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Induced macro-mutational spectrum and frequency in sesame (*Sesamum indicum* L.)

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Abstract

A mutation breeding study was carried out with sesame varieties *viz.*, SVPR 1 and Cardeboriga using 5 doses each of gamma rays (10,20,30,40 and 50 krad) and ethyl methane sulphonate (0.8, 1.0, 1.2, 1.4 and 1.6 %). In general the spectrum of viable mutants included mutants with alteration in branching habit, plant height, phyllotaxy, nodal distance, flower character, nodal distance of the first capsule, capsule and seed characters with a total of 68 mutants in SVPR 1 and 32 mutants in Cardeboriga from gamma irradiated population and 83 mutants in SVPR 1 and 49 mutants in Cardeboriga from EMS treated population. Among the wide spectrum of viable mutants, economically important mutants such as mutants with determinate plant type, early flowering, more number of branches and capsules, altered phyllotaxy, main stem with shorter inter nodes, multicapsules per axil, multilocules, increased capsules *etc.*, were isolated for further studies.

Key words: *Sesamum indicum* L., macro mutants, gamma rays, EMS and mutagenic traits

Introduction

Induced mutation has been perceived as an important tool to create additional variability for qualitative and quantitative traits in a number of crop plants. In sesame it has become an important tool of creating variation in certain much desired characters such as superior oil quality, tolerance to waterlogged conditions and resistance to endemic diseases which have not been found in the extensive germplasm collections. In Korea, a mutant variety "Yanbaeckae" with high oil quality and resistance to *phytophthora* has been released. Srilanka also developed a *phytophthora* resistant variety called "Ank-S2". The two mutants *viz.,* SM5 and SM7 having high seed yield coupled with tolerance to waterlogged condition and virus disease were developed in sesame through induced mutations. Development of shattering resistant lines is one of the most important objectives of sesame breeding. Through induced mutations, a number of semi-shattering types with good seed retention have been developed in Thailand. Success in mutation breeding programme for any crop can be achieved by increasing the spectrum and frequency in viable mutation. The inheritance of macro mutants is an important phenomenon as they lead to evolution of new genotypes. The present research was undertaken with the intention to develop desirable variants such as determinate plant type, early flowering, multilocules, multicapsules per axil and bigger size capsule to enhance the yield potential in sesame genotypes.

Materials and methods

A field study was conducted during the year 2008-09 in the Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai. Two promising sesame genotypes namely, SVPR 1 (popular white seeded type) and Cardeboriga (monostem African type) were treated with two mutagens *viz*., gamma rays and EMS. Two hundred well filled dry seeds were sealed in butter paper covers and exposed to 10 to 50 krad doses of gamma rays from ^{60}Co source at Indira Gandhi Centre for Research, Kalpakkam, Tamil Nadu. Another two hundred seeds of each variety, for each treatment were presoaked in distilled water for four hours then treated with different concentrations of EMS ranging from 0.8 to 1.6 per cent

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for three hours. After the treatment, the seeds were thoroughly washed with tap water ten times. The treated seeds were sown in the field along with the control. The normal good looking plants based on base population randomly selected in each treatment in the M_1 generation were advanced to M_2 generation. They were sown in family rows in a Randomized Block Design replicating four times with a spacing of 30 cm between rows and 30 cm between plants to study the macro mutations. Periodical observation of M_2 plants till maturity was made to score the viable mutants. The frequency of viable mutants was calculated on plant basis. These mutants were classified for deviation from the normal and taking into consideration the most conspicuous characters namely stature, duration, leaf shape, pod size etc. All the important characters of each mutant were recorded. Non viable mutants, sterile, non flowering and lethal mutants were identified in M_2 generation.

Results and discussion

The effectiveness of the mutagens can be better judged by studying the progenies in M_2 generation. This has been regarded as a reliable index by different investigators in mutation research [1, 2]. The relative mutation frequencies can be scored based on two criteria namely (i) M_1 plant basis and (ii) M_2 seedling basis. The second method is preferred since it is proportional to the initial mutation rate and rather independent of variations in the progeny size of mutated sector.

Frequency of chlorophyll mutants

The number of plants segregated for chlorophyll deficiency on the basis of M_1 plants and M_2 seedlings were computed and furnished in Table 1 and Table 2.

The rate of chlorophyll mutations are conveniently used as the preliminary index of effectiveness of mutagens and mutability of the variety and this inturn could be helpful to realize spectrum of desirable mutations in the treated populations. The frequency of chlorophyll mutants in the M_2 generation is mainly used as a dependable measure of genetic effects of mutagens since it provides the most reliable index of mutation rate because of the greater accuracy in scoring [2, 3]. This concept has reflected in present investigation where in the frequency of chlorophyll mutation in SVPR 1 varied from 19.04 (30 krad) to 41.66 per cent (50 krad) in M_1 and from 1.98 (50 krad) to 0.394 per cent (30 krad) in M_2 for gamma rays. For EMS treatments, the range was from 9.37 (1.0%) to 46.66 per cent (1.6 %) in M_1 and

Table 1. Chlorophyll mutation frequencies in M_2 generation of SVPR 1

Mutagen dose	No. of M_1 plants		No. of M_2 seedlings		Mutation frequency	
	Plants forwarded	Segregating	Studied	Chlorophyll mutants	M_1 plant basis	M_2 seedling basis
γ - ray						
V_1T_0	40	-	3685	-	-	-
V_1T_1	30	9	3100	38	30.00	1.225
V_1T_2	24	7	2515	25	26.16	0.994
V_1T_3	21	4	2279	09	19.04	0.394
V_1T_4	15	6	1588	18	40.00	1.133
V_1T_5	12	5	1157	23	41.66	1.987
EMS						
V_1T_0	40	-	3685	-	-	-
V_1T_6	32	3	3316	07	09.37	0.211
V_1T_7	27	3	2739	05	11.11	0.182
V_1T_8	23	9	2287	18	33.33	0.787
V_1T_9	19	4	1890	09	21.05	0.476
V_1T_{10}	15	7	1210	27	46.66	2.231

Table 2. Chlorophyll mutation frequencies in M_2 generation of Cardeboriga

Mutagen dose	No. of M_1 plants		No. of M_2 seedlings		Mutation frequency	
	Plants forwarded	Segregating	Studied	Chlorophyll mutants	M_1 plant basis	M_2 seedling basis
γ - ray						
V_2T_0	37	-	3560	-	-	-
V_2T_1	31	8	3255	26	25.80	0.798
V_2T_2	26	5	2720	15	19.23	0.551
V_2T_3	22	3	2184	10	13.63	0.457
V_2T_4	15	2	1615	04	13.33	0.247
V_2T_5	12	2	1098	02	08.33	0.182
EMS						
V_2T_0	37	-	3560	-	-	-
V_2T_6	32	2	3310	04	06.25	0.120
V_2T_7	26	3	2605	19	11.53	0.729
V_2T_8	21	3	2084	12	14.28	0.575
V_2T_9	18	5	1638	21	27.77	1.282
V_2T_{10}	1	4	1125	12	28.57	1.066

Table 3. Viable mutation frequencies in M_2 generation – SVPR 1

Mutagen dose	No. of M_1 plants		No. of M_2 seedlings		Mutation frequency	
	Plants forwarded	Segregating	Studied	Chlorophyll mutants	M_1 plant basis	M_2 seedling basis
γ - ray						
V_1T_0	40	-	3685	-	-	-
V_1T_1	30	9	3100	18	30.00	0.580
V_1T_2	24	10	2515	19	41.66	0.755
V_1T_3	21	7	2279	16	33.33	0.702
V_1T_4	15	2	1588	05	13.33	0.314
V_1T_5	12	4	1157	10	33.33	0.864
EMS						
V_1T_0	40	-	3685	-	-	-
V_1T_6	32	10	3316	24	31.25	0.723
V_1T_7	27	8	2739	18	29.62	0.657
V_1T_8	23	9	2287	17	39.13	0.743
V_1T_9	19	6	1890	15	31.57	0.793
V_1T_{10}	15	4	1210	09	26.66	0.743

Table 4. Viable mutation frequencies in M_2 generation – Cardeboriga

Mutagen dose	No. of M_1 plants		No. of M_2 seedlings		Mutation frequency	
	Plants forwarded	Segregating	Studied	Chlorophyll mutants	M_1 plant basis	M_2 seedling basis
γ - ray						
V_2T_0	37	-	3560	-	-	-
V_2T_1	31	4	3255	8	12.90	0.245
V_2T_2	26	5	2720	9	19.23	0.330
V_2T_3	22	3	2184	6	13.63	0.274
V_2T_4	15	1	1615	3	06.66	0.185
V_2T_5	12	3	1098	6	25.00	0.546
EMS						
V_2T_0	37	-	3560	-	-	-
V_2T_6	32	4	3310	7	12.50	0.211
V_2T_7	26	7	2605	11	26.92	0.422
V_2T_8	21	5	2084	10	23.80	0.479
V_2T_9	18	4	1638	9	22.20	0.549
V_2T_{10}	14	5	1125	12	35.71	1.066

0.18 (1.0 per cent) to 2.231 (1.6 per cent) in M_2. No clear trend could be observed for number of chlorophyll mutants in case of gamma rays, as there was declining trend upto 30 krad and with sudden increase at 40 krad and at 50 krad. In EMS also, the frequency values followed an irregular trend.

In Cardeboriga, the frequency of mutations showed a decreasing trend with an increase in dosage of gamma rays both in M_1 and M_2 and this was maximum in 10 krad in both the cases. In case of EMS, the frequency of chlorophyll mutatons showed an increasing trend upto 1.0 per cent followed by gradual decrease in M_2. The maximum value was recorded by 1.6 per cent on M_1 plant basis and by 1.4 per cent on M_2 seedling basis. When comparing the two mutagens, gamma rays induced greater magnitude of chlorophyll mutants than EMS in both the varieties. Among the two genotypes, SVPR 1 registered higher frequency than Cardeboriga. The frequency of chlorophyll mutations, in general, were low in this crop thus it may be attributed to the fact that oil seed crops are resistant to induced chlorophyll mutations [4, 5]. It may be further attributed to the probable reasons that there have been elimination of gametes carrying mutations or zygote inviability.

Spectrum of chlorophyll mutants

Types of chlorophyll mutations and their frequencies vary according to mutagen, its concentration, the genotype and method of treatment. In the present study, the spectrum of chlorophyll mutants comprised of *chlorina*, *xantha, striata* and *xantha viridis*. In SVPR 1, gamma rays exhibited maximum number of *Chlorina* mutants except in 30 krad while EMS exposed treatments showed the maximum frequency of *xantha viridis*. The chlorophyll mutants frequency ranged from 11.11per cent of *Striata* in 40 krad of gamma rays to 77.78 per cent of *xantha viridis* in 1.4 per cent of EMS.

In Cardeboriga chlorophyll mutants *viz*., *Chlorina* in 10, 20 and 30 krad; *Striata* in 10, 30 and 40 krad; Xantha in 10 and 20 krad and *Xantha viridis* in 10, 20 and 50 krad for gamma rays and chlorina in 0.8, 1.2, 1.4 and 1.6 per cent; *Xantha* in 0.8, 1.0 and 1.2 per cent; *Striata* in 0.8, 1.0, 1.4 and 1.6 per cent and *Xantha viridis* in 1.2, 1.4 and 1.6 per cent for EMS were observed. The frequency ranged from 4.77% of *Xantha viridis* in 1.4 per cent of EMS to 100% of *Xantha viridis* in 50 krad of gamma rays. Most of the mutants bearing mutlimutational events thus may be lethal in the M_1 generation and inturn affecting the frequency of occurrence of multimutations in M_2 and further

generations [6]. The reason for the appearance of greater number of *Xantha viridis* type may be attributed to involvement of polygenes in chlorophyll formation [2].

Mutagenic effectiveness and efficiency

The data on effectiveness and efficiency on the basis of lethality, injury and sterility were given in Table 5 and Table 6 for chlorophyll mutants. Mutagenic effectiveness can be considered as the frequency of gene mutations induced by a unit mutagen, while the mutagenic efficiency is a measure of the proportion of mutations in relation to undesirable changes like lethality, injury and sterility. For obtaining greater efficiency, the mutagenic effect should overcome other effects in the cells such

Table 5. Mutagenic effectiveness and efficiency for chlorophyll mutants in M_2 generation for SVPR 1

Mutagen dose	Percentage survival reduction at 30 days (lethality) (L)	Percentage height reduction at 30 days (injury) (I)	Percentage fertility reduction (sterility) (S)	Mutation per 100 M_2 plants (M)	Effectiveness (M x 100 / krad or C) x 100	Efficiency		
						(M x 100)/L	(M x 100)/I	(M x 100)/S
γ - ray								
V_1T_1	24.79	5.28	10.09	1.225	12.25	4.94	23.20	12.41
V_1T_2	33.94	7.39	16.71	0.994	4.970	2.93	13.45	5.94
V_1T_3	42.83	15.40	23.83	0.394	1.133	0.92	2.56	1.65
V_1T_4	49.98	30.63	30.72	1.133	2.832	2.27	3.69	3.68
V_1T_5	53.78	32.12	37.57	1.987	3.974	3.70	6.18	5.28
EMS								
V_1T_6	20.81	1.32	5.36	0.211	0.462	1.01	15.98	3.93
V_1T_7	31.67	7.87	8.29	0.182	0.182	0.57	2.31	2.19
V_1T_8	42.83	11.91	13.79	0.787	0.655	1.84	6.60	5.70
V_1T_9	45.76	18.76	17.15	0.476	0.340	1.04	2.53	2.77
V_1T_{10}	50.22	22.98	20.22	2.231	1.394	4.44	9.70	11.03

Table 6. Mutagenic effectiveness and efficiency for chlorophyll mutants in M2 generation for Cardeboriga

Mutagen dose	Percentage survival reduction at 30 days (lethality) (L)	Percentage height reduction at 30 days (injury) (I)	Percentage fertility reduction (sterility) (S)	Mutation per 100 M_2 plants (M)	Effectiveness (M x 100 / krad or C) x 100	Efficiency		
						(M x 100)/L	(M x 100)/I	(M x 100)/S
γ - ray								
V_2T_1	20.53	4.08	11.36	0.798	7.98	3.88	19.55	7.02
V_2T_2	29.54	8.75	21.66	0.551	2.75	1.86	6.20	2.54
V_2T_3	39.53	13.58	31.02	0.457	1.52	1.15	3.36	2.10
V_2T_4	47.19	18.90	39.70	0.247	0.61	0.52	1.31	0.62
V_2T_5	51.78	31.60	42.69	0.182	0.36	0.35	0.57	0.42
EMS								
V_2T_6	15.73	2.15	3.51	0.120	0.15	0.76	5.58	3.41
V_2T_7	28.99	7.38	9.39	0.729	0.72	2.51	9.87	7.76
V_2T_8	35.49	9.78	13.85	0.575	0.47	1.62	5.87	4.26
V_2T_9	42.51	12.08	17.47	1.282	0.92	3.01	10.61	7.18
V_2T_{10}	46.36	13.97	25.39	1.066	0.66	2.29	7.63	4.19

as chromosomal aberrations and toxic effects. For chlorophyll mutants, lower doses such as 10 krad in both the varieties were found to be more effective than other treatments of gamma rays. The greater efficiency of low dose of mutagens appeared in relation to the fact that lethality and injury increased with increase in dose at faster rate than the useful mutations [7].

Table 7. Viable mutation spectrum in M_2 generation for SVPR 1

Characters	γ - rays (krad)					EMS (%)				
	10	20	30	40	50	0.8	1.0	1.2	1.4	1.6
Leaf variations	-	1	1	-	-	-	2	1	1	-
Flower variations	-	-	-	-	-	-	-	-	-	-
Early flowering	-	-	3	-	-	-	1	1	-	-
Size	1	1	-	1	1	-	-	1	-	2
Shape	2	1	-	-	1	1	-	2	-	1
Varied coralla lips	-	-	-	1	-	1	-	-	-	2
Purple pigmented corolla	2	2		1	1				2	
Splitted flowers	-	-	-	1	1	-	4	-	2	1
Sterile plant	-	-	-	1	-	-	-	-	-	-
Plant height										
Tall plant	1	1				1		1		
Dwarf plant	1	-	-	-	1	-	1	-	-	-
Branching habit										
Profuse branching	-	-	-	2	-	-	-	-	-	-
More no. of primary branches	-	1	1	-	-	-	-	1	1	-
More no. of secondary branches	1	-	2	-	-	-	-	-	1	-
Main stem withlarger internodes	1	3	-	-	-	-	2	3	-	-
Capsule variations										
More no. of capsules	-	-	-	-	-	-	1	-	-	-
First capsule at different internode	1	2	-	-	-	2	-	3	-	-
Hairy pods	-	2	-	1	-	-	-	-	-	-
Plane arrangement of capsules	1	-	-	-	-	2	1	-	-	-
Alternate arrangement of capsules	-	-	1	-	1	-	-	3	-	1
One side capsule formation	-	-	1	-	-	-	1	-	1	-
Capsule formation at maturity	-	-	-	-	1	-	-	2	1	1
Capsule length variation	-	-	-	1	-	-	-	-	-	-
Capsule shape variation	-	-	-	1	-	2	-	-	3	-
Hexalocular capsule	1	-	1	-	-	-	-	-	-	-
Seed colour variation										
Light black	-	-	4	1	1	3	2	4	1	1
Dark brown	-	1	2	1	-	-	1	2	1	-
Light brown	1	-	-	1	-	2	-	1	-	1
Tan	-	-	-	-	2	-	-	-	2	1
Mutant with high yield and oil	-	-	-	1	-	-	-	-	-	-
Total	13	15	16	14	10	15	16	25	16	11
Grand total		For γ - rays = 68					For EMS = 83			

When comparing the mutagens and chlorophyll mutants, gamma rays were more efficient in causing mutations than EMS in both the varieties. When comparing the genotypes, the effectiveness and efficiency of both the mutagens was more in SVPR 1 than Cardeboriga indicating genotypic differences. The efficiency of mutagen on injury basis was more than the efficiency based on lethality and sterility in both the varieties and it indicated that reduced injury only to a smaller magnitude [8]. In case of viable mutants, low dose such as 10 krad in both the varieties noted to be more effective than other treatments of gamma rays. When comparing the mutagens, EMS was found to be efficient than gamma rays in both the genotypes and efficiency of mutagen on injury basis was more efficient than based on lethality and sterility in both the genotypes.

Viable mutants

Viable mutations were classified as macro and micro mutations, while others [9] grouped them as macro mutations and systematic mutations. The viable macro

Table 8. Viable mutation spectrum in M_2 generation for Cardeboriga

Characters	γ - rays (krad)					EMS (%)				
	10	20	30	40	50	0.8	1.0	1.2	1.4	1.6
Leaf variations	-	-	-	-	-	-	1	-	3	2
Flower variations	-	-	1	1	1	2	-	2	-	-
Other flower variations										
Early flowering	-	-	1	1	-	-	-	-	1	-
More number of flower buds	-	-	-	-	-	-	-	3	-	-
Corolla lip variation	-	-	-	-	1	-	-	-	-	-
Corolla without purple pigmentation	1	1	-	-	1	-	-	-	3	-
Plant height										
Tall	-	-	-	1	-	-	-	-	-	1
Dwarf	-	-	-	1	-	2	-	-	-	-
Branching habit										
Branching in monostem	-	-	-	-	-	-	2	1	1	-
Determinate type with lateral branching	-	-	-	-	-	-	2	2	-	-
Determinate type with leaf termination	-	-	-	-	-	-	1	-	2	-
Determinate type with capsule termination	-	-	-	-	-	-	1	-	2	-
Varied internodal length	-	1	-	-	1	-	-	-	-	1
Capsule variations										
Six capsules per node	-	-	-	-	-	-	-	-	2	-
Five capsules per node	-	-	-	1	-	-	-	-	-	-
Four capsules per node	-	-	2	-	-	-	-	-	1	-
Three capsules per node	-	-	-	-	-	-	-	-	-	2
Close arrangement of capsule	-	-	1	-	-	-	-	-	-	1
Alternate arrangement of capsules	-	-	1	-	2	-	-	-	-	-
Capsule length variations	1	1	-	-	1	-	-	-	-	-
Capsule shape variation	1	1	-	-	1	-	-	-	-	-
Hexalocular capsule	-	-	-	1	-	-	-	-	1	-
Seed colour variations	1	1	-	-	2	1	2	-	-	1
Capsules with more no. of seeds	-	-	-	1	-	1	-	2	-	1
Total	4	5	6	7	10	6	8	10	16	9
Grand total	For γ - rays = 32					For EMS = 49				

mutations, though induced quantitatively were very few, would be more valuable in genetic studies since plants with altered characteristics or phenotypes can serve as markers of the mutability of a variety or species. Frequency of such mutations also serves as an index of mutagenic sensitivity of various mutagenic agents and their dosage effects [6]. A number of new commercial sesame varieties *viz*., Yanbaeckae and Ank-S2 have originated from induced macro mutants and they have proved their usefulness in attaining distinct breeding objectives.

Viable mutations were recorded from early seedling stage to complete maturity stage. The data on frequency of viable mutations computed on M_1 and M_2 plant basis was furnished in Table 7 (SVPR 1) and Table 8 (Cardeboriga). In the present investigation, a large number of viable mutants were isolated from all the mutagenic treatments. This includes mutants with alteration in branching habit, plant height, phyllotaxy, nodal distance of the first capsule, flower, nodal length, capsule number and seed characters etc. Among the two mutagens employed, EMS treatments produced more number of viable mutants in both SVPR 1 (83 mutants) and Cardeboriga (49 mutants) than gamma irradiations. The frequency of viable mutants was high in EMS treatments on both M_1 and M_2 plant basis. Mutants with wider spectrum of variation were found at 10 and 20 krad of gamma rays and 0.8 and 1.0 per cent of EMS in SVPR 1 and 20 krad of gamma rays and 1.6 per cent of EMS in Cardeboriga. Among the treatments 20 krad of gamma rays in SVPR 1 and Cardeboriga, 0.8 per cent of EMS in SVPR 1 and 1.6 per cent of EMS in Cardeboriga registered maximum number of viable mutants.

Mutants with more number of primary and secondary branches (open type) were observed in both the mutagenic treatments of SVPR 1. Mutants with the main stem having more number of nodes that leads to reduction in internodal length and increase in capsule number (compact type) were observed in SVPR 1. Branching in monostem genotype Cardeboriga was also noted. Elite mutants with multicapsules, multilocules, more number of capsules per plant, increase in capsule length, change in seed colour and altered phyllotaxy occurred which would be useful from the breeding point of view. The occurrence of viable mutants in small proportion in M_2 generation suggested that each of them might represent changes in a single recessive gene from their parents [2].

Under mutants for plant height, tall and dwarf mutants occurred in both the mutagenic treatments in both the varieties. Similar reports of plant height mutants like dwarf and tall mutants in sesame were observed by many workers [10, 11]. Mutants with more number of primary and secondary branches (open type) were observed in both the mutagenic treatments of SVPR 1. Mutants with the main stem having more number of nodes that leads to reduction in internodal length and increase in capsule number (compact type) were observed in SVPR 1. Branching in monostem genotype Cardeboriga was also noted [12].

In Cardeboriga, mutants for branched plant type with altered phyllotaxy in treatments 40 kard and 0.8 per cent and determinate type with normal phyllotaxy in treatments 1.0 and 1.4 per cent while in SVPR 1 mutants for curved branch in treatment 50 krad and multicapsuled mutants in 10 krad and 40 krad of gamma rays in SVPR 1 were observed. Multicapsulated mutants were also reported in the sesame variety Yangbackkae [13]. Other capsule type mutants observed were curved, small and long capsuled mutants. Variations in such capsule length in mutants were already reported [14].

Mutants with bigger leaves and flowers were noted in 1.0 and 1.4 per cent of EMS in SVPR 1. Larger nodes with alternate capsule in 20 krad and larger nodes with shorter capsules in 1.6 per cent were observed in Cardeboriga [15, 16]. A unique tall mutant with medium sized capsules was isolated from the variety Cardeboriga in 1.6 per cent of EMS. This mutant possessed six uniform capsules and wider internodes. The plane arrangement of capsules was observed in the treatment 10 krad of gamma rays in SVPR 1. Mutants with hairy capsules were noted in 20 krad of gamma rays in SVPR 1.

Multicapsulated mutants upto six capsules per internode in EMS treatments which led to increase in number of capsules per plant and number of seeds per capsule reflecting on enhanced productivity of single plant yield was observed in Cardeboriga. Mutants exhibiting varied seed colour *viz.,* black, dark brown, light and tan from white seeded SVPR 1 and grey, light black and brown from black seeded Cardeboriga were noticed. The maximum seed colour mutants were observed in the genotypes SVPR 1. Mutants for seed colour were also observed in sesame by [10, 17]. A high yielding mutant with the yield of 21.20 g/plant was identified from 40 krad gamma irradiated population in SVPR 1. This mutant has more number of branches (five primary and four secondary branches) and more number of capsules (180 capsules per plant)

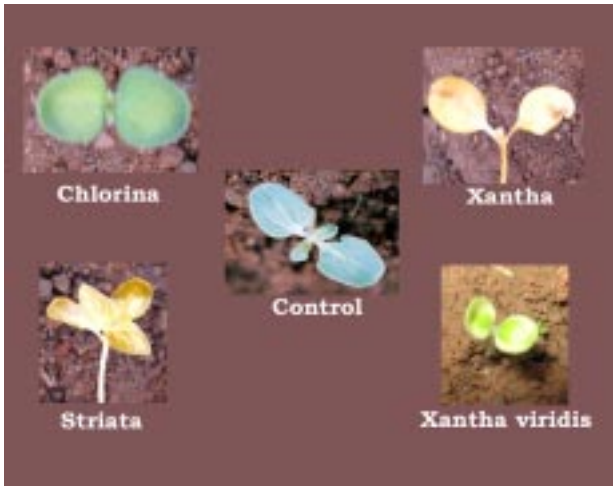

Fig. 1. Spectrum of chlorophyll mutants in SVPR 1

Fig. 2. Spectrum of chlorophyll mutants in Cardeborig

Fig. 3. Tall mutant plant of SVPR 1

Fig. 4. Tall mutant plant with six capsule per axil of Cardeboriga

which in turn increase the yield. Mutant with higher oil content of 43.36 per cent as against 42.50 per cent in control was also isolated from the variety Cardeboriga.

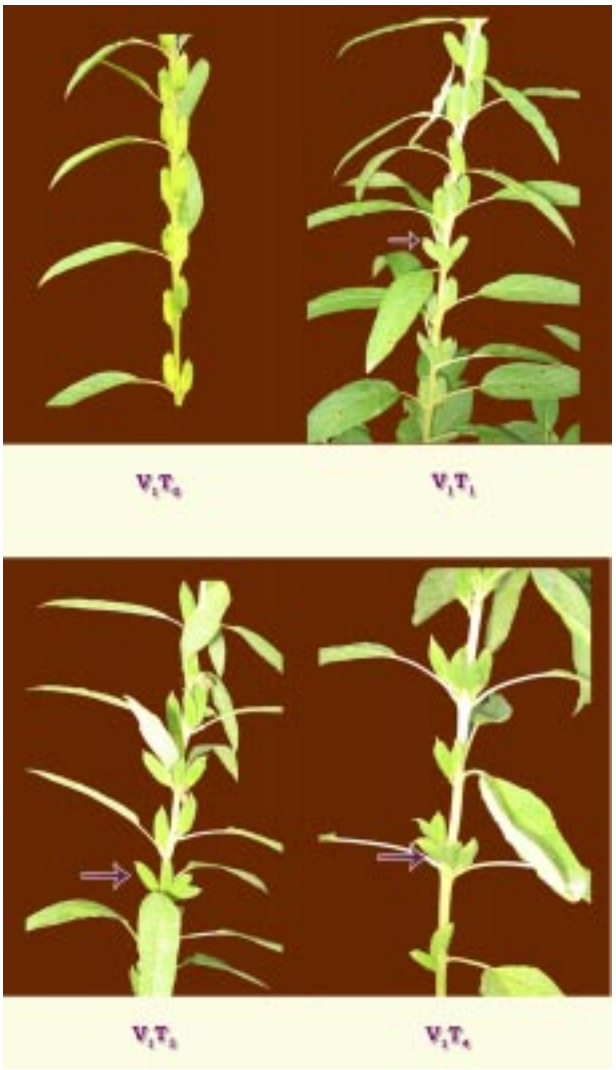

Fig. 5. Variation in capsule number in mutant of SVPR 1

Among the wide spectrum of viable mutants, economically important mutants such as mutants with determinate plant type, early flowering, more number of branches and capsules, altered phyllotaxy, main stem with shorter inter nodes, multicapsules per axil, multilocules, increased capsules etc., were isolated for further studies.

On overall basis, the following desirable mutants with improved characters over genotypes SVPR 1 and Cardeboriga were isolated to evolve elite, novel varieties in future.

- Early flowering mutants with duration of 33 days in SVPR 1 and 34 days in Cardeboriga.
- Determinate type mutants from the genotype Cardeboriga.

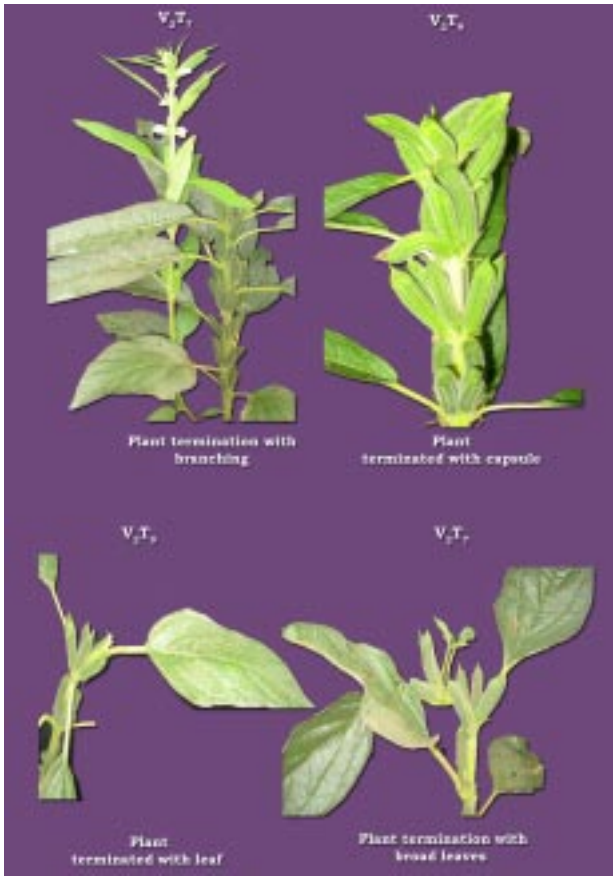

Fig. 6. Mutants with plant termination - Cardeboriga

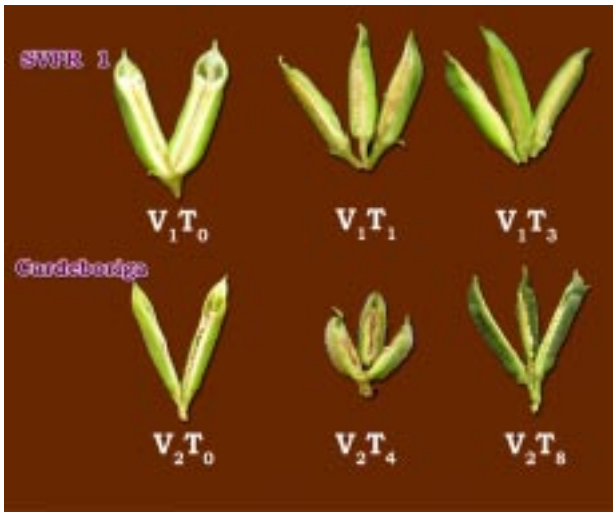

Fig. 7. Hexalocular mutants

- Multicapsuled mutants with five capsules on each axil in SVPR 1 and with six capsules on each axil in Cardeboriga.
- An unique tall mutant with uniform large size and more number of capsules in Cardeboriga.

Fig. 8. Variation in seed size - SVPR 1

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