits in barnyard milletand Sharma *et al*. (2018) in pearl millet for plant height with days to maturity; number of tillers significant and positively intercorrelated with number of productive tillers, number of raceme, single ear head weight and thousand-grain weight. The number of productive tillers expressed significantly and positively correlated with flag leaf length and number of racemes; days to 50% flowering with length of lower raceme and days to maturity; flag leaf length with flag leaf breadth, and length of lower raceme. The flag leaf breadth showed a significant positive association with number of racemes, length of lower raceme, days to maturity, single ear head weight and thousand-grain weight. A significant positive association was observedfor number of racemes with single ear head weight and thousand-grain weight; length of lower raceme with days to maturity.The single ear head weight showed a positive and significant association with thousand-grain weight (Table 3). Similar results were concluded by Monika *et al*. (2021) in barnyard millet.

Path analysis: Path coefficient analysis developed by Dewey and Lu (1959) is a standardized partial regression coefficient that divides the correlation coefficient into measures of direct and indirect effects. It was performed to identify the direct and indirect contribution of different independent characters on dependent character yield. The characters viz., number of productive tillers,number of racemes, days to maturity, single ear head weight and thousand-grain weight revealed positivedirect effects which indicate that selection criteria based on these characteristics could improve the plant yield (Table 5). Similar results were reported by Rajasekar *et al*. (2021) for productive tillers in rice; Prabhu *et al*. (2020) for number of racemesin barnyard millet and Monika *et al*. (2021) for single ear head weight in barnyard millet. Negative direct effects were observed for the studied characters *viz*., plant height, number of tillers, days to 50% flowering, flag leaf length, flag leaf breadth, and length of lower raceme. Among the examined characters, days to maturity (0.6347) had high direct effects followed by number of tillers (0.5622) and then followed by single ear head weight (0.4918). Theseresults were in accordance with Renganathan *et al*. (2017) for single ear head weight in barnyard millet. A moderate direct effect was noticed for the trait of number of racemes (0.285). The negligible direct effectwas found on the character of thousand-grain weight (0.0095). The residual effect of 0.3088 was noticed. This indicates that these traits contribute only 69.12% to total variability in plant yield and the remaining 30.88% variability was unnoticed. This suggested that certain other characters may also contribute to improving the yield.

Studies on the variability concluded that high PCV, GCV, heritability and GAM reveal less influence of environmental effect. The correlation studies showed that the characters *viz*, plant height, number of tillers, number of productive tillers, number of racemes, single ear head weight, and thousand-grain weight were highly significant and positively correlated with single plant yield. The path analysis elucidates the positive direct effect of number of productive tillers, number of racemes, days to maturity, single ear head weight and thousand-grain weight on the yield. Thus, selection based on the number of racemes and single ear head weight would help in increasing the grain yield.

Table 3: Genotypic correlation coefficient for yield and its contributing traits in 25 mutants in M5 generations.

Character	PH	NOT	NPT	DFF	FLL	FLB	NOR	LLR	DTM	SEHW	TGW	SPY
PH	1	0.547**	0.306**	-0.064	0.084	0.371**	0.775**	0.098	0.355**	0.452**	0.478**	0.557**
NOT		1	0.712**	-0.224*	0.027	0.179	0.560**	-0.047	0.094	0.356**	0.538**	0.695**
NPT			1	-0.068	0.311**	0.026	0.400**	0.140	0.109	0.135	0.128	0.687**
DFF				1	0.151	0.011	-0.051	0.372**	0.836**	-0.018	-0.177	-0.115
FLL					1	0.294**	0.179	0.333**	0.258*	0.100	0.131	0.200
FLB						1	0.310**	0.594**	0.455**	0.430**	0.393**	0.289
NOR							1	0.046	0.146	0.403**	0.538**	0.560**
LLR								1	0.587**	0.265*	0.133	0.181
DTM									1	0.444**	0.090	0.262
SEHW										1	0.365**	0.759**
TGW											1	0.346**
SPY												1

* Significant at 5% level ** Significant at 1% level.

PH - Plant Height(cm); NOT – Number of Tillers; NPT - Number of Productive Tillers; DFF -Days to 50% Flowering; FLL - Flag Leaf Length(cm); FLB - Flag Leaf Breadth(cm); NOR-Number of Raceme; LLR - Length of Lower Raceme(cm); DTM - Days to Maturity; SEHW-Single Ear Head Weight(g); TGW - Thousand-grain Weight(g); SPY- Single Plant Yield(g).

Table 4: Phenotypic correlation coefficient for yield and its contributing traits in 25 mutants in M5 generations.

Character	PH	NOT	NPT	DFF	FLL	FLB	NOR	LLR	DTM	SEHW	TGW	SPY
PH	1	0.519**	0.299**	-0.035	0.042	0.351**	0.736**	0.104	0.260*	0.441**	0.459**	0.541**
NOT		1	0.697**	-0.172	0.009	0.168	0.550**	-0.053	0.058	0.349**	0.527**	0.684**
NPT			1	-0.027	0.255*	0.022	0.382**	0.137	0.057	0.136	0.126	0.676**
DFF				1	0.123	0.001	-0.036	0.319**	0.494**	-0.002	-0.158	-0.086
FLL					1	0.255*	0.131	0.278*	0.127	0.071	0.112	0.179
FLB						1	0.299**	0.578**	0.329**	0.414**	0.373**	0.277
NOR							1	0.047	0.099	0.394**	0.520**	0.546**
LLR								1	0.423**	0.265*	0.131	0.176
DTM									1	0.307**	0.090	0.180
SEHW										1	0.357**	0.750**
TGW											1	0.340**
SPY												1

* Significant at 5% level   ** Significant at 1% level.

PH - Plant Height(cm); NOT – Number of Tillers; NPT - Number of Productive Tillers; DFF - Days to 50% Flowering; FLL - Flag Leaf Length(cm); FLB - Flag Leaf Breadth(cm); NOR -Number of Raceme; LLR - Length of Lower Raceme(cm); DTM - Days to Maturity; SEHW - Single Ear Head Weight(g); TGW - Thousand-grain Weight(g); SPY - Single Plant Yield(g).

Table 5: Path analysis for yield and its contributing traits in 25 mutants in M5 generations.

Characters	PH	NOT	NPT	DFF	FLL	FLB	NOR	LLR	DTM	SEHW	TGW	SPY
PH	**-0.1993**	-0.0542	0.172	0.0374	-0.0052	-0.0603	0.221	-0.0064	0.2251	0.2222	0.0045	0.557**
NOT	-0.109	**-0.0991**	0.3999	0.1308	-0.0017	-0.0289	0.1596	0.0031	0.0599	0.175	0.0051	0.695**
NPT	-0.061	-0.0705	**0.5622**	0.0391	-0.0194	-0.0043	0.1137	-0.0093	0.0692	0.0662	0.0012	0.687**
DFF	0.0128	0.0223	-0.0378	**-0.5818**	-0.0094	-0.002	-0.0146	-0.0247	0.5305	-0.0088	-0.0017	-0.115
FLL	-0.0167	-0.0027	0.1748	-0.0875	**-0.0624**	-0.048	0.0508	-0.0222	0.1638	0.0491	0.0012	0.200
FLB	-0.0743	-0.0177	0.0149	-0.0072	-0.0185	**-0.1619**	0.089	-0.0393	0.2895	0.2116	0.0037	0.289*
NOR	-0.1545	-0.0555	0.2244	0.0299	-0.0111	-0.0505	**0.285**	-0.003	0.0926	0.1982	0.0051	0.560**
LLR	-0.0193	0.0047	0.0786	-0.2169	-0.0209	-0.0962	0.0129	**-0.0662**	0.3724	0.1301	0.0013	0.181
DTM	-0.0707	-0.0094	0.0613	-0.4862	-0.0161	-0.0738	0.0416	-0.0389	**0.6347**	0.2182	0.0009	0.262*
SEHW	-0.09	-0.0353	0.0757	0.0104	-0.0062	-0.0697	0.1149	-0.0175	0.2816	**0.4918**	0.0035	0.759**
TGW	-0.0952	-0.0532	0.0714	0.1032	-0.0081	-0.0634	0.1532	-0.0088	0.0573	0.1792	**0.0095**	0.346**

Residual effect =   0.3088

* Significant at 5% level   ** Significant at 1% level.

PH - Plant Height(cm); NOT – Number of Tillers; NPT - Number of Productive Tillers; DFF - Days to 50% Flowering; FLL - Flag Leaf Length(cm); FLB - Flag Leaf Breadth; (cm) NOR -Number of Raceme; LLR - Length of Lower Raceme(cm); DTM - Days to Maturity; SEHW - Single Ear Head Weight(g); TGW - Thousand-grain Weight(g); SPY - Single Plant Yield(g)

CONCLUSION

It is concluded the path analysis for the traits such as number of productive tillers, number of racemes, days to maturity, single ear head weight and thousand-grain weight on the yield. Selection criteria based on these traits would be helpful for increasing the yield.

Acknowledgement. The current study was supported by the Department of Plant breeding and Genetics, Agricultural College and Research Institute, Madurai – Tamil Nadu Agricultural University, Tamil Nadu, India.

Conflict of interest. None

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How to cite this article: Sathish Kumar R., Vanniarajan C., Vetriventhan M., Chandirakala R., Saravanan S. and Renuka R. (2022). Association and Genetic variability Studies for Yield Contributing Traits in Barnyard Millet (*Echinochloafrumentacea* (Roxb.) Link) Mutants. *Biological Forum – An International Journal*, *14*(3): 474-479.