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Effect of different doses of chemical and physical mutagen on genetic variability and character association in M_1 and M_2 generation of *Momordical balsamina* L.

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Abstract

Momordica balsamina L. commonly known as the Balsam apple is an under-exploited cucurbit vegetable occurs wild type in nature which offers various dietary and nutraceutical properties. It is an annual to perennial, tendril-bearing herb, native to tropical regions of Africa. Since the crop occurs in wild forms, the variation exists among the genotype is limited. For the improvement of plant characteristics in diverse crops, mutation breeding has been extensively applied. In the present study, treated population was evaluated to study the extent of genetic variability and character association on growth and yield parameters in M_1 and M_2 generation of *Momordica balsamina* L. The results revealed that high heritability was exhibited by vine length at harvest, number of branches per plant at harvest, stem diameter, leaf area, number of fruits per plant, fruit girth, lycopene content, β-carotene content and ascorbic acid content. As per the character association studies, fruit yield per plant showed highly significant and positive association with number of fruits per plant, fruit weight, fruit length and days to first flowering. Whereas, highly significant but negative association was revealed by number of branches per plant at harvest, stem diameter and days to 50 per cent flowering among mutant population. Whereas, vine length at harvest, number of fruits per plant, fruit weight, fruit length and fruit girth recorded highest positive direct effect on fruit yield per plant. While, number of branches per plant at harvest, stem diameter and days to 50 per cent flowering exerted negative direct effect on fruit yield per plant.

INTRODUCTION

Momordica balsamina L., commonly known as the Balsam apple (secret gift of nature) is a Cucurbitaceae species having chromosome number 2n = 22 (Bharathi et al., 2012) that offers both medicinal and dietary benefits. It is an annual to perennial, tendril-bearing herb, native to tropical regions of Africa. It was naturally occurring in India's forests during the rainy season. This species is closely related to *Momordica charantia*, often known as bitter melon, which possesses a number of therapeutic benefits. The bark, seeds, fruits and leaves of this plant are known to contain a variety of nutraceutical characteristics. Balsam apple fruit pulp extract has anti-HIV properties. The 'Momordins' content of the fruit gives the ability to prevent the spread of HIV and other diseases. In African traditional medicine, the fruit and leaves extracts from this plant used to treat malaria because they have anti-plasmodial properties. There are antiviral, shigellocidal, anti-diarrheal, antibacterial, anti-inflammatory, antiseptic and antimicrobial activities in the extract of different portions of this plant (Thakur et al., 2009). In Hausa Land of Nigeria and Republic of Niger, the leaves are cooked as part of green vegetables soup for lactating mother, as it help the mother to regenerate her lost blood during labour and to purify breast milk (Hutchings et al., 1996).

M. balsamina has 4–5 mm diameter stems that are glabrous to faintly hairy and can reach heights up to 10–12 feet (Burkill *et al*., 1985). When bruised, the entire plant has a foul scent (very similar to datura). Leaves are waxy, deeply palmate, 5–7 lobed, up to 12 cm long, with a toothed and stalked border. Tendrils are simple. It grows at an altitude of 0 to 1293mts (0 to 4242feet) with bright green leaves, flowers are light yellow, round and little bit warty and solitary. Flowers are monoceious. It shows striking orange to red spindle-shaped fruit with nine or ten straight or uneven rows of short, blunt cream or yellowish spines. When the fruits are fully ripe, they abruptly split into three valves that curl back and open when the tip is touched, exposing countless seeds that are completely coated in a brilliant scarlet substance. The seeds are embedded within a pleasant, palatable and watermelon-flavoured red fleshy pulp. The balsam pear blossoms and bears fruit throughout the year, but primarily from October to May. (Northern Hemisphere) (Thakur et al., 2009). *M. balsamina* is wild type in nature, the variation exists among the genotypes is very less and the accessibility of genetic material is also less. In India, it is mainly found in north eastern states and Kerala.

The genus *Momordica* encompasses 59 species, out of them 47 are distributed in African continent and 12 species in Asia (Schaefer and Renner, 2010); Among 12 species, nine are currently occur in India (*M. charantia* L., *M. balsamina* L., *M. dioica* Roxb. Ex Willd., *M. cymbalaria* Fenzl ex Naus., *M. subangulata* Blume subsp. *renigera* (G. Don) de Wilde, *M. cochinchinensis* (Lour.) Spreng. and *M. sahyadrica* Joseph & Antony). *M. balsamina* has resemblance to *M. charantia* with respect to morphological and cytological features but they are non-crossable and it is very difficult to produce the hybrid (Bharathi et al., 2012). Few *M. balsamina* accessions showed elevated amount of tolerance to most of the cucurbit diseases and pests like lady bird beetle (*Epilacna septima*), pumpkin caterpillar (*Margaronia indica*), red pumpkin beetle (*Aulocophora fevicoli*), root knot nematode (*Meloidogyne incognita*), cucurbit yellow mosaic and little leaf disease (Joseph and Antony, 2008). *M. balsamina* thrives well in acidic soil with a pH range of 5.0-6.5 (Joseph and Antony, 2008) and showed resistance to biotic and abiotic stresses. Thus *M. balsamina* accessions acts as reservoir of resistance genes and can be used accordingly in crop improvement programme. *M. balsamina* is wild type in nature, the variation exists among the genotypes is very less and the accessibility of genetic material is also less. In India, it is mainly found in north eastern states and Kerala.

For the improvement of plant characteristics in diverse crops, mutation breeding has been extensively applied. Mackey (1956) in a review on mutation breeding had stated that in adding a single characteristic to a delicate system of genetic balance, in which recombination may cause a breakdown of the whole system, the mutation breeding would be of special use. For self-pollinated crops with a limited genetic profile, mutation breeding is a potent and beneficial tool in the hands of plant breeders (Micke, 1988).

The selection of an effective and efficient mutagen is crucial to any mutation breeding programme in order to create a high frequency of desired mutation. Various chemical mutagens have been used to create beneficial mutants in a variety of crop species (Singh and Singh, 2001). Different researchers have clearly demonstrated the importance of mutation breeding in increasing the genetic diversity for the desirable characters in

various crop plants (Tah, 2006; Adamu and Aliyu, 2007; Khan and Goyal, 2009; Kozgar et al., 2011; Mostafa, 2011). *M. balsamina* is also referred as neutraceutical crop which is wild type in nature, the variation exists among the genotypes is very less and the availability of genetic material is also less. Hence, in order to create variation in this crop, mutations can be used as a tool for gene functional studies and to create genetic variability in *M. balsamina* by using both physical mutagen gamma rays and chemical mutagen Ethyl Methanesulphonate (EMS).

Variability is essential for any breeding programme and exploitation of natural and induced genetic diversity is the basic requirement of plant breeding in developing crop varieties suitable for sustainable crop production. Under such circumstances, induced mutations can be used to generate useful variation in quantitatively inherited characters (Jagajanantham *et al*., 2012). Mutations produce new variations, which accounts to the basis for evolution of new species in nature as well as for breeding new varieties. By producing new phenotypic characters, mutations widen the scope for hybridization and selection. Therefore, artificial induction of mutations play indispensable role in hybridization work particularly if the parents lack variability or are deficient in desirable characters. The knowledge of association between different characters and yield helps the breeder to sort out the characters associated with yield. To increase the yield, genetic information and efficient breeding methods are required. Knowledge of inter character relationship is very important in plant breeding for indirect selection for characters that are not easily measured. However, under complex situation, correlation alone become insufficient to explain relationships among characters and thus path analysis of economic yield components with yield is important (Rao et al., 2017). Therefore, present field investigation was carried out to determine the nature and degree of association among the characters and their direct and indirect effects of independent characters for yield in *Momordica balsamina* L. in M_1 and M_2 mutant population.

MATERIALS AND METHODS

The present investigation was carried out at the Department of Vegetable Science, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences. Bagalkot, in Karnataka state of India during 2021-22. *Momordica balsamina* L. accession (IC-467683) have been taken for investigation. The experiment was laid out in an augmented design with nine treatments. Treatments details is furnished in Table 1. Thin ridges by adopting a spacing of 120 cm × 90. The individual plant progenies obtained by harvesting the seeds from individual plants in M_1 generation separately and were grown during July 2021 and seeds from all the plants of each row containing or suspected to contain the mutant allele are harvested separately from M_2 population plants and carry forwarded for M_3 generation. All the intercultural activities including plant protection measures were carried out as per the recommended package of practices of University of Horticultural Sciences, Bagalkote. Observations were recorded from individual plant in each treatment *viz*., vine length at harvest (cm), number of branches per plant at harvest, stem diameter (cm), Leaf area (cm^2), days to first flowering, days to fifty per cent flowering, pollen viability (%), sex ratio, number of fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (g), fruit yield per plant (kg), fruit thickness (cm), lycopene content (mg/100g), Beta-carotene (mg/100g) and ascorbic acid (mg/100g). The data were subjected to statistical analysis using “R” Software to calculate genotypic and phenotypic correlation coefficient and also the direct and indirect effects of components characters on yield.

Table 1
Treatment details

Treatments (T)	Mutagen (physical/ chemical)	Dose/ Concentration
T_1	Untreated Control	0.0
T_2	Ethyl methanesulphonate	0.2%
T_3	Ethyl methanesulphonate	0.4%
T_4	Ethyl methanesulphonate	0.6%
T_5	Ethyl methanesulphonate	0.8%
T_6	Gamma rays	50 Grays (Gy)
T_7	Gamma rays	100 Grays (Gy)
T_8	Gamma rays	150 Grays (Gy)
T_9	Gamma rays	200 Grays (Gy)

Chemical mutagenic treatment

Total 500 seeds from individual treatment (T_2 to T_5) were immersed in distilled water for six hours to initiate pre-soaking. Such pre-soaked seeds were later on immersed in the mutagen solution for 6 hours with continuous shaking. Pre-soaking accelerates the rate of mutagen uptake by increasing cell permeability and it also initiates the metabolism in the seed for mutagen treatment. To ensure uniform absorption, the amount of

chemical mutagenic solution employed was five times that of the seeds. The seeds immersed in distilled water for 12 hours served as control. The different concentrations used for chemical mutagenic treatments were 0.2 per cent, 0.4 per cent, 0.6 per cent and 0.8 per cent of Ethyl methanesulphonate (EMS). The seeds were properly rinsed under running water after the chemical mutagen treatment.

Physical mutagenic treatment

To irradiate the seeds with gamma rays, 500 seeds from each treatment (T_6 toT_9) were employed. The seeds were exposed to different doses (50,100,150 and 200 Gy) in Gamma Cell-200 (Cobalt-60 source emitting 3600 rads per minute) at the Nuclear Agriculture and Biotech Division, Bhabha Atomic Research Centre (BARC), Mumbai, Maharashtra. After the gamma rays treatment, seeds were immersed in distilled water for 12 hours.

RESULTS AND DISCUSSION

M_1 generation:

Analysis of variance (ANOVA)

The present experiment in mutated population of *Momordica balsamina* L. accession (IC-467683) which was treated with EMS and gamma rays was done mainly to quantify the extent of genetic variability created after mutagenesis, which would be useful for further improvement by selection and genetic advancement. The nature and extent of the breeding programme depends on the variability present in the base population, extent of heritability and association among the characters. The variability as measured by PCV and GCV also gives an idea about the variation created in mutated populations.

The analysis of variance for yield components and its attributing traits indicated the existence of significant differences among the mutant population (M_1 generation) derived from physical and chemical mutagenesis for all the characters under study *viz*., vine length at harvest, number of branches per plant at harvest, stem diameter, leaf Area, days to first flowering, days to 50 percent flowering, pollen viability, sex ratio, number of fruits per plant, fruit length, fruit girth, fruit weight, fruit yield per plant, fruit thickness, lycopene content, β-carotene and ascorbic acid (Table 1).

Fruit yield improvement is one of the most important breeding objectives that directly related to the yield of the crop. It is a dependent character that depends on several developmental traits as well as environmental factors. So, the present study was carried out to analyse variability parameters and correlation studies which would give information about amount and association between two traits, while path coefficient analysis would help in knowing the direct and indirect influence of various traits on the economic trait.

Genetic variability parameters

The genetic variability parameters like mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2), genetic advance (GA) and genetic advance over per cent of mean (GAM) for seventeen characters were worked out to understand the extent to which the variations observed due to genetic factors and results are presented in Table 2.

In EMS treated and gamma irradiated mutant population (M_1 generation), high values of PCV were observed for number of branches per plant at harvest (21.77%), stem diameter (20.57%), leaf area (66.37%), number of fruits per plant (26.88%), fruit length (21.99%), fruit weight (24.66%) and fruit yield per plant (36.45%). Similar results were reported by Shah et al. (2015) in cucumber. This showed the presence of substantial variability in the mutated population of *Momordica balsamina* L. High values for GCV was observed for leaf area (64.80%), number of fruits per plant (25.77%) and fruit yield per plant (27.60%).Similar findings were reported by Shah et al. (2015) in cucumber. These traits which revealed high PCV and GCV suggested the existence of wide variation for these characters, which indicated that these traits were governed by additive gene action. So, there is a scope for improvement of these traits through selection for further breeding programme.

High estimate of heritability were recorded for number of branches per plant at harvest (74.08%), stem diameter (64.21%), leaf area (95.32%), days to first flowering (92.71%), sex ratio (64.45%) and number of fruits per plant (91.87%), while moderate estimate of heritability were observed for days to 50 per cent flowering (41.22%), fruit weight (32.85%) and fruit yield per plant (57.34%), whereas, low estimate of heritability was found for vine length at harvest (16.20%) and fruit length (4.65%). The same heritability pattern was reported by Shah et al. (2015) in cucumber and Verma et al. (2017) in chilli. This indicates the higher response for the selection of high yielding mutants as these characters are governed by additive gene actions and helps the plant breeder for making the effective selection.

High estimates of genetic advance as per cent of mean was recorded by number of branches per plant at harvest (33.27%), stem diameter (27.25%), leaf area (130.52%), number of fruits per plant (50.95%), %) and fruit yield per plant (43.12%). While, moderate estimate of genetic advance as per cent of mean was noted for days to first flowering (10.77%), sex ratio (18.87%) and fruit weight (16.71%). Similar observations were reported by Shah et al. (2015) and Xue et al. (2016) in cucumber. High estimate of heritability along with high value of genetic advance as per cent

of mean observed for number of branches per plant at harvest, stem diameter, leaf area and number of fruits per plant which signifies the preponderance of additive genes and could be improved through selection for further breeding programme.

Table 1
Analysis of variance (ANOVA) for yield components and quality traits in M_1 generation of *Momordica balsamina* L.

Sources of variance	Df	VL	NB	SD	LA	DFF	D50F	PV	SR
Block	15	29.19	0.23	158.99	2.51*	0.78	3.18	20.56	8.36
Entries	881	267.43**	1.16**	0.37	18.79**	4.00**	9.63*	14.47	4.36*
Checks	1	276.12**	38.28**	143.20	0.05	22.78**	13.78	34.03	2.30
Lines	879	232.65**	1.10**	0.02	18.59**	3.92**	9.17*	14.32*	4.35*
Check vs. Lines	1	30830.51**	12.93**	172.92	218.37**	53.14**	402.57**	122.74**	12.17
Error	15	25.13	0.28	159.37	0.87	0.38	3.51	13.23	1.55

Sources of variance	Df	NFP	FL	FG	FW	FYP	FT	LC	βC	AA
Block	15	3.90	0.25	0.31**	0.93	0.01**	0.01	0.11**	0.01**	551.08*
Entries	881	394.55**	0.82	0.08	2.41*	0.004**	0.03**	0.24**	0.03**	404.30*
Checks	1	6.13	0.57	0.04	1.04	0.01**	0.01	0.02	0.0034	103.40
Lines	879	395.44**	0.77**	0.08**	2.41*	0.004**	0.03**	0.24**	0.03**	404.89*
Check vs. Lines	1	0.56	47.95**	0.75**	2.82	0.01**	0.06*	0.09*	0.61**	179.78
Error	15	4.06	0.44	0.08	1.13	0.0009	0.01	0.01	0.00078	185.62

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

VL- Vine length at harvest (cm), NB- Number of branches per plant at harvest, SD- Stem diameter (cm), LA- Leaf area (cm^2), DFF- Days to first flowering, D50F- Days to 50 percent flowering, PV- Pollen viability (%), SR- Sex Ratio, NFP- Number of fruits per plant, FL- Fruit length (cm), FG- Fruit girth (cm), FW- Fruit weight (g), FYP- Fruit yield per plant (kg), FT- Fruit thickness (cm), LC- Lycopene (mg/100g), βC- Beta carotene (mg/100g), AA- Ascorbic acid (mg/100g)

Table 2. Genetic variability parameters for yield and its components and quality traits in M_1 generation of *Momordica balsamina* L.

Sl.No.	Trait	Mean	Range	GCV (%)	PCV (%)	h^2 (%)	GA	GAM
1	Vine length at harvest (cm)	101.12	53.75-173.75	6.07	15.08	16.20	5.10	5.04
2	Number of branches per plant at harvest	4.82	2.63–7.12	18.74	21.77	74.08	1.60	33.27
3	Stem diameter (cm)	0.61	0.29–0.91	16.48	20.57	64.21	0.17	27.25
4	Leaf area (cm^2)	6.50	0.36–23.90	64.80	66.37	95.32	8.48	130.52
5	Days to first flowering	35.15	30.38–40.37	5.42	5.63	92.71	3.79	10.77
6	Days to 50 percent flowering	62.45	54.00–72.00	3.11	4.85	41.22	2.58	4.12
7	Sex ratio	14.70	9.42–20.75	11.40	14.20	64.45	2.77	18.87
8	Number of fruits per plant	73.98	17.81-142.31	25.77	26.88	91.87	37.69	50.95
9	Fruit length (cm)	4.00	3.30–7.18	4.74	21.99	4.65	0.08	2.11
10	Fruit girth (cm)	2.12	1.12–5.92	6.78	13.11	26.7	0.15	7.22
11	Fruit weight (g)	6.29	1.73–11.53	14.13	24.66	32.85	1.05	16.71
12	Fruit yield per plant (kg)	0.47	0.10–1.94	27.60	36.45	57.34	0.20	43.12

GCV-Genotypic coefficient of variation PCV- Phenotypic coefficient of variation h^2- Broad sense heritability

GA- Genetic advance GAM- Genetic advance over per cent of mean

Correlation studies for yield and contributing traits

Character association analysis gives an idea about the relationship among various characters and determines the component characters, on which selection can be used for genetic improvement in the fruit yield. Data pertaining to the correlation coefficient for eleven characters at phenotypic level revealed mutual relationship between traits, which could be helpful in deciding nature of selection to be followed for obtaining high number of fruits per plant.

Fruit yield per plant is a complex trait as it is controlled by several other associated traits. As a result, the association of these characters with fruit yield per plant and among themselves is important for selection of the best individuals in mutated population. Phenotypic correlation study was carried out to understand the nature of relationship existing among the yield and its contributing traits for mutant population (M_1 generation) derived from physical and chemical mutagenesis in *Momordica balsamina* is presented in the Table 3.

The fruit yield per plant revealed a positive and highly significant association with number of fruits per plant, fruit weight, fruit thickness, fruit length and days to first flowering. Similar results were obtained by Priyanka *et al*. (2020) in bitter gourd, Ramesh et al. (2018) in ridge gourd. This indicated that these attributes were more influencing the fruit yield of balsam apple. Hence, it is of greater significance and could be effectively utilized in formulating an effective selection scheme.

At phenotypic level, vine length at harvest had positive and significant association with stem diameter, fruit weight and fruit girth. Stem diameter revealed highly significant and positive association with fruit girth and fruit weight. Days to first flowering exerted highly significant and positive association with days to 50 per cent flowering and number of fruits per plant. Number of fruits per plant showed highly significant association with fruit length and fruit thickness. Similar results were obtained by Yadav *et al*. (2013) and Prasanth et al. (2020) in bitter gourd. Fruit length showed significant and positive association with fruit thickness. Whereas, fruit weight recorded negative and highly significant association with fruit thickness. The results obtained in the study were in accordance with Bartaula et al. (2019) in cucumber and Kalpana et al. (2019) in bottle gourd. The significant positive association revealed in this study depicts the inherent genetic relationship among these traits, which could be of knowledge for simultaneous improvement of related traits.

Table 3
Correlation coefficient for yield and its component traits in M_1 generation of *Momordica balsamina* L.

Characters	1	2	3	4	5	6	7	8	9	10	11
1	**1.000**	0.033	0.294**	-0.120**	-0.128**	-0.114**	0.040	0.066*	0.206**	-0.054	0.062**
2		**1.000**	0.032	-0.069*	-0.069*	-0.026	-0.027	0.022	0.013	-0.082*	-0.017
3			**1.000**	-0.077*	-0.075*	-0.166**	0.018	0.106**	0.068*	-0.069*	-0.084*
4				**1.000**	0.999**	0.167**	0.040	-0.009	-0.003	0.135**	0.109**
5					**1.000**	0.167**	0.040	-0.009	-0.004	0.135**	0.129**
6						**1.000**	0.083*	0.015	-0.016	0.266**	0.728**
7							**1.000**	0.040	0.028	0.067*	0.090**
8								**1.000**	0.009	-0.166**	0.016
9									**1.000**	0.039	0.649**
10										**1.000**	0.236**

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

(1) Vine length at harvest (cm) (2) Number of branches per plant at harvest (3) Stem diameter (cm)

(4) Days to first flowering (5) Days to 50 percent flowering (6) Number of fruits per plant

(7) Fruit length (cm) (8) Fruit girth (cm) (9) Fruit weight (g)

(10) Fruit thickness (cm) (11) Fruit yield per plant (kg)

Path analysis studies for yield and contributing traits

Correlation coefficient which measures association between two characters may not give true or comprehensive picture of a rather complex situation due to mutual relationship among different characters which may be positive or negative. In such situation, path coefficient analysis devised by Wright (1921) furnish a means of measuring direct or indirect effects of each individual variable through other variables on the end product (fruit yield per plant).

The correlation coefficient between fruit yield per plant and its component characters were positioned into their corresponding direct and indirect effects through path coefficient analysis. Phenotypic path analysis study was conducted to know the direct and indirect effects of those traits which influence the yield of *Momordica balsamina* L. Path coefficients among the parameters recorded for mutant population (M_1 generation) derived from physical and chemical mutagenesis is presented in the Table 4.

At phenotypic level, number of fruits per plant recorded highest direct effect on fruit yield per plant followed by fruit weight, vine length at harvest, fruit thickness, fruit girth and days to 50 per cent flowering. Similar findings were reported by Rani et al. (2015), Arvind et al, (2017) in bitter gourd and Kumari et al. (2021) in bottle gourd. Hence, direct selection for these traits would be highly effective in improving fruit yield per plant. Days to first flowering, stem diameter and number of branches per plant at harvest exerted negative indirect effect on fruit yield per plant. These results implied that negatively related traits with yield will influence other parameters that are positively correlated with yield factor. These results are in agreement with Rashid et al. (2020) in bitter gourd, Vivek et al. (2020) in sponge gourd and Kumar et al. (2020) in ridge gourd.

Path analysis for fruit yield per plant as dependent variable at phenotypic level revealed high indirect and positive influence by traits like number of fruits per plant, fruit length, fruit girth, fruit weight, fruit thickness and days to first flowering. Whereas, negative indirect effect by vine length at harvest, number of branches per plant at harvest, stem diameter and days to 50 per cent flowering. Hence, emphasis should be laid on these characters to increase fruit yield per plant while applying selection strategies in mutant populations. These results are in accordance with the findings reported by Rani et al. (2015), Arvind et al. (2017), Rashid et al. (2020) in bitter gourd and Kumar et al. (2020) in ridge gourd.

Table 4
Path coefficient for yield and its component traits in M_1 generation of *Momordica balsamina* L.

Characters	1	2	3	4	5	6	7	8	9	10	rP
1	**0.1263**	-0.00018	-0.00287	0.0016	-0.00083	-0.8346	0.00038	0.00008	0.13565	-0.0008	0.062**
2	0.00041	**-0.00558**	-0.00031	0.00092	-0.00006	-0.01925	-0.00026	0.00003	0.00836	-0.00123	-0.017
3	0.00372	-0.00018	**-0.00974**	0.00103	-0.00064	-0.12182	0.00017	0.00013	0.04448	-0.00104	-0.084*
4	-0.00152	0.00039	0.00075	**-0.01334**	0.00026	0.12252	0.00038	-0.00001	-0.00228	0.00202	0.109**
5	-0.00328	0.00011	0.00195	-0.0011	**0.0032**	0.01916	-0.00034	-0.00004	-0.05932	0.00012	0.129**
6	-0.00143	0.00015	0.00161	-0.00222	0.00008	**0.73518**	0.00079	0.00002	-0.01041	0.00399	0.728**
7	0.0005	0.00015	-0.00017	-0.00054	-0.00011	0.06089	**0.00952**	0.00005	0.01845	0.001	0.090**
8	0.00084	-0.00012	-0.00103	0.00012	-0.00011	0.01107	0.00038	**0.00121**	0.00599	-0.00249	0.016
9	0.0026	-0.00007	-0.00066	0.00005	-0.00029	-0.01163	0.00027	0.00001	**0.65853**	0.00059	0.649**
10	-0.00068	0.00046	0.00067	-0.0018	0.00058	0.19562	0.00063	-0.0002	0.02585	**0.01495**	0.236**

*Significant at 5% level;** Significant at 1% level rP- Phenotypic correlation with Fruit yield per plant Residual value-0.0328

(1) Vine length at harvest (cm) (2) Number of branches per plant at harvest (3) Stem diameter (cm)

(4) Days to first flowering (5) Days to 50 percent flowering (6) Number of fruits per plant

(7) Fruit length (cm) (8) Fruit girth (cm) (9) Fruit weight (g)

(10) Fruit thickness (cm)

M_2 generation:

Analysis of variance (ANOVA)

Vine length at harvest, stem diameter, leaf area, days to 50 per cent flowering, sex ratio, fruit length, fruit girth, lycopene content, β-carotene content and ascorbic acid content exhibited significant variation between the mutant lines in the M_2 generation, indicating the presence of sufficient amount of genetic variability among the mutants, it is possible to identify high yielding lines for growth, yield and quality traits. Similar findings

were also reported by Wang et al. (2015) in cucumber, Shah et al. (2015) in cucumber Norfadzrin *et al.* (2007) in tomato and Girija and Dhanavel (2009) in cowpea (Table 5).

Table 5. Analysis of variance (ANOVA) for yield components and quality traits in M_2 generation of *Momordica balsamina* L.

Sources of variance	Df	VL	NB	SD	LA	DFF	D50F	PV	SR	NFP
Block	15	169.08	0.48	0.01*	1.35	2.73	3.73	12.17	9.37	749.93**
Entries	641	288.93*	1.29	0.01*	25.57**	3.52	3.52	13.58	4.18	1004.82**
Check	1	1.53	0.03	0.0015	0.01	0.80	0.50	24.50	1.19	36.13
Lines	639	288.35*	1.29 *	0.01*	24.27**	4.25 *	3.52*	13.41**	4.07*	902.76**
Check vs. Lines	1	952**	0.01	0.00032	882.55**	6.57	7.57	110.93**	76.90	67192.16**
Error	15	100.6	0.63	0.0045	0.61	1.82	1.70	11.37	2.54	77.06

Sources of variance	Df	FL	FG	FW	FYP	FT	LC	βC	17
Block	15	0.50	0.08	1.38	0.01**	0.02	0.11**	0.0021	751.63**
Entries	641	1.57	0.15*	2.22	0.0043**	0.10**	0.18**	0.03**	463.61*
Check	1	0.05	0.0027	4.88	0.00095	0.07	0.07	0.00076	550.63
Lines	639	1.57*	0.15*	2.2 *	0.004**	0.1**	0.18**	0.03**	462.74*
Check vs. Lines	1	3.14	2.69**	7.75*	0.17**	4.07**	0.96**	0.65**	934.63*
Error	15	0.86	0.06	1.44	0.00047	0.02	0.03	0.0016	203.45

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

VL- Vine length at harvest (cm), NB- Number of branches per plant at harvest, SD- Stem diameter (cm), LA- Leaf area (cm^2), DFF- Days to first flowering, D50F- Days to 50 percent flowering, PV- Pollen viability (%), SR- Sex Ratio, NFP- Number of fruits per plant, FL- Fruit length (cm), FG- Fruit girth (cm), FW- Fruit weight (g), FYP- Fruit yield per plant (kg), FT- Fruit thickness (cm), LC- Lycopene (mg/100g), βC- Beta carotene (mg/100g), AA- Ascorbic acid (mg/100g)

Table 6. Genetic variability parameters for yield components and quality traits in M_2 generation of *Momordica balsamina* L.

Sl. No.	Trait	Mean	Range	GCV (%)	PCV (%)	h^2 (%)	GA	GAM
1	Vine length at harvest (cm)	89.67	49.09-160.59	15.28	18.94	65.11	22.81	25.44
2	Number of branches per plant at harvest	4.92	2.41–8.41	16.48	23.06	51.07	1.20	24.30
3	Stem diameter (cm)	0.48	0.12–0.87	16.80	21.90	58.86	0.13	26.59
4	Leaf area (cm^2)	7.71	0.41–32.15	63.06	63.87	97.51	9.91	128.47
5	Days to first flowering	35.43	29.94–42.44	3.80	5.29	51.66	2.00	5.64
6	Days to 50 percent flowering	44.43	38.94–51.44	3.03	4.22	51.62	2.00	4.50
7	Pollen viability (%)	86.98	82.00–98.00	1.60	4.12	15.21	1.15	1.29
8	Sex ratio	14.03	9.17–20.90	8.82	14.38	37.61	1.56	11.16
9	Number of fruits per plant	146.5	47.19-241.19	19.61	20.51	91.46	56.69	38.70
10	Fruit length (cm)	5.29	2.07–9.27	15.99	23.71	45.48	1.18	22.24
11	Fruit girth (cm)	1.52	0.42–2.53	20.11	25.56	61.94	0.50	32.66
12	Fruit weight (g)	5.84	1.88–10.28	14.93	25.44	34.47	1.06	18.09
13	Fruit yield per plant (kg)	0.24	0.18–2.19	32.05	35.58	81.17	0.52	59.58
14	Fruit thickness (cm)	0.88	0.12–0.46	24.71	26.30	88.32	0.12	47.91
15	Lycopene (mg/100g)	1.34	0.07–2.52	28.47	31.36	82.42	0.72	53.33
16	Beta carotene (mg/100g)	0.48	0.17–0.94	32.16	33.19	93.87	0.31	64.27
17	Ascorbic acid (mg/100g)	83.48	20.64-158.33	19.29	25.77	56.03	24.87	29.79

GCV-Genotypic coefficient of variation PCV- Phenotypic coefficient of variation h^2- Broad sense heritability

GA- Genetic advance GAM- Genetic advance over per cent of mean

Genetic variability parameters

The variability in a character could be assessed through a simple approach of examining the characters means as well as character range. The extent of variability as measured by PCV and GCV also gives information regarding the relative amount of variation in different populations. The PCV measures the magnitude of variation arising out differences in phenotypic values while, the GCV measures the magnitude of variation arising out differences in genotypic values. The phenotypic and genotypic coefficient of variation showed wide variation for most of the characters in mutant populations. Heritability estimates and genetic advancement over mean helps in assessing the effectiveness of selection and thus planning breeding programme for further improvement in mutated population of *Momordica balsamina* L. EMS and Gamma radiations are the most popular group of mutagens and the mutated traits are responsible for the expression of phenotypes (Guimaraes, 2009). The genetic variability parameters like mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2), genetic advance (GA) and genetic advance over per cent of mean (GAM) for seventeen characters is presented in Table 6.

The estimates of phenotypic and genotypic coefficients of variation gave clear picture of the amount of variations present in the mutated population. High values of PCV were noted for number of branches per plant at harvest (23.06%), stem diameter (21.90%), leaf area (63.87%), number of fruits per plant (20.51%), fruit length (23.71%), fruit girth (25.26%), fruit weight (25.44%), fruit yield per plant (35.58%), fruit thickness (26.03%), lycopene content (31.36%), β- carotene content (33.19%) and ascorbic acid (25.77%). Similar results were reported by Aparna *et al*. (2014) in watermelon. High values of GCV was observed for leaf area (63.06%), fruit girth (20.11%), fruit yield per plant (32.05%), fruit thickness (24.71%), lycopene content (28.47%) and β- carotene content (32.16%). Similar results were reported by Aparna *et al*. (2014) in watermelon and Navnath *et al*. (2014) in okra. These traits noted high PCV and GCV are of economic importance and it would be possible for their improvement through further selection.

Higher heritability were observed for vine length at harvest (65.11%), leaf area (97.51%), number of fruits per plant (91.46%), fruit girth (61.94%), fruit yield per plant (81.17%), fruit thickness (88.32%), lycopene content (82.42%) and β- carotene content (93.87%). While moderate heritability was recorded for number of branches per plant at harvest (51.07%), stem diameter (58.86%), days to first flowering (51.66%), days to 50 per cent flowering (51.62%), sex ratio (37.61%), fruit length (45.48%), fruit weight (34.47%) and ascorbic acid (56.03%). Whereas, low heritability was recorded for pollen viability (15.21%). Similar findings were reported by Aparna *et al*. (2014) in watermelon and Navnath *et al*. (2014) in okra. Hence, these traits should be taken into consideration at the time of selection. The heritability estimates alone will not provide an indication of the genetic

improvement that could be possible from selection of superior genotypes. The heritability would be reliable along with the estimates of genetic advance.

High estimates of genetic advance as per cent of mean was noted for vine length at harvest (25.44%), number of branches per plant at harvest (24.30%), stem diameter (26.59%), leaf area (128.47%), number of fruits per plant (38.70%), %), fruit length (22.24%), fruit girth (32.66%), fruit yield per plant (59.58%), fruit thickness (47.91%), lycopene content (53.33%), β- carotene content (64.27%) and ascorbic acid (29.79%). While, moderate estimate of genetic advance as per cent of mean was observed for sex ratio (11.16%), fruit weight (18.09%) and days to first flowering (5.64%). Whereas, low estimates were observed for days 50 per cent flowering (4.50%) and pollen viability (1.29%). Similar findings were reported by Navnath *et al*. (2014) in okra and Sindhya and Pandit (2015) in snake gourd. The high estimates of heritability along with high genetic advance as per cent of mean was noted for vine length at harvest, leaf area, number of fruits per plant, fruit girth, fruit yield per plant, fruit thickness, lycopene content and β- carotene content. It indicates that these traits are governed by additive gene actions and could be improved through selection (Fig. 1 & Fig. 2).

Correlation studies for yield and contributing traits

Knowledge regarding the association of various characters among themselves and with economic traits helps in indirect selection for economic traits. Since selection breeding usually involves handling of large population in achieving the objectives, it is impossible to evaluate the population for each and every quantitative trait. Correlation among traits may vary with environmental conditions. Therefore, it is necessary to have information about correlation of yield with other characters and correlation analysis aids in examining traits which are highly interrelated with yield. Yield is a complex parameter as it is controlled by several other traits. Hence, the connection of these characters with yield and among themselves is important for selection of the genotypes. Phenotypic correlation study was carried out to understand the nature of relationship existing among the yield and its contributing traits for mutant population (M_2 generation) derived from physical and chemical mutagenesis in *Momordica balsamina* is presented in the Table 7.

Fruit yield per plant recorded highly significant and positive association with fruit weight, number of fruits per plant, fruit thickness, days to 50 per cent flowering, days to first flowering and vine length at harvest. Similar findings were reported by Aparna *et al*. (2014) in watermelon, Mudassar (2015) and Prasanth et al. (2020) in bitter gourd. Hence, selection for these traits would also help in improving fruit yield per plant.

At phenotypic level in M_2 generation, vine length at harvest showed highly significant and positive association with number of fruits per plant and days to 50 per cent flowering. Number of branches per plant at harvest noted positive and significant correlation with days to 50 per cent flowering. Stem diameter revealed highly significant and positive association with days to 50 per cent flowering. Days to first flowering was highly significant and positively associated with days to 50 per cent flowering. Number of fruits per plant exerted highly significant and positive association with fruit thickness and fruit weight. Fruit length was positively and significantly associated with fruit weight and fruit thickness. Whereas, fruit weight revealed positive and highly significant correlation with fruit thickness. Therefore, selection for improvement of one character will lead to simultaneous improvement for fruit yield per plant. Similar results were reported by Ullah et al. (2014) in okra, Iqbal et al. (2016) in bitter gourd and Vivek et al. (2020) in sponge gourd. The traits which are positively associated with fruit yield could be improved for improving a complex traits. Further high and positive significant correlation among yield related characters would be of knowledge for simultaneous improvement of several yield contributing traits.

Table 7

Correlation coefficient for yield and its component traits in M_2 generation of Momordica balsamina L.

Characters	1	2	3	4	5	6	7	8	9	10	11
1	**1.000**	-0.001	0.057	0.074	0.079*	0.150**	-0.047	0.067	0.013	0.009	0.099*
2		**1.000**	0.068	0.037	0.094*	0.059	0.047	-0.074	0.040	0.048	0.070
3			**1.000**	-0.005	0.107**	0.023	-0.040	-0.080*	0.028	-0.013	0.021
4				**1.000**	0.199**	0.093*	0.076	0.012	0.009	0.176	0.104**
5					**1.000**	0.212**	0.046	-0.120**	0.122**	0.232**	0.185**
6						**1.000**	0.077	0.043	0.114**	0.370**	0.623**
7							**1.000**	-0.015	0.115**	0.088*	0.142**
8								**1.000**	-0.142**	-0.054	-0.051
9									**1.000**	0.148**	0.751**
10										**1.000**	0.343**

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

(1) Vine length at harvest (cm) (2) Number of branches per plant at harvest (3) Stem diameter (cm)

(4) Days to first flowering (5) Days to 50 percent flowering (6) Number of fruits per plant

(7) Fruit length (cm) (8) Fruit girth (cm) (9) Fruit weight (g)

(10) Fruit thickness (cm) (11) Fruit yield per plant (kg)

Path analysis studies for yield and contributing traits

Path analysis is helpful to understand clearly the association among different variables. It helps to know the direct contribution of a character to the yield and also its influence (indirect effect) through other component characters. In the present experiment, the phenotypic path analysis considering fruit yield per plant as dependent variable was worked out and the results are presented in the Table 8.

In M_2 generation, at phenotypic level highest direct effect in positive direction was recorded by fruit weight followed by number of fruits per plant, fruit thickness, days to first flowering, fruit girth, fruit length and number of branches per plant at harvest. Similar findings are reported by Rashid et al. (2020) in bitter gourd, Vivek et al. (2020) in sponge gourd and Kumar et al. (2020) in ridge gourd. Therefore, selection of these traits helpful in applying selection strategies to enhance fruit yield per plant. Whereas, stem diameter and days to 50 per cent flowering showed negative direct effect on fruit yield per plant.

Path analysis for fruit yield per plant as dependent variable at phenotypic level recorded high indirect and positive influence by traits like fruit weight, number of fruits per plant, fruit thickness, days to 50 per cent flowering, fruit length, days to first flowering, vine length at harvest and stem diameter. Whereas, negative and indirect effects by fruit girth. Hence, direct selection foe these traits would reward for improvement of fruit yield. The results obtained in the study were in accordance with findings reported by Ramesh et al. (2018) in ridge gourd, Kumar et al. (2018) in pumpkin, Maurya et al. (2019) in bitter gourd and Vivek et al. (2020) in sponge gourd.

Table 8
Path coefficient for yield and its component traits in M_2 generation of *Momordica balsamina* L.

Characters	1	2	3	4	5	6	7	8	9	10	rP
1	**0.00901**	-0.00002	-0.0003	0.00326	-0.0023	0.07881	-0.0008	0.0015	0.00903	0.00042	0.099*
2	-0.00001	**0.01174**	-0.0004	0.00165	-0.0027	0.03112	0.00076	-0.0017	0.02769	0.00217	0.070
3	0.00051	0.0008	**-0.0055**	-0.0002	-0.0031	0.01235	-0.0007	-0.0018	0.01936	-0.0006	0.021
4	0.00067	0.00044	0.00003	**0.04398**	-0.0057	0.04882	0.00124	0.00027	0.00616	0.00792	0.104**
5	0.00071	0.00111	-0.0006	0.00874	**-0.0287**	0.11124	0.00074	-0.0027	0.08423	0.01044	0.185**
6	0.00135	0.00069	-0.0001	0.00408	-0.0061	**0.52579**	0.00125	0.00096	0.07815	0.01661	0.623**
7	-0.00042	0.00055	0.00022	0.00335	-0.0013	0.04041	**0.01625**	-0.0003	0.07886	0.00396	0.142**
8	0.00061	-0.0009	0.00044	0.00054	0.00344	0.02263	-0.0002	**0.02232**	-0.0974	-0.0025	-0.051
9	0.00012	0.00047	-0.0002	0.00039	-0.0035	0.0597	0.00186	-0.0032	**0.68826**	0.00666	0.751**
10	0.00008	0.00057	0.00007	0.00775	-0.0067	0.19437	0.00143	-0.0012	0.10196	**0.04494**	0.343**

*Significant at 5% level;** Significant at 1% level rP- Phenotypic correlation with Fruit yield per plant Residual value-0.1385

(1) Vine length at harvest (cm) (2) Number of branches per plant at harvest (3) Stem diameter (cm)

(4) Days to first flowering (5) Days to 50 percent flowering (6) Number of fruits per plant

(7) Fruit length (cm) (8) Fruit girth (cm) (9) Fruit weight (g)

(10) Fruit thickness (cm)

CONCLUSION

The expression of a complex character like yield is a sum total of the contribution of many simply inherited characters therefore, direct selection for yield may not be effective since it is dependent on many contributing traits. These traits are generally correlated to each other and also with yield, therefore, selection practiced for an individual character might subsequently bring about a simultaneous change in other. In the present investigation, characters *viz*., number of fruits per plant, fruit weight, fruit length, fruit girth, lycopene content and β-carotene content exhibited greater variability along with higher heritability coupled with genetic advance. The characters that exhibited positive significant correlation and positive direct effect with fruit yield per plant depicts the inherent genetic relationship among these traits, which could be of knowledge for simultaneous improvement of related traits in *Momordica balsamina* L.

Declarations

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References

1. Adamu, A. K. and Aliyu, H. (2007). Morphological effects of sodium azide on tomato (*Lycopersicon esculentum* Mill.). *Sci. World J.,* 2(4): 9-12.
2. Aparna. D. (2014). Studies on the efficiency gamma rays and EMS inducing mutations in water melon (*Citrulluslanatus*). *M.Sc Thesis*, MPKV, Rahuri.
3. Arvind, N., Sureja, A. K., Abhijit, K. and Rakesh, B., 2017, Profiling of mineral nutrients and variability study in pumpkin (*Cucurbitamoschata*) genotypes. *Agric. Res*., 7(2): 1-7.
4. Bartaula, S., Anil, A., Urbashi, P., Karki, P. and Kiran, T., 2019, Genetic variability, heritability and genetic advance in cucumber (*Cucumis sativus* L.). *J. Agric. Nat. Resour.*, 2(1): 215-222.
5. Bharathi, L. K., Munshi, A. D., Behera, T. K., Vinod, Joseph, J. K., Bhat, K. V., Das, A. B. and Sidhu, A. S., 2012, Production and preliminary characterization of novel inter-specific hybrids derived from *Momordica* species. *Curr. Sci*., 103: 178-186.
6. Burkill, H. W. (1985). The useful plants of west tropical Africa. Royal Botanical Gardens publishers, Kew, 1: 594- 601

7. Dewey, D. H. and Lu, K. H., 1959, A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.,* 51: 515-518.
8. Girija, M. and Dhanavel, D. (2009). Mutagenic effectiveness and efficiency of gamma rays, ethyl methane sulphonate and their combined treatments in cowpea (*Vigna unguiculata* (L.) Walp). *Global J. Mol. Sci.,* 4 (2): 68-75.
9. Guimaraes, E. P. (2009). Rice breeding, Cereals, (Eds) Carena, M. J., Rome, pp. 99-126.
10. Hutchings, A., Scott, A. H., Lewis, G. and Cunningham, A. B. (1996). Zulu medicinal plants, an inventory. University of Natal press, Pietermaritzburg.
11. Iqbal, M., Munawar, M., Najeebullah, M. and Din, A. (2016). Assessment of genetic diversity in bitter gourd. *Int. J. Veg. Sci*., 22(6): 578-584.
12. Jagajanantham, N., Dhanavel., Pavadai. and Chidambaram., 2012, Growth and yield parameters using gamma rays in bhendi (*Abelmoschus esculentus* (L.) Moench). *Int. J. Plant Sci*., 2: 350-355.
13. Joseph, J. K. and Antony, V. T. (2008). Ethnobotanical investigations in the genus *Momordica* in the southern western ghats of India. *Genet. Resour. Crop Evol*., 21(1): 59-62.
14. Kalpana, K., Pravin, K. S., Indu, S. and Bhupendra, K., 2019, Correlation studies and path analysis in bottle gourd [*Lagenaria siceraria* (Molina) Standl.]. *J. Pharmacogn. Phytochem.,* 8(1): 1554-1556.
15. Khan, S. and Goyal, S. (2009). Improvement of mungbean varieties through induced mutations. *Afr. J. Plant Sci.,* 3**:** 174-180.
16. Kozgar, M. I., Goyal, S. and Khan, S. (2011). EMS induced mutational variability in *Vigna radiata* and *Vigna mungo. Res. J. Bot.,* 6: 31-37.
17. Kumar, A., Chaurasia, A. K. and Yadav, P. K. (2020). Mutagenic effect of gamma radiation on macro mutation spectrums, effectiveness and efficiency under M_3 generation in pea (*Pisum sativum* L.). *Int. J. App. Life Sci.,* 23(4): 45-51.
18. Kumar, R., Rajasree, V., Praneetha, S., Rajeswari, S. and Tripura, U. (2018). Correlation and path coefficient analysis studies in pumpkin (*Cucurbita moschata* Duch. Ex poir) for yield and quality traits. *Int. J. Curr. Microbiol. App. Sci*., 7(5): 3067-3075.
19. Kumari, K., Kamal, K. and Randhir, K., 2021, Correlation studies and path analysis in bottle gourd. *Pharma Innov*., 10 (10): 557-560.
20. Mackey, J. (1956). Mutation breeding in Europe. *Brookhaven Symp. Biol*., 9: 141-156.
21. Maurya, M., Singh, V. B., Yadav, G. C., Veerendra, K., Shivam, D. and Ashok, K. P. (2019). Study on the correlation coefficient and path coefficient for the yield and yield component of bitter gourd (*Momordica charantia* L.). *Int. J. Curr. Microbiol. App. Sci*., 8(2): 952-960.
22. Micke, A. (1988). Genetic improvement of grain legumes using induced mutations. An overview In: Improvement of grain legume production using induced mutations. IAEA, Vienna, pp. 1-51.
23. Mostafa, G. G. (2011). Effect of sodium azide on the growth and variability induction in *Helianthus annuus* L. *Int. J. Plant Breed. Genet.,* 5:76-85.
24. Mudassar, I. (2015). Study of correlation among morpho-physiological attributes in bitter gourd (*Momordica charantia* L.). *J. Agric. Res.,* 53(3): 345-349.
25. Navnath, G. K. and Kulthe, M. P. (2014). Effect of physical and chemical mutagens on pod length in okra (*Abelmoschus esculentus* (L.) Moench). *Sci. Resh. Reporter*, 4(2): 151- 154.
26. Norfadzrin, Ahmed, O. H., Shaharudin, S. and Rahman, A. D. (2007). A preliminary study on gamma radiosensitivity of tomato (*Lycopersicon esculentum*) and okra (*Abelmoschus esculentus* (L.) Moench). *Int. J.Agric. Res*., 2: 620-625.
27. Prasanth, K., Sadashiva, A. T., Pitchaimuthu, M. and Varalakshmi, B., 2020, Genetic diversity, variability and correlation studies in bitter gourd (*Momordica charantia* L.). *Indian J. Plant Genet. Resour*., 33(2): 179-186.
28. Priyanka, Santosh, C. and Moond, S. K., 2020, Correlation and path analysis in muskmelon (*Cucumis melo* L.) genotypes. *Pharm. Innov. J*., 9(3): 764-768.
29. Ramesh, N. D., Praveen, C., Radhelal, D., Pushpa, S., Gudadinni, Priyanka, P., Ligade and Kalyan, S. S., 2018, Correlation and path analysis study in studied in ridge gourd (*Luffa acutangula* (L.) Roxb.). *Int. J. Curr. Microbiol. App. Sci*., 7(8): 1511-1519.
30. Rani, K. R., Raju, S. and Reddy, K. R., 2015, Variability, correlation and path analysis studies in bitter gourd (*Momordica charantia*L.). *Agric. Sci. Digest.,* 35 (2): 106-110.
31. Rao, B. B., Swami, D.V., Ashok, P., Babu, B. K., Ramanujam, D. and Sasikala, K. 2017. Correlation and path coefficient analysis of cassava (*Manihot esculenta* Crantz) genotypes. *Int. J. Curr. Microbiol. and App. Sci*. 6(9): 549-557.
32. Rashid, M., Wani, K. P., Hussain, K., Dar, Z. A., Hussain, S. M., Muzamil, A., Insha, J. S. and Sameena, M., 2020, Correlation and path coefficient analysis for various traits in bottle gourd [*Lagenariasiceraria* (Molina) Standl.] genotypes. *J. Pharmacogn. Phytochem.,* 9(3): 806-809.
33. Schaefer, H. and Renner, S. S. (2010). A three-genome phenology of *Momordica* (Cucurbitaceae) suggests seven returns from dioecy to monoecy and recent long-distance dispersal to Asia. *Mol. Phylogenet. Evol*., 54: 553-560.
34. Shah, S., Gong N. M., Arisha, M. H, Khan, A. and Tian, S. (2015). Effect of ethyl methyl sulfonate concentration and different treatment conditions on germination and seedling growth of the cucumber cultivar Chinese long (9930). *Genet. Mol. Res.,* 14 (1): 2440-2449.

35. Sindhya, P. and Pandit, M. K. (2015). Mutagenic effectiveness and efficiency of gamma rays in snake gourd (*Trichosanthes anguina L.*). *J. Appl. & Natural Sci.,* 7(2): 649-651.
36. Singh, J. and Singh, S. (2001). Induced mutations in basmati rice (*Oryza sativa* L.). Diamond Jubilee Symposium, New Delhi, pp. 212.
37. Singh, R. H. and Choudhary, B. D., 1979, Biometrical methods in quantitative genetic analysis. Kalyani Publishers, Ludhiana.
38. Tah, P. R. (2006). Induced macro-mutation in mung bean (*Vigna radiate* (L.) Wilczek). *Int. J. Bot.,* 2: 219-228.
39. Thakur, G. S., Bag, M., Sanodiya, B. S., Bhadauriya, P. and Bisen, P. S., 2009, *Momordica balsamina*: A medicinal and neutraceutical plant for health care management. *Curr. Pharmaceutical Biotech.*, 10: 667-682.
40. Ullah, H., Khan, R. U., Khan, S. U., Mehmood, S., Sherwani, S. K., Muhammad, A., Gilani, S. A., Ullah, H. and Muhammad, Y. (2014). Estimation of induced variability of yield contributing traits in M1 gamma irradiated germplasm of okra (*Abelmoschus esculentus* l.). *S. Asian J. life sci.,* 2(1): 4-7.
41. Verma, R. C., Bhala, V. C. and Khan, M. A., 2017, Studies on mutagenic effects of gamma irradiation on chilli (*Capsicum annuum* L.). *Chromosome Botany,* 12(1): 13-16.
42. Vivek, K. S., Ekka, R. E., Sinha, S. K. and Tiwari, J. K. (2020). Genetic variability, correlation and path analysis of fruit yield in spine gourd (*Momordica dioica* roxb.). *Appl. Biol. Res.*, 22(1): 20-25.
43. Wang, L., Zhang, B., Li, J., Yang, X. and Ren, Z. (2015). Ethyl Methane sulfonate (EMS)-mediated mutagenesis of cucumber (*Cucumis sativus* L.). *Agril. Sci.*, 5: 716-721.
44. Xue, C., Wang, C. and Hao, N., 2016, Ethyl methanesulfonate mutagenesis of cucumber for large-scale mutant screens. *Pakistan J. Botany*, 48(6): 2261-2266.

Figures

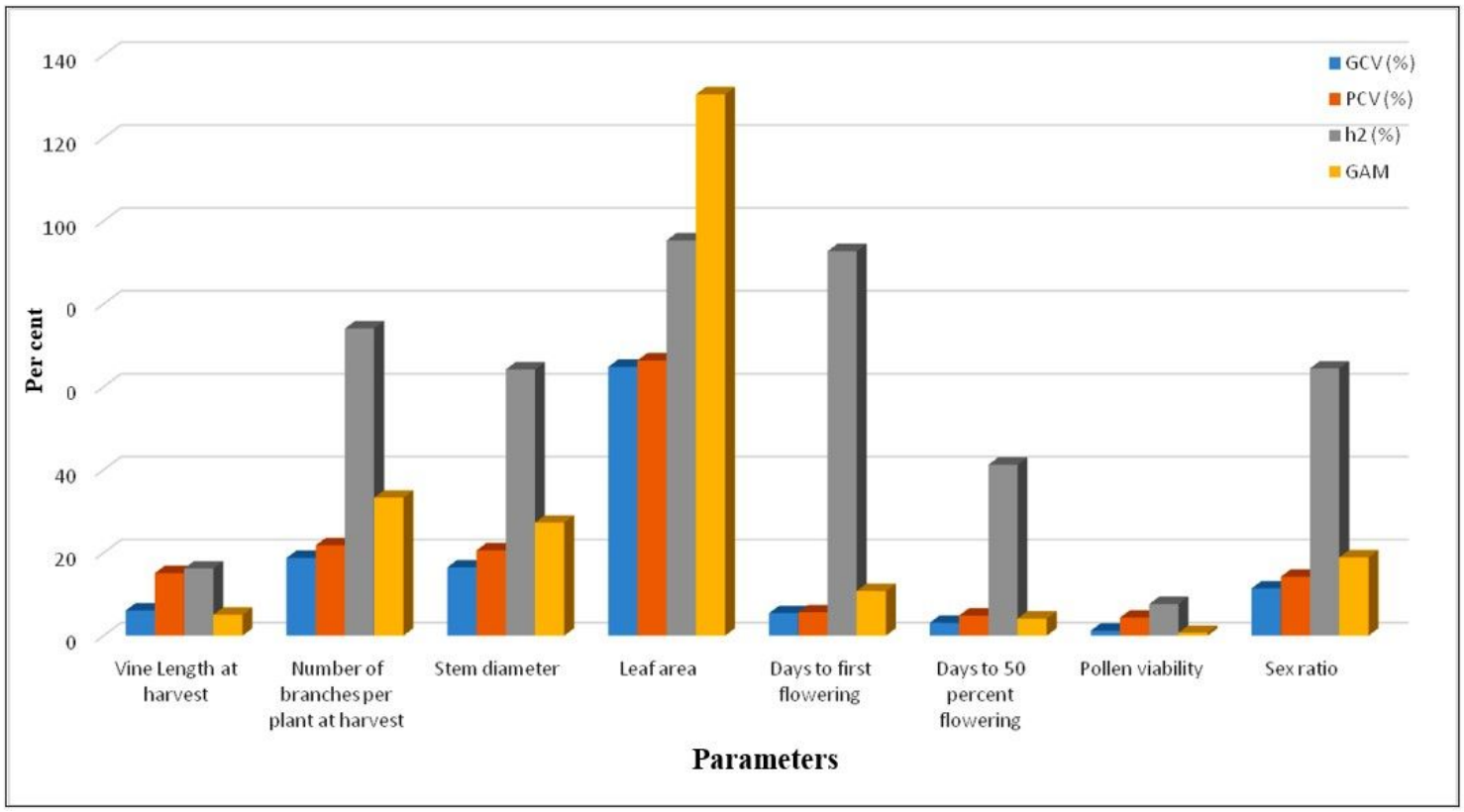


Figure 1

GCV, PCV, h^2 and genetic advance over per cent of mean for growth and flowering parameters in M_1 generation of *Momordica balsamina* L.

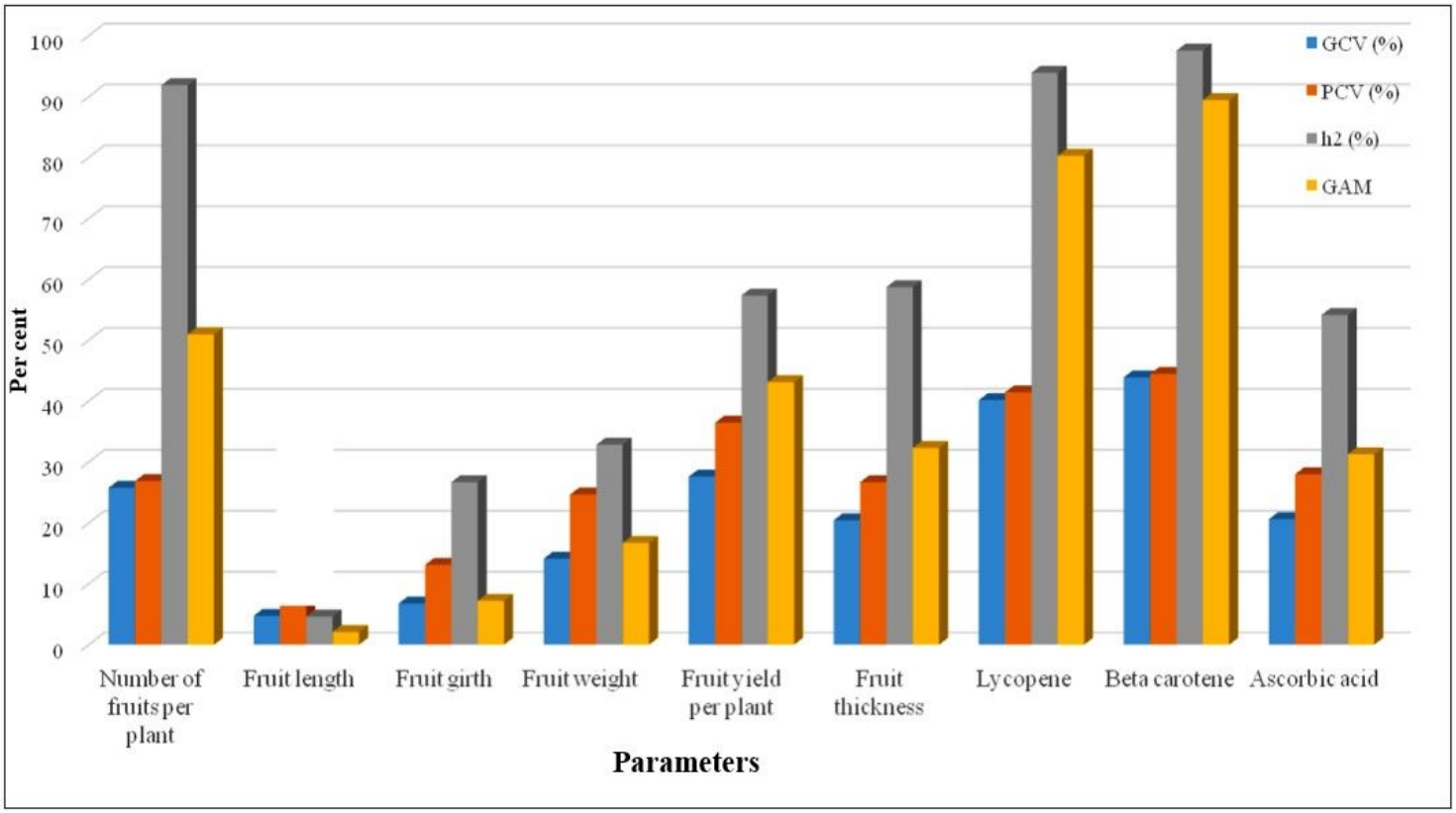


Figure 2

GCV, PCV, h^2 and genetic advance over per cent of mean for yield and quality parameters in M_1 generation of *Momordica balsamina* L.

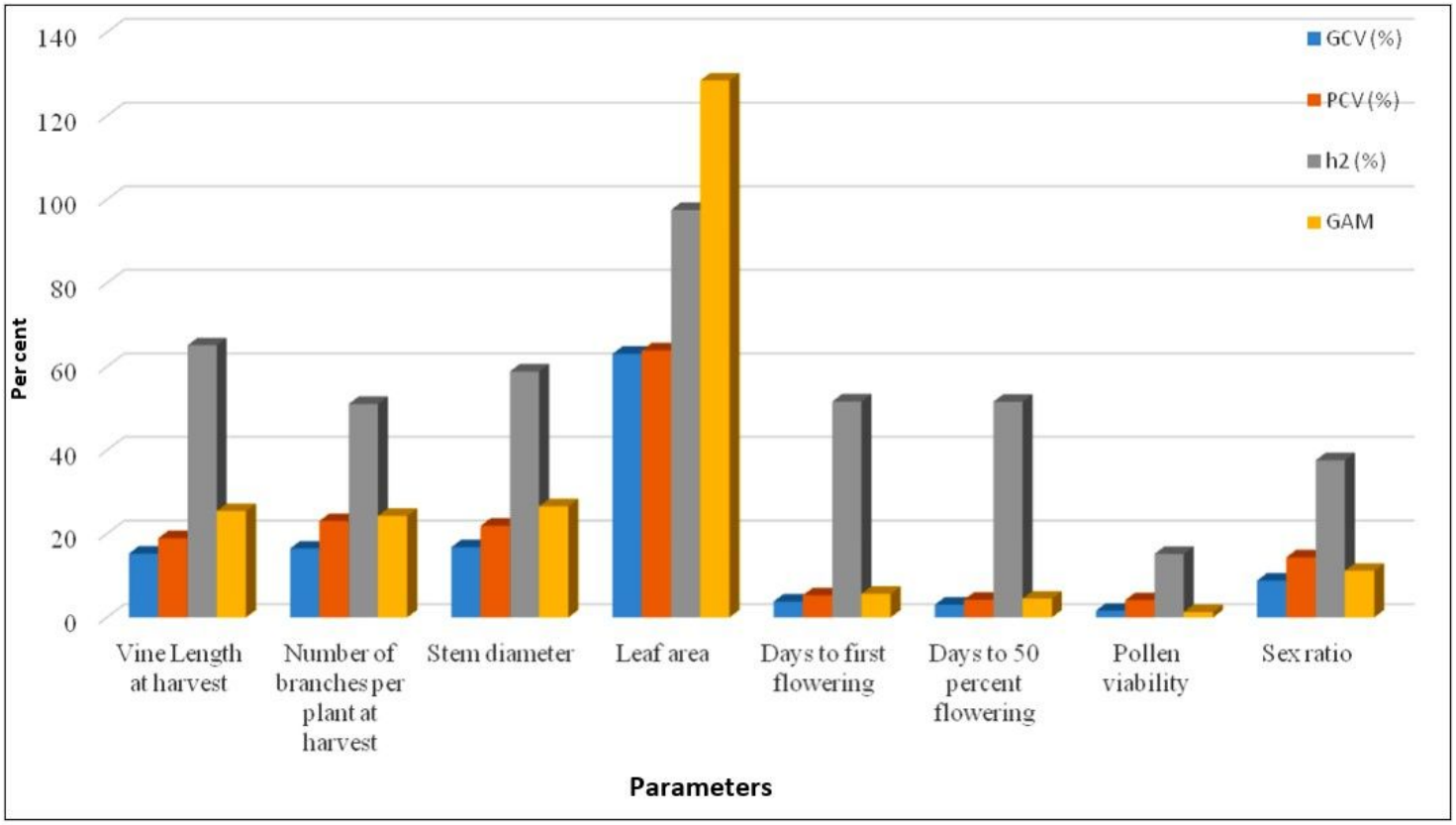


Figure 3

GCV, PCV, h^2 and genetic advance over per cent of mean for growth and flowering parameters in M_2 generation of *Momordica balsamina* L.

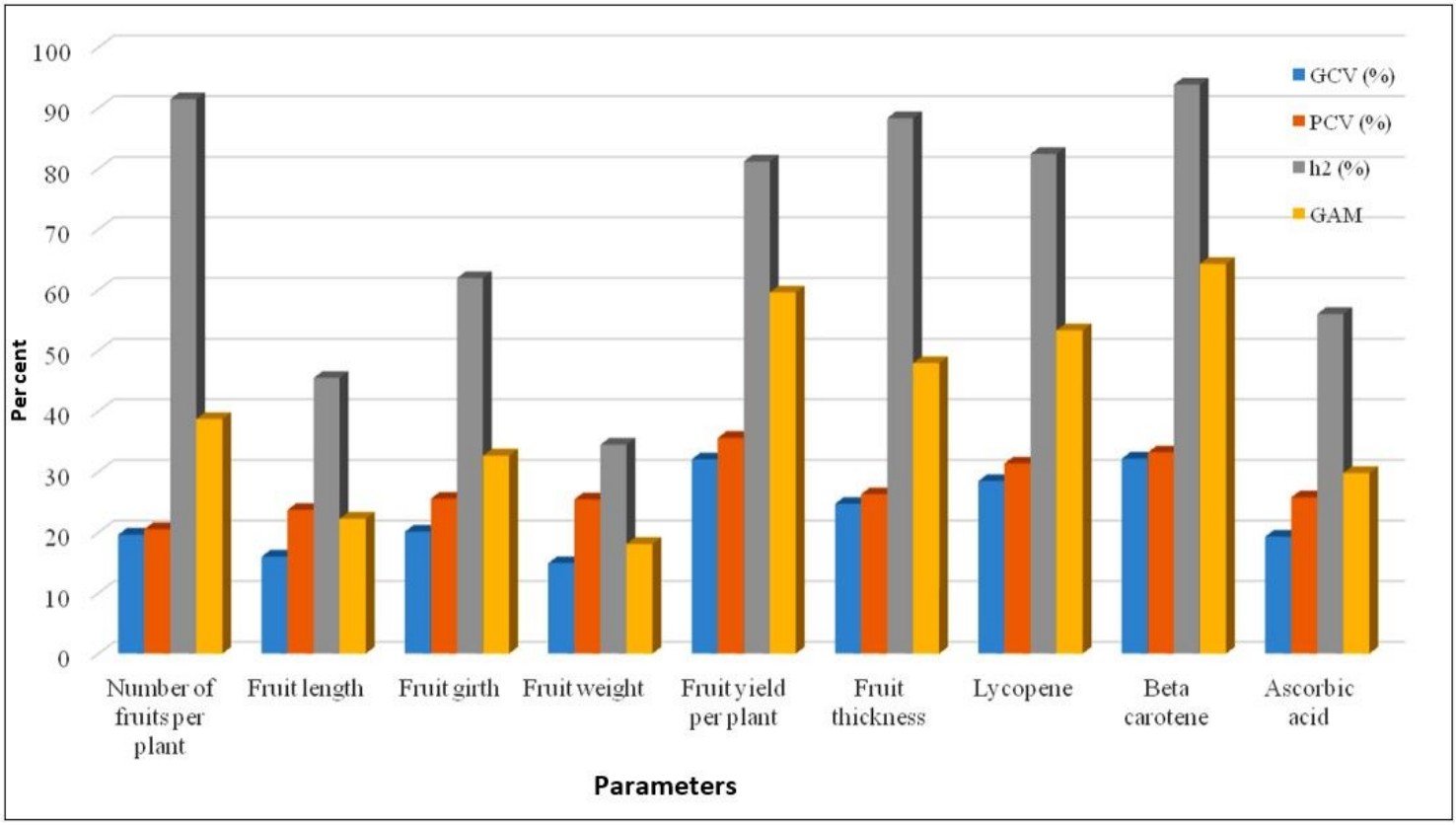


Figure 4

GCV, PCV, h^2 and genetic advance over per cent of mean for yield and quality parameters in M_2 generation of *Momordica balsamina* L