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Qualitative and Quantitative characters of M_3 mutants in *Trigonella foenum-graecum* L. (*Desi methi*)

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ABSTRACT: Mutagens have remarkable possibilities of improving plants with regard to their quantitative as well as qualitative characters. The present study was undertaken to explore the scope of mutagenesis of three radiomimetic agents in two varieties of *Trigonella foenum-graecum* L. *Desi methi* and *Kasuri methi* common cultivars of Central India. To accompany these aim investigations were carried out to determine comparative mutagenic sensitivity of two varieties. Standardization of dose of EMS, MMS and MES of three radiomimetic agents, frequency of spectrum of mutation, effectiveness and efficiency as well as nature of newly induced macro and micromutations with respect to some quantitative characters of economic importance particularly seed yield.

The results indicated an additional variability when the treated populations were advanced from M_2 to M_3 generation. It thus became evident that there is sufficient scope for selection of beneficial mutants from M_3 progeny of treated population. It has also been found that the chemicals like alkaloid present in the seed protect them from the effect of radiomimetic agents.

Keywords: Mutagens, qualitative characters, radiomimetic agents mutagenesis, *Trigonella foenum-graecum*

I. INTRODUCTION

Yield being a complex character requires an efficient breeding programme to achieve the desired genetic improvement for the genetic architecture of yield must be thoroughly understood. Mutagens have remarkable possibilities of improving plants with regard to their quantitative as well as qualitative characters. As a result of progressive in understanding the role of induced mutations, a number of economically useful mutant varieties have been commercially released.

The pertinent literature which could be consulted the present investigations is briefly reviewed here. It helps to understand the great use of inducing genetic divergence in different crops. The great urge of researchers leads into the field of genetic variability breeding programmes.

Sub-species of *Oryza sativa* treated with gamma rays and ethyl methane sulphonate were studied in the M_2 and M_3 generations for induced quantitative variation in respect of yield and its major components. It also increased variation in the treated population as compared to their respective controls [26].

Venkatachalam *et al*. (1999) studied on twelve new groundnut (*Arachis hypogea* L.) mutated germplasm. Two mutant lines of high yield and oil content, one mutant of disease and on of drought resistance and six mutants for pod, kernel and improvement of other characters were identified [35].

Kaushik and Dashora (2001) studied the action of ionizing radiations on nucleic acids [16]. According to Kharkwal (2001) in case of *Cicer arietinum* L. chemical mutagens have been found to be relatively more efficient than physical in generating variability in M_2 and M_3 generations [17].

According to Cantor *et al*. (2002) the effect of gamma radiation and magnetic field exposure showed the variability in the case of *Gladiolus* [5]. The result showed that when we increasing level of Phosphorus up to 40 Kg P_2O_5/ha and Potassium up to 45 kg/ha significantly increased all the growth characters (plant height, dry matter per meter row length, branches per plant etc.) yield attributes, yield, net return and B : C ratio/hectare as compared to other P and K levels [20].

According to Cheema and Atta (2003) in basmati rice the increase in radiation doses of gamma rays the decrease in germination, seeding height, root

length and emergence under field conditions was observed in M_1 generation. The frequency of chlorophyll mutations in M_2 generation increased with the increase the radiation doses upto 250 Gly which sharply decreased thereafter [7]. Avtar *et al*. (2003) gather information on nature and magnitude of gene effects for biological and seed yield in fenugreek [2].

Gamma rays were found to be more efficient and effective than EMS in both varieties of *Sesamum indicum* L. *viz*., SVPRI and COI in M_2 generation. The effectiveness and efficiency of both the mutagens was more in SVPRI than COI [30].

Maximum increase in the growth parameter was with combined treatment of Azotobacter + PSB inoculated crop and then the crop treated with Azotobacter showed somewhat less growth parameters and the least growth parameters in these three inoculations with PSB treatment [18].

The highest chlorophyll mutation frequency was obtained with 0.3% EMS & chlorophyll mutation spectrum with MMS in kasuri methi, but the mutation spectrum was broader in desi methi as compared to kasuri methi [34].

The results showed that using 3 mM salicylic acid in drought conditions had left significant and positive effects on quantitative and qualitative characteristics of peanuts, so it can be a good alternative in Sistan region for reducing the severe impact of water shortage [15].

TRIA, which is a natural compound could be used as a promising compound in the improvement of properties of Kiwifruit [24].

Evaluation of rice germplasm based on agro morphological characters revealed presence of substantial variability within the germplasm [27].

Higher estimates of heritability along with extremely high genetic advance was observed for number of clusters per plant indicating major role of additive gene action [9].

MATERIAL AND METHODS

Material

Two varieties, seeds of *Trigonella foenum-graecum* L. *viz., Desi methi* and *Kasuri methi* were procured from Jawahar Lal Agriculture farm Eintkhedi, Berasia Road, Bhopal (M.P.).

Mutagens

Three mutagens EMS, MMS and MES which are radiomimetic agents, were used in present investigation. Three concentrations of each mutagen *i.e.,* 0.1%, 0.2% and 0.3% are selected on the basis of preliminary experiment, LD-50 dose.

These radiomimetic agents have bi-functional alkyl reactive groups that react with DNA, causes extensive cross linkage of DNA, chromosome breakage, chromosome mutations and gene mutation.

Methodology

Fully mature and healthy seeds of uniform size free from mould and mechanical injury were selected for different concentration of mutagenic treatment. To determine the effective range of mutagens pilot experiment were conducted in preceding year with the two varieties, *Desi methi* and *Kasuri methi* by way of employing wide dose range. Period of presoaking the seeds making them vulnerable to the action of different mutagens was also ascertained through preliminary experiments.

Radiomimetic Agents: EMS, (Ethyl Methane Sulphonate) MMS (Methyl Methane Sulphonate) and MES (Methyl Ethane Sulphonate) were under treatment.

Three mutagens EMS, MMS and MES (*i.e*. 0.1%, 0.2%, and 0.3% of each mutagen) and 1200 seeds in control replications are selected.

Seeds presoaked in distilled water for 12 hours were treated with freshly prepared aqueous solutions of EMS, MMS and MES (by volume) at three different concentrations *viz*., 0.1%, 0.2% and 0.3% for 4 hours of each mutagen. Three dilutions of original liquid EMS, MMS and MES solutions used for treatment were about 10 times that of the seeds. Intermittent shaking was done throughout the duration of treatment. The seeds after treatment were thoroughly washed in running water under a tap for 15 minutes before sowing.

RESULTS AND DISCUSSIONS

Observation in M_3 generation

(i) Macromutations

Seeds of the morphological mutants isolated in M_2 generation were grown separately as M_3 progeny to confirm their true breeding behaviour. Detailed observations regarding their useful characters were recorded. Some of the important beneficial mutants with their qualitative and quantitative characters are presented in (Table 1 and 2).

Table 1: Some of important Qualitative and Quantitative characters of M_3 mutants in *Trigonella foenum-graecum* L. (*Desi methi*).

Sr. No.	Radiomimetic agents	Doses (%)	Number assigned to the M_3 mutants	Morphologically distinctive features of the mutants	Number of pods per plant	Size of pod in (cm)	Single plant yield (gm)	Number of days required to reach maturity	Meiotic behaviour
1	2	3	4	5	6	7	8	9	10
1.	—	Control	C -2-D	—	18	12	2.3	103	Normal
2.	—	Control	C-1-I	—	19	12	2.4	103	Normal
3.	—	Control	C-38-G	—	18	11	2.4	104	Normal
4.	—	Control	C-76-G	—	18	12	2.3	103	Normal
5.	—	Control	C-91-D	—	18	12	2.4	103	Normal
6.	EMS	0.1	E-2-G	Dwarf	16	10.2	2.0	103	Normal
7.	EMS	0.1	E-6-H	Uni-foliate leaf	18	11.3	2.3	102	Abnormal
8.	EMS	0.1	E-5-I	Early ripening	18	12.0	2.4	102	Normal
9.	EMS	0.1	E-4-J	Blackish seeds	17	11.9	2.4	102	Normal
10.	EMS	0.1	E-26-D	Late ripening	18	12.2	2.6	102	Normal
11.	EMS	0.2	EM-39-D	Bi-foliate leaf	17	11.2	2.0	101	Abnormal
12.	EMS	0.2	EM-3-I	Rolled leaf	16	10.9	2.2	102	Normal
13.	EMS	0.2	EM-4-D	Blackish seeds	17	11.0	2.3	103	Normal
14.	EMS	0.2	EM-38-H	Dwarf	14	9.2	1.9	103	Normal
15.	EMS	0.2	EM-30-I	Increase pod number	24	11.2	2.6	102	Normal
16.	EMS	0.3	EMS-39-G	Dwarf	15	10.2	2.2	101	Normal
17	EMS	0.3	EMS-20-H	Small size pod	18	12.0	2.1	102	Normal
18.	EMS	0.3	EMS-9-I	Uni & bi-foliate leaves	14	11.9	2.3	103	Uni & multivalent
19.	EMS	0.3	EMS-11-G	Small size seeds	16	12.2	2.0	103	Normal
20.	EMS	0.3	EMS-8-C	Shimmy seeds	17	12.0	2.4	103	Normal
21.	MMS	0.1	M-22-I	Dwarf	14	11.1	2.0	102	Normal
22.	MMS	0.1	M-06-G	Large size seeds	1.6	12.2	2.3	103	Normal
23.	MMS	0.1	M-16-H	Chlorophyll abnormal leaf	15	12.4	2.4	102	Abnormal
24.	MMS	0.1	M-32-C	Elongated seeds Size	17	12.0	2.4	101	Normal
25.	MMS	0.1	M-18-A	Tall	19	12.3	2.5	103	Normal
26.	MMS	0.2	MM-21-A	Tall	18	12.6	2.6	103	Normal
27.	MMS	0.2	MM-31-D	Large size pod	17	12.8	2.5	102	Normal
28.	MMS	0.2	MM-18-G	Bold seeds	18	14.0	2.6	103	Normal
29.	MMS	0.2	MM-09-B	Shimmy seeds	17	12.0	2.0	102	Normal
30.	MMS	0.2	MM-06-L	Less number of pod	14	12.3	2.0	103	Normal
31.	MMS	0.3	MM-13-D	Dwarf	15	11.0	2.0	101	Normal
32.	MMS	0.3	MMS-09-A	Small size pod	14	10.9	2.2	101	Normal
33.	MMS	0.3	MMS-07-B	Uni-foliate leaf	13	10.7	2.2	102	Univalent
34.	MMS	0.3	MMS-22-H	Small size seeds	15	10.6	1.9	101	Normal

35.	MMS	0.3	MMS-27-C	Blackish seeds	16	11.2	2.0	102	Normal
36.	MES	0.1	ME-38-D	Tall	18	12.0	2.5	103	Normal
37.	MES	0.1	ME-24-C	Increase pod	18	12.1	2.8	103	Normal
38.	MES	0.1	ME-20-A	Two pods	19	11.9	3.2	102	Normal
39.	MES	0.1	ME-09-D	Bold size	18	11.8	2.7	103	Normal
40.	MES	0.1	ME-04-G	Large size pod	18	12.0	2.8	103	Normal
41.	MES	0.2	MEE-24-B	Number of seeds increase	18	12.0	2.9	103	Normal
42.	MES	0.2	MEE-30-A	Tall	19	13.0	3.0	103	Normal
43.	MES	0.2	MEE-09-D	Flower white	18	12.0	2.2	102	Normal
44.	MES	0.2	MEE-06-G	Large size of pod	19	12.3	2.7	102	Normal
45.	MES	0.2	MEE-04 H	Increase seed number	18	13.0	2.4	103	Normal
46.	MES	0.3	MES-13-D	Dwarf	16	12.1	2.0	103	Normal
47.	MES	0.3	MES-10-A	Small size pod	14	12.0	1.9	102	Normal
48.	MES	0.3	MES-6-B	Uni, bi & trifoliate leaves	13	11.8	1.8	104	Abnormal
49.	MES	0.3	MES-04-D	Small size seeds	14	12.0	1.7	102	Normal
50.	MES	0.3	MES-28- H	Branches less number	15	12.0	1.3	103	Normal

Table 2: Some of the important Qualitative and Quantitative characters of M_3 mutants in *Trigonella foenum-graecum* L. (*Kasuri methi*).

Sr. No.	Radiomimetic agents	Doses (%)	Number assigned to the M_3 mutants	Morphologically distinctive features of the mutants	Number of pods per plant	Size of pod in (cm)	Single plant yield (gm)	Number of days required to reach maturity	Meiotic behaviour
1	2	3	4	5	6	7	8	9	10
1.	—	Control	C-38-D	—	16	11	2.0	102	Normal
2.	—	Control	C-29-A	—	17	10	1.9	100	Normal
3.	—	Control	C-09-H	—	16	11	2.0	102	Normal
4.	—	Control	C-11-G	—	16	10	2.0	100	Normal
5.	—	Control	C-06-H	—	16	10	2.0	101	Normal
6.	EMS	0.1	E-09-D	Tall	18	11	2.1	102	Normal
7.	EMS	0.1	E-11-H	Increase length of pod	16	14	2.4	101	Normal
8.	EMS	0.1	E-29-I	Increase number of seeds	16	14	2.5	102	Normal
9.	EMS	0.1	E-04-G	Bold seeds	16	11.5	2.6	102	Normal
10.	EMS	0.1	E-28-G	Blackish seeds	15	11	2.0	101	Normal
11.	EMS	0.2	EM-26-D	Dwarf	13	10.1	1.8	101	Normal
12.	EMS	0.2	EM-14-A	Less branching	10	11	1.8	102	Normal
13.	EMS	0.2	EM-32-G	Bold seeds	16	11	2.4	101	Normal
14.	EMS	0.2	EM-06-I	Increase number of pods	20	11.1	2.6	102	Normal

15.	EMS	0.2	EM-02-G	Shimmy seeds	—	—	—	—	—
16.	EMS	0.3	EMS-11-I	Dwarf	12	9.8	1.8	101	Normal
17.	EMS	0.3	EMS-02-G	Uni-foliate leaf	13	9.2	1.8	102	Multivalent
18.	EMS	0.3	EMS-09-D	Small size seeds	15	10	1.7	100	Normal
19.	EMS	0.3	EMS-26-H	Brown seeds	16	11	2.0	101	Normal
20.	EMS	0.3	EMS-31-C	Less number of pods	10	11	2.0	102	Normal
21.	MMS	0.1	M-32-D	Tall	19	11.2	2.3	101	Normal
22.	MMS	0.1	M-16-C	Branching	24	11.0	2.2	102	Normal
23.	MMS	0.1	M-21-D	Increase pod	14	11.2	2.1	101	Normal
24.	MMS	0.1	M-06-G	Small size seeds	16	9.7	1.8	102	Normal
25.	MMS	0.1	M-11-I	Shimmy seeds	15	11.2	2.3	102	Normal
26.	MMS	0.2	MM-06-I	Dwarf	13	9.7	2.1	101	Normal
27.	MMS	0.2	MM-23-G	Bi-foliate leaf	15	10.3	1.9	103	Univalent
28.	MMS	0.2	MM-9-C	Increase pod number	21	11.0	2.6	102	Normal
29.	MMS	0.2	MM-13-D	Increase size of seed	16	11	2.8	102	Normal
30.	MMS	0.2	MM-02-A	Blackish seeds	16	10.8	1.9	101	Normal
31.	MMS	0.3	MMS-31-D	Dwarf	14	10.9	1.9	102	Normal
32.	MMS	0.3	MMS-09-A	Less number of seeds	15	11.1	1.7	101	Normal
33.	MMS	0.3	MMS-13-B	Small size pod	12	8.5	1.6	108	Abnormal
34.	MMS	0.3	MMS-23-G	Brown to Blackish seeds	15	10.9	2.0	102	Normal
35.	MMS	0.3	MMS-07-H	Uni-foliate leaf	16	11.2	2.3	104	Univalent & multivalent
36.	MES	0.1	ME-18-G	Tall	19	11.2	2.2	102	Normal
37.	MMS	0.1	ME-09-I	Large size pod	16	13.8	2.4	103	Normal
38.	MMS	0.1	ME-07-D	Increase number of seed	16	11.0	2.3	102	Normal
39.	MMS	0.1	ME-21-A	Shimmy seeds	15	10.6	2.0	101	Normal
40.	MMS	0.1	ME-03-C	Large size leaflet	14	10.4	2.0	102	Abnormal
41.	MES	0.2	MEE-19-D	Tall	16	13.0	2.1	102	Normal
42.	MMS	0.2	MEE-17-C	Large size leaflet	18	11.2	2.3	105	Laggards
43.	MMS	0.2	MEE-09-G	Branching	21	11.3	2.1	102	Normal
44.	MMS	0.2	MEE-06-I	Uni and Bi-foliate leaf	16	11.0	2.0	101	Normal
45.	MMS	0.2	MEE-13-H	Brown seeds	15	10.9	1.9	102	Normal
46.	MES	0.3	MES-28-C	Dwarf	14	10.9	2.0	102	Abnormal
47.	MES	0.3	MES-19-D	Small size leaf	15	11.0	1.9	101	Univalent
48.	MES	0.3	MES-09-B	Small size pod	16	9.0	1.7	101	Normal
49.	MES	0.3	MES-13-A	Less number of seeds	15	11.0	1.6	102	Normal
50.	MES	0.3	MES-10-D	Uni-foliate leaf	16	11.0	1.9	102	Abnormal

Yield Per Plant

(a) Behaviour of mean. Mean values regarding yield for both varieties treated with three radiomimetic agents in M_2 and M_3 generations are summarized in (Table 1 and 2). In both the varieties there were no significant differences as compared to their controls in both generations. In variety *Desi methi* highest mean 4.99 in 0.3% MMS in M_2 generation and 4.90 in 0.3 % MMS in M_3 generation, while in *Kasuri methi* 4.99 in 0.2% MMS in M_2 generation and 4.30 in 0.3% MMS in M_3 generation against their controls 4.00 and 4.01, respectively.

(b) Variance. In variety *Desi methi* highest range of variance was 2.9-5.5 is under 0.3% MES treatment in M_2 generation and 2.8-6.0 under 0.2% MMS in M_3 generation against 2.9-4.9 and 2.9-5.4 of respective controls. In variety Kasuri methi highest range 2.5-5.6 with 0.2% MMS treatment in M_2 generation and 2.7-5.9 with 0.3% MMS treatment in M_3 generation against their controls *i.e*. 2.6-5.4 and 2.6-5.5, respectively.

In variety *Desi methi* highest overall variance was recorded under 0.3%, MMS *i.e*. 3.98 in M_2 generation and under 0.3% MMS *i.e*. 3.99 in M_3 generation against their control 2.92 and 2.89, respectively.

All the treatment in both the varieties in both M_2 and M_3 generation showed a significantly higher overall variance as compared to their respective controls. In both the varieties negative as well as positive variability was induced.

In both varieties significantly higher phenotypic variability was observed under all the treatments of radiomimetic agents in both generations. The higher PCV in variety *Desi methi* was 11.31% obtain with 0.3% MMS treatment in M_2 generation and 10.98% was obtained with 0.3% MMS in M_3 generation. In variety *Kasuri methi* highest PCV was 7.32% under 0.3% MMS in M_2 generation and 8.32% under 0.3% MMS in M_3 generation. Similarly in both varieties with all the treatments of three radiomimetic agents in both generations significantly higher genotypic variability was observed as compared to their respective control (Table 1 and 2).

Table 3: Range, Mean, Overall variance, Components of variability and genetic parameters for Yield in M_2 and M_3 generations of *Trigonella foenum-graecum* L. (*Desi methi*).

Sr. No.	Radiomimetic agents	Doses (%)	Range	Mean	Overall variance	PCV %	GCV %	Heritability	Genetic advancement as % of mean
M_2 generation									
1.	—	Control	2.9-4.9	4.32	2.92	6.23	1.92	4.23	1.92
2.		0.1	2.9-5.0	4.78	3.76	8.01	2.34	5.78	2.13
3.	EMS	0.2	2.9-5.1	4.82	3.12	9.21	2.64	6.24	2.54
4.		0.3	2.9-5.4	4.90	3.92	10.61	2.97	9.21	2.92
5.		0.1	2.8-5.0	4.82	3.12	8.01	2.62	5.91	2.51
6.	MMS	0.2	2.9-5.3	4.91	3.12	9.12	2.86	6.89	2.67
7.		0.3	2.8-5.4	4.99	3.98	11.31	3.91	10.32	3.00
8.		0.1	2.8-5.0	4.30	3.12	7.92	2.32	4.98	2.13
9.	MES	0.2	2.9-5.4	4.82	3.12	8.97	2.46	5.01	2.60
10.		0.3	2.9-5.5	4.90	3.78	10.76	3.01	10.02	2.98
M_3 generation									
1.	—	Control	2.9-5.4	4.30	2.89	5.78	1.97	3.96	1.90
2.		0.1	2.8-5.8	4.60	2.12	8.13	2.30	5.70	2.10
3.	EMS	0.2	2.9-5.9	4.67	2.91	8.99	2.59	6.10	2.34
4.		0.3	2.8-5.0	4.82	3.76	10.26	2.92	9.00	2.80
5.		0.1	2.9-5.9	4.68	2.10	7.98	2.51	5.92	2.49
6.	MMS	0.2	2.8-6.0	4.78	3.19	8.92	2.80	6.16	2.56
7.		0.3	2.8-5.4	4.90	3.99	10.98	3.34	10.12	3.01
8.		0.1	2.9-5.9	4.52	2.30	7.67	2.28	4.91	2.10
9.	MES	0.2	2.8-5.8	4.60	3.00	9.01	2.51	5.00	2.46
10.		0.3	2.8-5.0	4.91	3.67	10.12	3.03	9.89	2.89

Table 4: Range, Mean, Overall Variance, Components of variability and genetic parameters for Yield in M_2 and M_3 generation of *Trigonella foenum-graecum* L. (*Kasuri methi*).

Sr. No.	Radiomimetic agents	Doses (%)	Range	Mean	Overall variance	PCV %	GCV %	Heritability	Genetic advancement as % of mean
M_2-generation									
1.	—	Control	2.6-5.4	4.00	1.96	5.99	1.92	3.20	0.98
2.	EMS	0.1	2.6-5.7	4.13	1.97	6.01	2.00	4.90	1.34
3.	EMS	0.2	2.5-5.7	4.16	1.87	6.72	2.14	5.11	1.54
4.	EMS	0.3	2.5-5.9	4.28	2.11	7.12	3.31	6.36	2.72
5.	MMS	0.1	2.6-5.8	4.20	1.92	6.62	2.14	5.10	1.64
6.	MMS	0.2	2.5-5.6	4.29	1.99	6.92	2.64	5.58	2.01
7.	MMS	0.3	2.6-5.9	4.30	2.30	7.32	3.92	6.98	2.97
8.	MES	0.1	2.5-5.6	4.10	1.87	5.32	2.12	4.98	1.56
9.	MES	0.2	2.6-5.7	4.19	1.81	5.72	2.39	5.41	2.01
10.	MES	0.3	2.5-5.8	4.27	2.10	6.92	3.67	6.16	2.02
M_3 generation									
1.	—	Control	2.6-5.5	4.01	1.84	5.60	1.89	3.01	0.90
2.	EMS	0.1	2.7-5.6	4.12	1.86	6.01	2.01	4.98	1.42
3.	EMS	0.2	2.6-5.7	4.19	1.87	7.60	2.32	5.12	1.72
4.	EMS	0.3	2.5-5.8	4.25	1.97	8.12	3.12	6.20	2.90
5.	MMS	0.1	2.6-5.7	4.20	1.62	6.92	2.89	5.21	1.80
6.	MMS	0.2	2.6-5.8	4.26	1.88	7.70	3.01	5.70	2.01
7.	MMS	0.3	2.7-5.9	2.30	2.52	8.32	3.76	6.24	3.18
8.	MES	0.1	2.7-5.6	4.14	1.52	6.00	2.10	4.89	1.63
9.	MES	0.2	2.6-5.9	4.18	1.67	7.01	2.40	5.23	2.13
10.	MES	0.3	2.5-5.8	4.24	1.98	7.89	3.10	6.00	2.99

(c) Heritability and genetic advancement

All the treatments of three radiomimetic agents in both M_2 and M_3 generation in both varieties *Desi methi* and *Kasuri methi* induced significantly higher heritability as compared to their respective controls. Genetic advancement was also found to be significantly higher in two varieties in all the three radiomimetic agents, in both M_2 and M_3 generations against their respective controls.

The average seed yield per plant decreased in M_2 generations of both varieties with all the treatments given. However the average seed yield per plant improved with all the treatments (Fig. 2 and 3). The decreased in average seed yield capacity in M_2 generation was due to decrease in pollen fertility which directly effect on pod frequency and seed yielding. The improvement in the seed yielding capacity in M_3 generation is due to random selection as the generation was raised from the seeds of only highest yielding plants of each M_2 family. Scossiroli (1966) also observed a decreased of seed yield per plant in *Triticum durum* in M_2 population which increased in M_3 generation. They considered this change as recovery effect and attributed to the elimination of bad genes after selfing [28]. Similar results were obtained by Gaul and Aestveit (1966) in hexaploid wheat [11]. The data on range, variance and phenotypic co-efficient of variation revealed that there was a net increase in variability in both M_2 and M_3 generations.

The comparison of frequency distribution curve in M_2 and M_3 generations (Fig. 2 and 3) indicate more variability in M_3 over M_2 generation. The curve shifted more towards higher seed yield per plant in both M_2 and M_3 generations. The increased variability for seed yield per plant has been reported by several workers in different crops like, Ahloowalia (1967) in ryegrass [1]; Bansal (1969) in barley [3]; Verma (1973) in *Brassica* [36]; Rao and Joshi (1976) in *Triticales* [25]; Kwon and Oh (1983) in mungbean [19]; Verma *et al.* (1993) in *Coriandrum sativum* L. [37] and Castro *et al.* (2003) in ryegrass (*Lolium perenne* L.) [6] and Mensah *et al*., (2005) in *Vigna unguiculata* L. (walp) [21] and Suneetha *et al.* (2006) in brinjal [32], Yadav and Kumar 2021 in Finger Millet [39], Tiwari *et al*., 2021 in Rice [33].

Although the seed yield per plant with most of the treatments given was less than the control in M_2 generations yet the genotypic variability increased with all the treatments due to an increase in overall variance. The increase in the genetic component of variation further enhanced the heritability and the genetic advance.

In M_3 generation there was a further increase in the genotypic variability as the estimates of genotypic co-efficient of variation heritability and genetic advanced expressed as percentage of mean were of higher magnitude as compared to their corresponding estimates in M_2 generations. Therefore the selection will be more effective for higher seed yield per plant in M_3 as compared to M_2 generation. Several workers have reported an increased in genotypic variability and other genetic parameters in the treated population. William and Narway (1961) in Soybean [38]; Gill *et al.* (1974) in barley [12]; Jain and Agarwal (1993) in *Trigonella foenum-graecum* L. [14], Singh *et al.* (1995) in Lineseed [31]; Berwal *et al.* (1996) in fenugreek [4]; Mohanti and Prusti (2000) in brinjal [23]; Dash and Kole (2001) in fenugreek [8]; Datta and Chatterjee (2004) in fenugreek [10]; Mensah *et al.* (2005) in Cowpea and Menash *et al.* (2007) in Sesame [21, 22].

Manifestation of Micromutations in M_2 and M_3 Generation

In the foregoing discussion, it has been stated that the character differed in the manifestation of polygenic variability in different generations. The extent of earliness and lateness induced in M_2 for number of days to initiate flowering was equal and did not differ much from earliness and lateness induced in M_3 generation of both varieties (Fig. 1 and 2). In both the varieties a little difference was observed in the induction of lateness in M_2 and M_3 generations. The frequency of distribution curve of both the generations and their respective controls are presented (Fig. 3). It is clear from the figures that the curves of M_2 and M_3 generation have comparable dispersion in both the directions. The comparable magnitude of genetic advancement expressed as percent of mean in M_2 and M_3 generations further suggested that the selection is equally effective in M_2 and M_3 generations.

In case of seed yield, the phenotypic frequency distribution of all the treatments in M_2 and M_3 generations of both varieties *Desi methi* and *Kasuri methi* with their respective controls is depicted in Table 1 and 2. It is clear from the figures that the curve of M_3 generation has more dispersions than that of M_2 generation. The estimate of genetic advancement of yield expressed as percent of mean of different treatments of both varieties were higher in M_2 than the corresponding estimates of M_3 generation. In other characters like number of pods per plant, seed weight etc. the variability was almost equal in both the generations in both varieties.

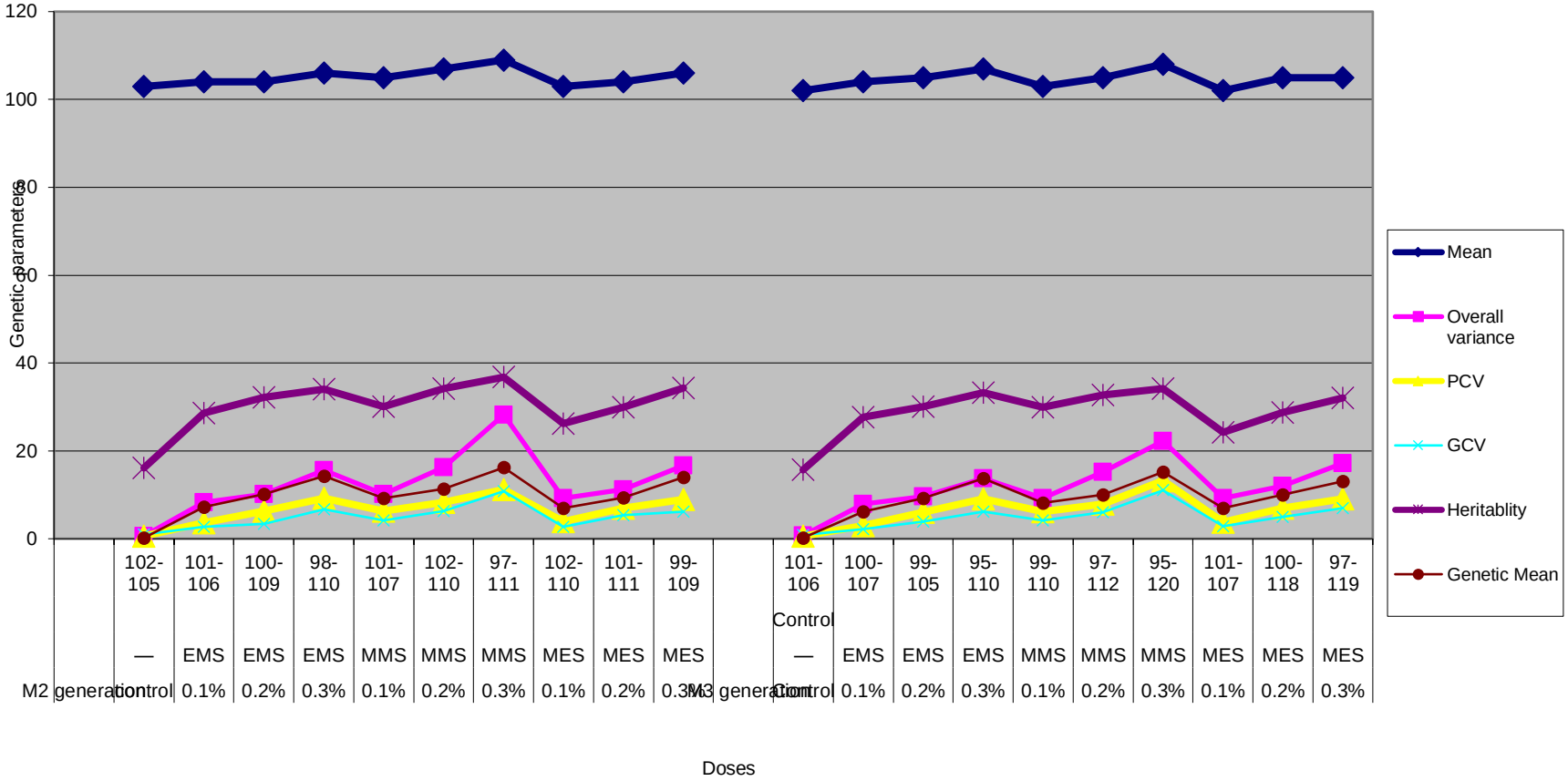

Fig. 1. Showing range, mean, overall variance, component of variation and genetic parameters for weight of 1000 seeds in M_2 and M_3 generations of *Trigonella foenum graecum* L. (Kasuri methi) with the treatment of EMS, MMS and MES.

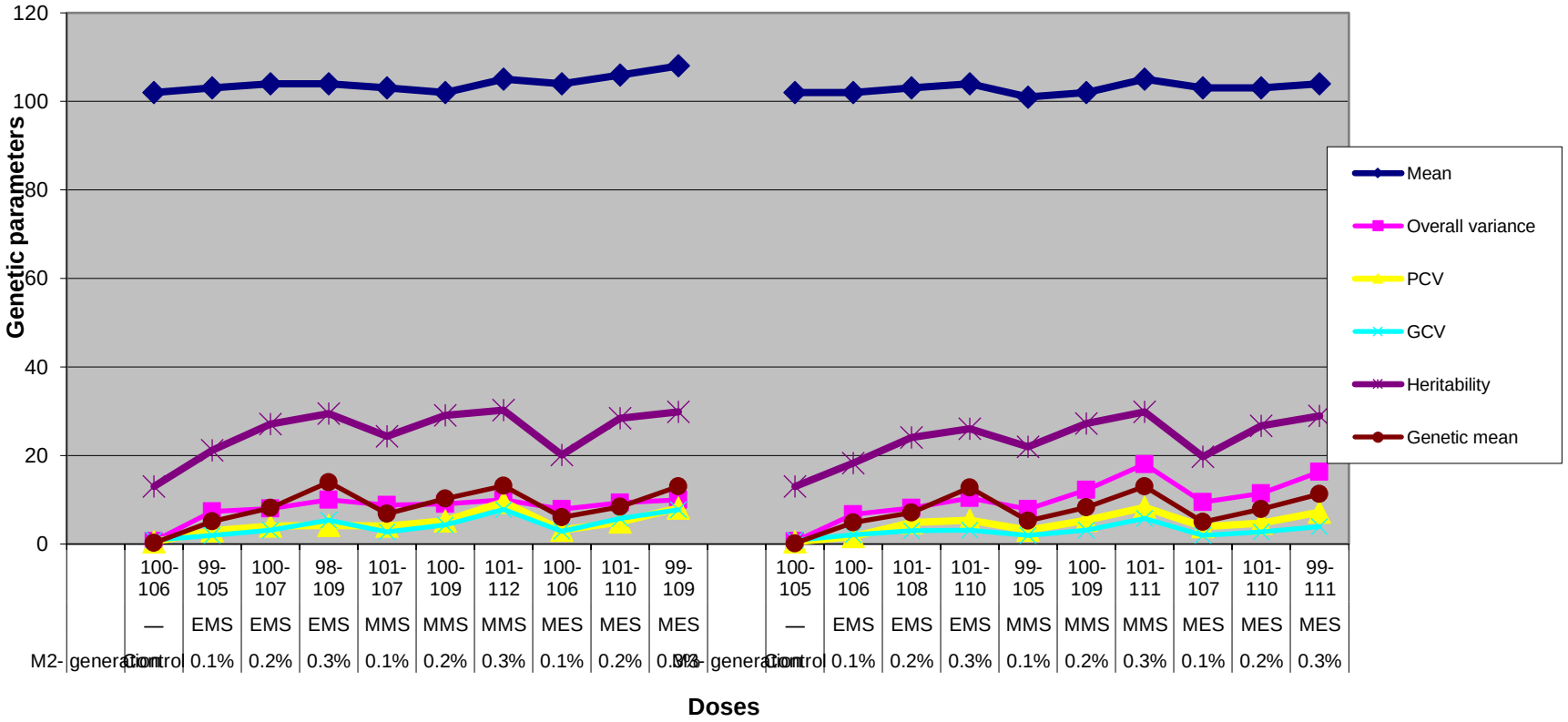

Fig. 2. Showing range, mean, overall variance, components of variability and genetic parameters for yield in M_2 and M_3 generations of *Trigonella foenum graecum* L. (Desi methi) with the treatment of EMS, MMS and MES.

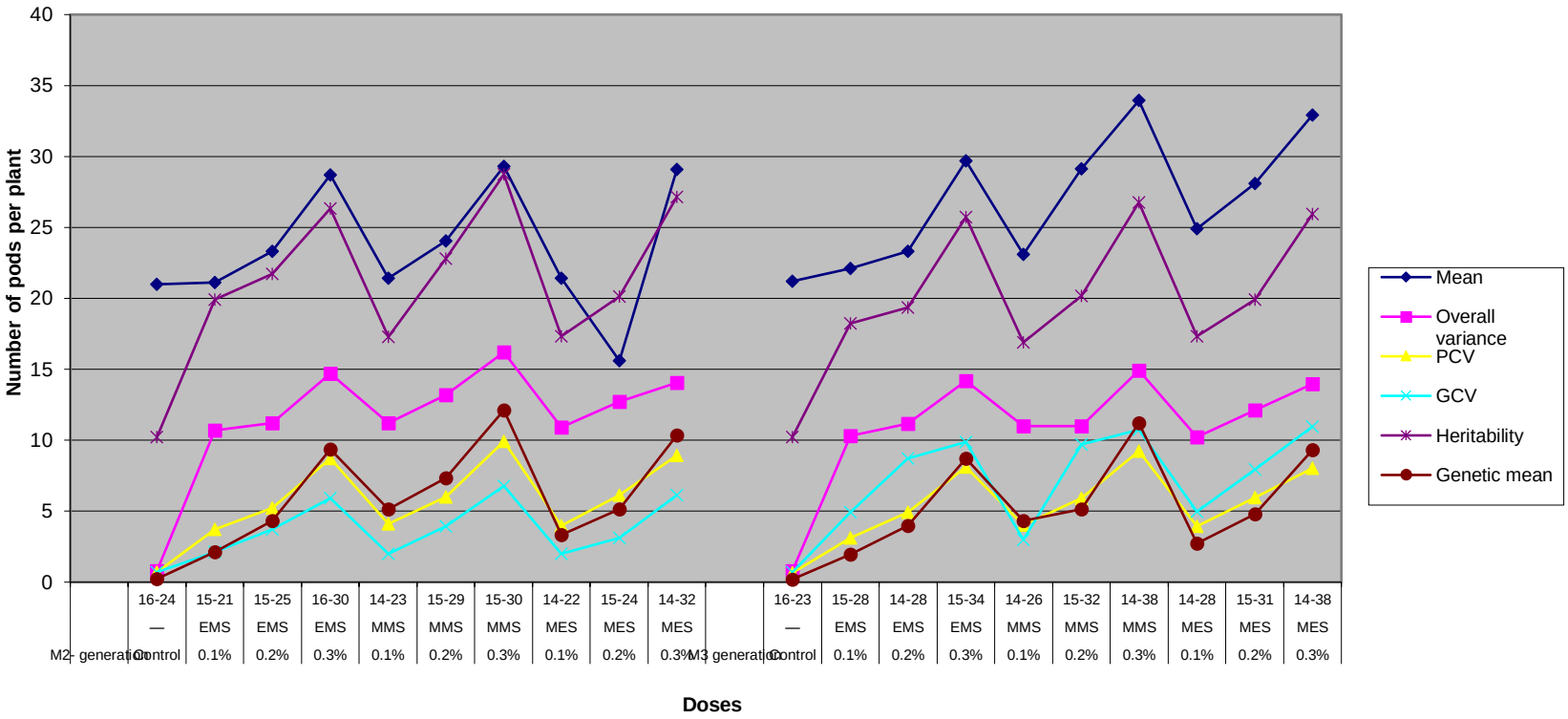

Fig. 3. Showing range, mean, overall variance, components of variability and genetic parameters for yield in M_2 and M_3 generations of *Trigonella foenum graecum* L. (Kasuri methi) with the treatment of EMS, MMS and MES.

The question that as to whether the selection should be made from M_2 or from M_3 generations is important in mutation breeding. Felensona (1966) [13], while studying the progress of selection for quantitative traits in wheat concluded that selection started in M_3 was more effective that if started in M_2 generation. Scossiroli (1968) on the other hand did not find large difference whether selection started either from M_2 or from M_3 generation. The present study reveals that it may vary from crop to crop and character to character. For example, maximum variability for number of days to initial flowering can be exploited in M_2 generation itself, while selection of higher yield will be effective in M_3 generation. However, for some characters such as the selection of plants for higher number of pods, seed weight will be more regarding in M_2 generation than M_3 generation as the induced variability is more pronounced in M_2 generation [29].

CONCLUSIONS

From these studies it may also be concluded that chemicals like, present in seeds of *Trigonella foenum-graecum* L. two varieties *Desi methi* and *Kasuri methi* protect it from the effect of radiomimetic agents. It may be suggested that chemicals which are radiomimetic and alkylating agents MMS, is more effective for such crop and are therefore important tools for inducing beneficial mutations in *Trigonella* (methi).

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