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Genetic Variability, Correlation and Path Analysis of M_3 Generation Mutants in Moringa (*Moringa oleifera* L.) for Leaf Biomass

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ABSTRACT: In annual moringa var. PKM 1 of M_3 generation mutants were evaluated for leaf yield and the analysis of variance indicated that there is an existence of significant variability among the four mutants (2-1&7-1 mutants from gamma rays (100Gy) and 35-1&35-2 (0.15%) mutants from EMS %) from M_2 generation, for all the traits under this study. It is important to study mutation to induce novel and heritable genetic variation within a short period of time, easily create new variation not found in nature and mutation breeding is considered an appropriate strategy to improve the breeding efficiency of evolving novel moringa leafy types. The highest genotypic coefficient of variation was recorded for internodal length, number of rachis per tree, height at first branching, dry leaf yield and fresh leaf yield. Heritability and genetic advance as percent of mean estimates were high for internodal length, trunk girth, number of secondary branches per tree and fresh leaf yield per plant. Yield per plant had significant and positive association with number of rachis per tree, internodal length and fresh leaf yield. Non significant and negative association was observed for shoot length, trunk girth and leaf powder recovery (%). In path coefficient analysis, high direct effect was observed for number of secondary branches per tree, number of rachis per tree, trunk girth and height at first branching. Negative direct effect on yield was noticed by trunk girth, height at first harvest, shoot length, dry leaf yield and leaf powder recovery (%). The high values of variability, correlation and path analysis for all these traits indicate the possibility of induced desirable mutants for polygenic traits accompanied by effective selection in M_3 and later generations.

Keywords: Mutation, genetic variability, correlation, path analysis, Moringa.

INTRODUCTION

Moringa (*Moringa oleifera* Lam.,) is an incredible plant to mankind, because of its pharmacognostical and nutritional properties (Fahey, 2005). Out of 13 known species, *Moringa* is the single genus of the family Moringaceae (Mahmood *et al.,* 2010) and *Moringa oleifera* is the most exploited species among them. Other names includes Miracle tree, Never die or Nature gift, or Mother's best friend. All the plant parts of moringa has been utilized for various purposes; the leaves are considered as a nutritionally superior vegetable containing more beta-carotene than carrots, more protein than peas, more vitamin C than oranges, more calcium than milk, more potassium than bananas and more iron than spinach (Prabhakar and Hebbar 2008). Moringa leaf/powder is the second most exported moringa product, with the value of 1.1 billion US dollars, after moringa seeds (1.6 billion). Moringa leaf or powder is most commonly exported from India. The European Union leads the way in importing moringa leaf or powder (Moringa-Meet 2015). Despite the high demand, no moringa variety has been developed specifically for leaf biomass. Induced mutation using physical and chemical mutagens is one way to create genetic variation which results in new varieties varieties with better characteristics (Devi and Mullainathan 2012). In order to improve leaf yield and other polygenic characters, mutation breeding can be effectively utilized (Deepalakshmi and Kumar 2004). Mutation breeding is one of the most effective ways of inducing genetic variability available to the plant breeder (Muhammed *et al.*, 2016). The mutation breeding helps to improve one or two characters without changing the rest of the genotype (Arunal *et al.,* 2010). Artificial induction of mutation provides raw materials for the genetic improvement of economic crops (Adamu and Aliyu 2007) and also used to create genetic variability in quantitative traits of various crop plants within the shortest possible times (Aruldoss *et al.,* 2015).

To assist in selecting for work on yield improvement, attributes linked to yield should also be determined using correlation and path coefficient analysis. Despite the fact that correlation analysis shows the pattern of relationships between component qualities and yield, it also illustrates the overall influence of a particular attribute on yield rather than a cause-and-effect relation. The method of path coefficient analysis makes it easier to distinguish genotypic correlation into the direct and indirect effects of different characters on yield (Mahbub *et al.,* 2015). The goal of the current study was to evaluate the genetic variability, correlation, and path coefficient analysis of the moringa M_3 generation mutants for leaf biomass.

MATERIALS AND METHODS

The present experiment was undertaken at Department of Vegetable Science, Horticultural College and Research Institute, Periyakulam, TNAU during 2021-2022. The experiment material is mutated annual moringa PKM 1 and the seeds of each treatment from M_2 generation was forwarded into M_3 generation with the spacing of 2.0 m between rows and 1.5m between plants. A total set of four mutants (2-1&7-1 mutants from gamma rays (100Gy) and 35-1&35-2 mutants from EMS (0.15%) from M_2 generation were evaluated for different morphological traits. In each mutant 20 plants were evaluated and Observations on morphological traits *viz.,* shoot length (cm), number of secondary branches per tree, number of rachis per tree, height at first branching (cm), internodal length (cm), trunk girth (cm), height at first harvest (cm), dry leaf yield (g), leaf powder recovery (%) and fresh leaf yield (g) was recorded. The variability for different quantitative parameters was estimated as per procedure suggested by Panse and Sukhatme (1961), GCV and PCV as per Burton (1952) heritability and genetic advance as per Johnson *et al*. (1955). Correlation coefficient was worked out as per Panse and Sukhatme (1961) and path coefficient analysis was worked out according to formula given by Dewey and Lu (1959).

RESULT AND DISCUSSION

A. Mutant 2-1(100Gy)

The results of the estimation of genetic variability indicated that the considerable variability for all the traits in this mutant (Table 1). The phenotypic co-efficient of variation values are slightly greater than genotypic coefficient of variation values for most of the traits. There was a close relationship between genotypic coefficient of variation and phenotypic coefficient of variation for most of the traits which indicate that there was very little effect of environment on their gene expression. In this mutant the higher estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for shoot length, height at first branching, internodal length, dry leaf yield and fresh leaf yield. This indicates that the variability existing in these traits is due to genetic makeup. These results were in accordance with the findings of Karunagar *et al.* (2018) in Moringa and Praseetha (2015) in okra. Moderate estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for number of secondary branches per tree, number of rachis per tree and leaf powder recovery percentage. Similar results reported by Chandra *et al.* (2013) in okra. Low estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for the trait trunk girth and height at first harvest.

High heritability coupled with high genetic advance as percent of mean was observed for the traits *viz.,* shoot length, number of rachis per tree, height at first branching, internodal length, dry leaf yield, leaf powder recovery (%) and fresh leaf yield. Similar results were observed by Das *et al.* (2012) in okra. Moderate heritability and moderate genetic advance as percent of mean were observed for number of secondary branches per tree and trunk girth. High genetic advance as percent of mean was observed for height at first harvest. High heritability accompanied with high genetic advance as percent of mean indicates the involvement of additive gene action, therefore selection may be effective at later generations.

Simple correlation co-efficient of 10 characters in all possible combinations was calculated to know the relationship among the mutants. The fresh leaf yield per plant had significant and positive association with shoot length (0.603), height at first branching (0.445), internodal length (0.642), height at first harvest (0.811), dry leaf yield (0.931) and leaf powder recovery percentage (0.809) (Table 5).

Path coefficient analysis results revealed that the positive and high direct effect for number of secondary branches per tree (0.4014), height at first branching (0.3067), trunk girth (0.3691) and leaf powder recovery percentage (0.3685). These traits contributed the most towards fresh leaf yield per plant. Positive and low direct effect was observed only for this trait height at first harvest. The shoot length (-0.4640) and dry leaf yield (-0.7609) was registered negative and high direct effect. Negative and negligible direct effect for number of rachis per tree was observed in this mutant. Based on the path coefficient analysis number of secondary branches per tree, height at first branching, trunk girth and leaf powder recovery (%) may be considered as selection indices for yield improvement.

B. Mutant 7-1 (100Gy)

The results of the estimation of genetic variability indicated that the considerable variability for all the traits in this mutant (Table 2). The higher estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for the traits height at first branching, internodal length, dry leaf yield and fresh leaf yield. Similar findings was reported by Meena *et al.* (2012) in cabbage. The moderate estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for number of secondary branches per tree , number of rachis per tree, trunk girth and leaf powder recovery (%). Similar results were reported by Adiger *et al.* (2011) in moringa. The low estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for shoot length and height at first harvest.

High heritability couple with high genetic advance as percent of mean was observed for the traits *viz.,* number of secondary branches per tree, number of rachis per tree, height at first branching, internodal length, trunk girth, dry leaf yield, leaf powder recovery (%) and fresh leaf yield. Similar result were reported by Selvakumari *et al.* (2013) in moringa. Low heritability and genetic advance as percent of mean was observed for shoot length and height at first harvest.

The fresh leaf yield per plant had significant and positive association was observed for number of secondary branches per tree (0.699), no of rachis per tree (0.874), trunk girth (0.394), height at first harvest (0.510), dry leaf yield (0.989) and leaf powder recovery percentage (0.863) (Table 6).

Path coefficient analysis results revealed that the positive and high direct effect for number of rachis per tree (0.9248), leaf powder recovery percentage (0.7814), number of secondary branches per tree (0.7337), height at first harvest (0.4779) and trunk girth (0.3909). These traits contributed for fresh leaf yield per plant. Further positive and low direct effect was observed for internodal length (0.1316). Negative and high direct effect for shoot length (-0.4485) and negative and low direct effect on dry leaf yield (-0.1174). In this mutant based on this number of rachis per tree, number of secondary branches per tree, height at first harvest, trunk girth and leaf powder recovery (%) may be considered as selection indices for leaf yield improvement (Table 10)

C. Mutant 35-1 (0.15% EMS)

The results of the estimation of genetic variability indicated that the considerable variability for all the traits in this mutant (Table 3). The higher estimates of genotypic coefficient of variation and phenotypic coefficient of variation were observed for height at first branching, internodal length and fresh leaf yield. Moderate estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for shoot length, number of secondary branches per tree, number of rachis per tree, trunk girth and dry leaf yield. Similar result were observed by Chandra *et al.,* (2014) in okra. Lower estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for height at first harvest and leaf powder recovery (%).

High heritability coupled with high genetic advance as percent of mean was observed for the traits *viz.,* number of rachis per tree, height at first branching, internodal length, trunk girth, dry leaf yield and fresh leaf yield. Similar results were observed by Raja and Bagle (2008) in moringa. High heritability with moderate genetic advance as percent of mean was observed for shoot length, height at first harvest. Moderate heritability with moderate genetic advance as percent of mean was observed for the trait number of secondary branches per tree. Low heritability with low genetic advance as percent of mean was observed for leaf powder recovery (%).

The fresh leaf yield per plant had significant and positive association was observed for number of secondary branches per tree (0.885), number of rachis per tree (0.766), height at first harvest (0.805) and dry leaf yield (0.951). These findings coincides with the findings of Roy *et al.* (2016) in moringa and Naresh *et al.* (2021) in dolichos bean (Table 7).

Path coefficient analysis results revealed that the positive and high direct effect for height at first harvest (0.9057). This traits contribute the most towards fresh leaf yield per plant. Further, positive and moderate direct effects were observed for height at first branching (0.2540) and internodal length (0.2750). Positive and negligible direct effect for shoot length (0.0469), and trunk girth(0.0654). These traits indicated strong positive association with leaf yield. Negative and high direct effects for the traits *viz.,* leaf powder recovery (-0.7272), fresh leaf yield (-0.6839) and number of secondary branches per tree. Negative and low direct effect for dry leaf yield (-0.1061). Negative and negligible direct effects for number of rachis per tree (-0.0165). Based on the results of path co-efficient analysis it was observed that the height at first harvest, height at first branching, internodal length and trunk girth may be considered as selection indices for leaf yield improvement (Table 11).

D. Mutant 35-2 (0.15% EMS)

The results of the estimation of genetic variability indicated that the considerable variability for all the traits in this mutant (Table 4). The higher estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for number of rachis per tree, height at first branching , dry leaf yield and fresh leaf yield. These findings coincides with the findings of Sheetal and Maurya (2015) in moringa. Moderate estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for shoot length, internodal length, trunk girth and leaf powder recovery (%). Similar results were observed by

Adiger *et al.* (2011) in moringa. Lower estimates of genotypic coefficient of variation and phenotypic coefficient of variation was observed for number of secondary branches per tree and height at first harvest.

High heritability coupled with high genetic advance as percent of mean was observed for the traits *viz.,* shoot length, number of rachis per tree, height at first branching, internodal length, trunk girth, dry leaf yield, leaf powder recovery (%) and fresh leaf yield. Similar results were reported by Sheetal and Maurya, (2015) in moringa. High heritability with moderate genetic advance as percent of mean were observed for height at first harvest. Low heritability and genetic advance as percent of mean was observed for number of secondary branches per tree.

The fresh leaf yield per plant had significant and positive association with number of rachis per tree (0.574), trunk girth (0.648) and dry leaf yield (0.992). Similar results were reported by Selvakumari and Ponnuswamy (2015) in moringa (Table 8).

Path coefficient analysis results revealed that positive and high direct effect for number of secondary branches per tree (0.9200), trunk girth (0.5840) and number of rachis per tree (0.3226). These traits contributed the most towards fresh leaf yield per plant. Further, positive and low direct effect on height at first harvest (0.1683) and dry leaf yield (0.1456). These traits indicated a strong positive association with yield. Negative and moderate direct effect on height at first branching (-0.2193) and internodal length (-0.2320). Negative and low direct effect for shoot length (-0.0511) and fresh leaf yield (-0.1195). Negative and negligible direct effects on leaf powder recovery percentage (-0.0511). Based on this number of rachis per tree, trunk girth, internodal length and leaf powder recovery (%) may be considered as selection indices for leaf yield improvement.

Table 1: Estimation of genetic variability parameters in M_3 generation of the mutant 2-1(100Gy).

Characters	Mean	Coefficient of variation		Heritability (%)	GA as percent of mean (%)
		GCV (%)	PCV (%)		
Shoot length (cm)	41.01	21.30	21.35	99.46	43.75
No. of secondary branches per tree	7.48	13.09	23.84	30.13	14.80
No of rachis per tree	58.9	10.84	11.44	89.68	21.14
Height at first branching (cm)	23.53	51.28	51.31	93.87	95.57
Internodal length (cm)	4.22	22.25	23.03	93.37	44.29
Trunk girth (cm)	6.85	8.98	9.46	90.20	17.58
Height at first harvest (cm)	130.29	2.29	2.34	96.24	4.64
Dry leaf yield (g)	74.3	48.63	52.98	84.24	91.95
Leaf powder recovery (%)	61.83	14.34	14.35	84.81	29.51
Fresh leaf yield (g)	150.83	48.01	50.33	90.98	94.33

Table 2: Estimation of genetic variability parameters in M_3 generation for the mutant 7-1 (100Gy).

Characters	Mean	Coefficient of variation		Heritability (%)	GA as percent of mean (%)
		GCV (%)	PCV (%)		
Shoot length (cm)	55.4	5.27	6.45	66.80	8.88
No. of secondary branches per tree	7.28	19.73	25.02	62.20	32.04
No. of rachis per tree	53.43	17.53	17.71	98.00	35.75
Height at first branching (cm)	23.83	34.86	34.86	91.00	71.80
Internodal length (cm)	3.65	24.87	25.73	93.50	49.55
Trunk girth (cm)	6.12	19.22	19.22	99.90	39.57
Height at first harvest (cm)	129.21	4.71	4.71	99.70	9.68
Dry leaf yield (g)	46.46	72.36	72.38	87.00	95.02
Leaf powder recovery (%)	56.98	15.41	15.42	92.90	31.72
Fresh leaf yield (g)	183.65	71.65	71.72	99.80	91.47

Table 3: Estimation of genetic variability parameters in M_3 generation of the mutant 35-1 (0.15% EMS).

Characters	Mean	Coefficient of variation		Heritability (%)	GA as percent of mean (%)
		GCV (%)	PCV (%)		
Shoot length (cm)	41.91	10.17	10.77	89.20	19.79
No. of secondary branches per tree	9.28	11.86	17.15	47.80	16.89
No. of rachis per tree	98.53	16.59	18.75	78.30	30.25
Height at first branching (cm)	42.69	35.45	37.46	89.50	69.10
Internodal length (cm)	8.84	20.31	21.28	91.10	39.92
Trunk girth (cm)	5.78	17.36	17.60	97.30	35.29
Height at first harvest (cm)	128.59	6.33	6.98	82.20	11.81
Dry leaf yield (g)	155.60	18.95	19.66	93.00	37.65
Leaf powder recovery (%)	72.17	6.22	14.73	17.80	5.41
Fresh leaf yield (g)	609.16	20.08	20.19	99.00	41.16

Table 4: Estimation of genetic variability parameters in M_3 generation of the mutant 35-2 (0.15% EMS).

Characters	Mean	Coefficient of variation		Heritability (%)	GA as percent of mean (%)
		GCV (%)	PCV (%)		
Shoot length (cm)	45.36	14.99	15.69	91.20	29.49
No. of secondary branches per tree	8.36	9.09	20.51	19.70	8.31
No. of rachis per tree	74.41	22.65	23.05	96.60	45.87
Height at first branching (cm)	36.16	39.70	40.05	98.20	81.05
Internodal length (cm)	4.99	16.15	16.43	96.60	32.71
Trunk girth (cm)	5.51	19.02	19.57	94.50	38.09
Height at first harvest (cm)	120.18	6.11	7.16	72.80	10.75
Dry leaf yield (g)	74.86	35.95	36.47	97.20	73.00
Leaf powder recovery (%)	59.38	16.36	16.64	96.70	33.15
Fresh leaf yield (g)	295.58	39.68	39.85	99.10	81.38

Table 5: Simple correlation coefficients for fresh leaf yield and yield components of mutant 2-1 (100Gy).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.00	-0.127	0.064	0.585**	0.314	0.189	0.450**	0.608**	0.694**	0.603**
X2		1.00	0.518**	0.121	0.103	-0.192	0.081	0.237	0.068	0.219
X3			1.00	-0.050	0.024	0.156	0.071	0.158	0.102	0.202
X4				1.00	0.193	0.305	0.176	0.380	0.431**	0.445**
X5					1.00	0.106	0.501**	0.654**	0.523**	0.642**
X6						1.00	0.062	0.185	0.117	0.241
X7							1.00	0.804**	0.589**	0.811**
X8								1.00	0.801**	0.931**
X9									1.00	0.809**
X10										1.00

** Significant at 1% level ; * Significant at 5% level

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

Table 6: Simple correlation coefficients for fresh leaf yield and yield components of mutant 7-1 (100Gy).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.00	-0.479	-0.483	0.095	0.072	-0.262	-0.431	-0.463	-0.421	0.448
X2		1.00	0.630**	-0.080	0.242	0.045	0.434*	0.669**	0.813**	0.699**
X3			1.00	0.086	0.202	0.308	0.492**	0.889**	0.727**	0.874**
X4				1.00	0.316	-0.134	-0.235	-0.014	0.116	-0.028
X5					1.00	0.069	0.131	0.145	0.328	0.205
X6						1.00	0.243	0.404*	0.154	0.394*
X7							1.00	0.514**	0.534**	0.510**
X8								1.00	0.838**	0.989**
X9									1.00	0.863**
X10										1.00

** Significant at 1% level; * Significant at 5% level

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

Table 7: Simple correlation coefficients for fresh leaf yield and yield components of mutant 35-1 (0.15% EMS).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.00	0.167	0.067	0.270	0.004	-0.052	-0.205	0.081	-0.130	0.086
X2		1.00	-0.092	0.155	0.108	-0.096	0.016	-0.216	-0.103	0.885**
X3			1.00	-0.090	-0.165	0.458*	0.119	0.192	-0.034	0.766**
X4				1.00	0.462*	-0.160	-0.082	0.081	-0.069	0.208
X5					1.00	-0.262	0.006	0.217	-0.066	0.271
X6						1.00	0.762*	0.264	0.689**	0.239
X7							1.00	0.094	0.866**	0.805** 0.152
X8								1.00	0.092	0.951**
X9									1.00	0.113
X10										1.00

** Significant at 1% level ; * Significant at 5% level

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

Table 8: Simple correlation coefficients for fresh leaf yield and yield components of mutant 35-2 (0.15% EMS).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.00	0.248	-0.071	0.174	0.049	-0.467	0.031	-0.212	0.012	-0.232
X2		1.00	0.177	-0.067	-0.099	-0.012	0.114	0.183	0.044	0.202
X3			1.00	0.300	-0.025	0.471	0.343	0.596*	0.420	0.574**
X4				1.00	0.334	-0.493	-0.025	-0.293	0.022	-0.293
X5					1.00	-0.177	-0.303	-0.220	-0.300	-0.216
X6						1.00	0.442*	0.661**	0.302	0.648**
X7							1.00	0.182	0.857**	0.164
X8								1.00	0.167	0.992**
X9									1.00	0.116
X10										1.00

** Significant at 1% level ; * Significant at 5% level

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

Table 9: Path coefficient analysis showing direct and indirect effects on leaf yield per plant of the mutant 2-1.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	-0.4640	0.0060	0.0160	0.0610	-0.0595	-0.0456	-0.1113	0.1010	-0.4171	-0.0145
X2	-0.0086	**0.4014**	0.1831	-0.0175	-0.0253	0.0686	-0.0248	0.5708	-0.0570	-0.2879
X3	0.0034	-0.0299	**-0.0407**	-0.0061	-0.0051	-0.0391	-0.0194	0.2754	-0.0623	-0.1576
X4	0.0301	0.0066	-0.0141	**0.3067**	-0.0364	-0.0733	-0.0431	0.6899	-0.2590	0.0060
X5	0.0163	-0.0054	0.0066	0.0204	**-0.1993**	-0.0245	-0.1248	0.1949	-0.3180	0.0352
X6	0.0099	0.0116	0.0405	0.0327	-0.0195	**0.3691**	-0.0148	0.3257	-0.0723	0.0553
X7	0.0233	-0.0040	0.0193	0.0185	-0.0956	-0.0142	**0.1444**	0.4744	-0.3561	0.0788
8	0.0321	-0.0129	0.0383	0.0413	-0.1276	-0.0437	-0.2056	**-0.7609**	-0.4955	0.0127
X9	0.0357	-0.0038	0.0254	0.0455	-0.0995	-0.0284	-0.1455	0.4520	**0.3685**	0.0871
X10	0.0021	-0.0330	0.1107	-0.0018	0.0190	0.0375	0.0556	-0.0644	0.1503	**0.2760**

Residual effect = 0.64; Bold values refer to direct effects

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

Table 10: Path coefficient analysis showing direct and indirect effects on leaf yield per plant of the mutant 7-1.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	**-0.4485**	0.0023	0.0581	-0.0023	0.0041	0.0306	0.0018	-0.5248	-0.0207	0.0024
X2	-0.0159	**0.7337**	-0.0751	0.0020	0.0187	-0.0055	-0.0018	0.7706	0.0408	-0.0001
X3	-0.0160	-0.0030	**0.9248**	-0.0020	0.0138	-0.0334	-0.0019	0.9365	0.0334	-0.0026
X4	0.0031	0.0004	-0.0095	**0.0239**	0.0213	0.0145	0.0009	-0.0150	0.0053	0.0029
X5	0.0019	-0.0013	-0.0229	-0.0072	**0.1316**	-0.0076	-0.0005	0.1546	0.0152	-0.0006
X6	-0.0086	-0.0002	-0.0341	0.0030	0.0047	**0.3909**	-0.0009	0.4239	0.0071	-0.0040
X7	-0.0142	-0.0021	-0.0545	0.0053	0.0088	-0.0262	**0.4779**	0.5406	0.0245	-0.0043
X8	-0.0152	-0.0033	-0.0983	0.0003	0.0098	-0.0436	-0.0020	**-0.1174**	0.0383	-0.0034
X9	-0.0138	-0.0040	-0.0804	-0.0026	0.0221	-0.0167	-0.0020	0.8800	**0.7814**	-0.0012
X10	-0.0089	-0.0001	-0.0347	0.0080	0.0045	-0.0522	-0.0020	0.4345	0.0064	**0.3555**

Residual effect = 0.108 ; Bold values refer to direct effects

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

Table 11: Path coefficient analysis showing direct and indirect effects on leaf yield per plantof the mutant 35-1.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	**0.0469**	0.0676	-0.0085	-0.0139	-0.0001	-0.0021	0.1810	0.0908	0.0041	-0.2720
X2	-0.0228	**-0.3652**	0.0154	-0.0104	0.0102	-0.0047	0.0322	-0.2871	0.0048	-0.1028
X3	-0.0073	-0.0392	**-0.0165**	0.0049	-0.0122	0.0203	-0.0973	0.2265	0.0017	-0.1139
X4	-0.0286	0.0637	0.0119	**0.2540**	0.0309	-0.0070	0.0705	0.0868	0.0019	0.0239
X5	0.0002	0.0454	0.0213	-0.0225	**0.2750**	-0.0113	-0.0051	0.2357	0.0021	0.0092
X6	0.0052	-0.0345	-0.0587	0.0085	-0.0188	**0.0654**	-0.6551	0.2910	-0.0231	0.5509
X7	0.0228	-0.0120	-0.0143	0.0043	0.0004	0.0333	**0.9057**	0.1125	-0.0272	0.7859
X8	-0.0087	-0.0818	-0.0254	-0.0041	0.0151	0.0113	-0.0857	**-0.1061**	-0.0023	0.0755
X9	0.0212	-0.0739	0.0100	0.0048	-0.0071	0.0481	-1.1154	0.1240	**-0.7272**	0.2611
X10	0.0302	-0.0338	0.0147	-0.0013	0.0007	0.0246	-0.7790	0.0871	-0.0271	**-0.6839**

Residual effect = 0.148 ; Bold values refer to direct effects

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

Table 12: Path coefficient analysis showing direct and indirect effects on leaf yield per plant of the mutant 35-2.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	**-0.1195**	0.1032	-0.0103	-0.0270	0.0058	-0.0043	-0.0071	-0.1391	0.0015	-0.0422
X2	-0.0767	**0.9200**	0.0326	0.0187	-0.0200	-0.0001	-0.0184	0.1551	0.0052	-0.0044
X3	0.0157	0.0669	**0.3226**	-0.0482	-0.0035	0.0043	-0.0468	0.3770	0.0327	-0.0755
X4	-0.0344	-0.0322	0.0403	**-0.2193**	0.0436	-0.0045	0.0018	-0.1854	0.0019	-0.0504
X5	-0.0091	-0.0423	-0.0036	-0.0537	**-0.2320**	-0.0016	0.0400	-0.1415	-0.0233	0.0031
X6	0.0961	-0.0034	0.0637	0.0792	-0.0233	**0.5840**	-0.0575	0.4207	0.0235	-0.0150
X7	-0.0114	0.0398	0.0494	0.0022	-0.0409	0.0041	**0.1683**	0.1183	0.0693	-0.0625
X8	0.0452	0.0678	0.0804	0.0472	-0.0292	0.0061	-0.0239	**0.1456**	0.0132	-0.0612
X9	-0.0039	0.0184	0.0566	-0.0039	-0.0391	0.0028	-0.1140	0.1073	**-0.0511**	-0.0753
X10	-0.0184	-0.0051	0.0273	-0.0353	-0.0184	-0.0006	-0.0592	-0.0745	0.0358	**-0.1484**

Residual effect = 0.123; Bold values refer to direct effects

X1-Shoot length (cm)
X2-Number of secondary branches per tree
X3-No. of rachis per tree
X4 -Height at first branching (cm)
X5- Internodal length (cm)
X6- Trunk girth (cm)
X7 - Height at first harvest (cm)
X8- Dry leaf yield (g)
X9 -Leaf powder recovery (%)
X10- Fresh leaf yield (g)

CONCLUSION

In this study, the quantitative traits of the M_3 generation revealed the enhancement of the significant level of yield parameters in annual moringa PKM 1. Among the various mutants, 0.15% (35-1) of EMS and 100Gy (2-1) of gamma rays treatment were more desirable, which resulted high leaf biomass and higher genetic variation. In all the four mutant leaf powder recovery (%), number of secondary branches per tree and number of rachis per tree was considered as the important trait for selection of mutant in leaf yield followed by internodal length and trunk girth.

FUTURE SCOPE

As such, the maximum variation in quantitative traits may show the stable gene mutation in further generation. The results indicate that moringa mutant lines are useful for crop improvement and further study is needed for the evaluate of these mutants.

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