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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, â-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, 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.

Key words: *Momordica balsamina* L., Under-exploited, Mutation, Variability, Heritability, Character association.

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 extract from this plant used to treat malaria because they have anti-plasmodial properties. There is 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 helps 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.

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.

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 plays 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. 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. Planting was carried out by adopting a spacing of 120 × 90 cm. 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_1 population plants and carry forwarded for M_2 generation. 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)

Table 2: 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)

For chemical mutagen treatment, 500 seeds from individual treatment (T_2 to T_5) were treated with Ethyl methanesulphonate (EMS) at different concentrations (0.2 %, 0.4 %, 0.6 % and 0.8 %) and for physical mutagen treatment, 500 seeds from each treatment (T_6 toT_9) 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.

Results and Discussion

M_1 generation

Analysis of variance (ANOVA)

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, â-carotene and ascorbic acid (Table 2).

Genetic variability parameters

The genetic variability parameters like mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2), genetic

Table 3: Genetic variability parameters for yield and its components and quality traits in M_1 generation of *Momordica balsamina* L.

S.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

Table 4: 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)

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 (Table 3).

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 %). 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 %) (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 %) (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 %) (Shah *et al*., (2015) , Xue *et al*., (2016) in cucumber). High estimate of heritability along with high value of genetic advance as per cent of

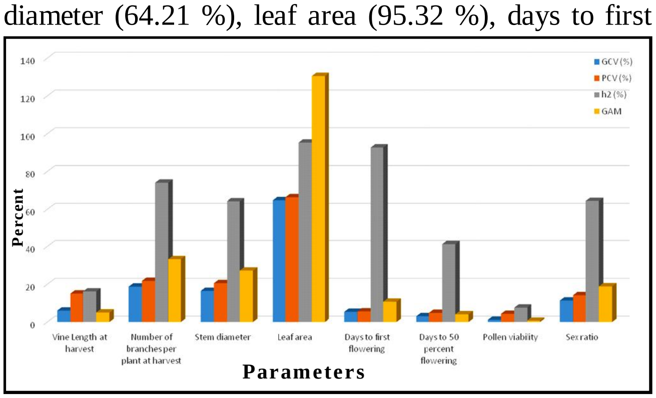

Fig. 1: GCV, PCV, h^2 and genetic advance over per cent of mean for growth and flowering parameters in M_1 generation of *Momordica balsamina* L.

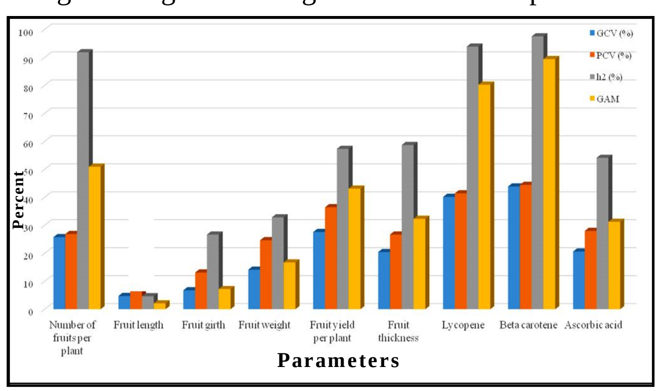

Fig. 2: GCV, PCV, h^2 and genetic advance over per cent of mean for yield and quality parameters in M_1 generation of *Momordica balsamina* L.

Table 5: 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)

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 (Fig. 1 & Fig. 2).

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. 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 (Table 4).

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 (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

Table 6: Analysis of variance (ANOVA) for yield components and quality traits in M_2 generation of *Momordica balsamina* L.

Sources of variance	Df	FL	FG	FW	FYOP	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*
Checks	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

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**
Checks	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

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

S.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

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 (Yadav *et al*., (2013) and Prasanth *et al*., (2020) in bitter 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.

Path analysis studies for yield and contributing traits

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 5.

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. Hence, emphasis should be laid on these characters to increase fruit yield per plant while applying selection strategies in mutant populations (Rani *et al*., (2015), Arvind *et al.*, (2017) in bitter gourd, Kumari *et al*., (2021) in bottle gourd)

M_2 generation:

Analysis of variance (ANOVA)

Vine length at harvest, stem diameter, leaf area, days

Table 8: 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)

Table 9: 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-0.0328
(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)

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 (Wang *et al.*, (2015) in cucumber, Shah *et al.*, (2015) in cucumber Norfadzrin *et al.*, (2007) in tomato, Girija and Dhanavel (2009) in cowpea) (Table 6).

Genetic variability parameters

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 %) (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 %). These traits noted high PCV and GCV are of economic importance and it would be possible for their improvement through further selection (Table 7).

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 %) (Aparna *et al.*, (2014) in watermelon, 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

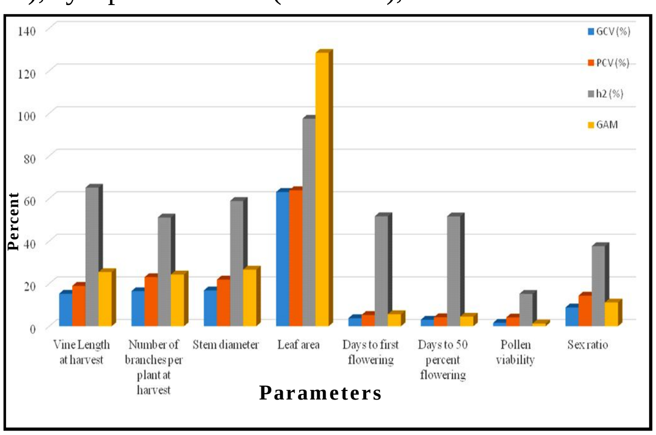

Fig. 3: GCV, PCV, h^2 and genetic advance over per cent of mean for growth and flowering parameters in M_2 generation of *Momordica balsamina* L.

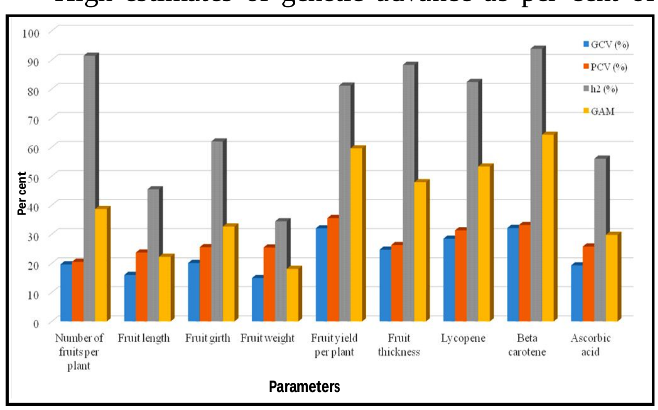

Fig. 4: GCV, PCV, h^2 and genetic advance over per cent of mean for yield and quality parameters in M_2 generation of *Momordica balsamina* L.

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 %), â-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 %) (Navnath *et al*., (2014) in okra, 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. 3 & Fig. 4).

Correlation studies for yield and contributing traits

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 (Ullah *et al*., (2014) in okra, Iqbal *et al*., (2016) in bitter gourd, 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 8).

Path analysis studies for yield and contributing traits

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 (Rashid *et al*., (2020) in bitter gourd, Vivek *et al*., (2020) in sponge gourd, Kumar *et al*., (2020) in ridge gourd) (Table 9). 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.

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. Independent 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 â-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.

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