INDUCED MUTAGENESIS IN SESAME

(*Sesamum indicum* L.)

A THESIS SUBMITTED TO THE

ANAND AGRICULTURAL UNIVERSITY

IN THE PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

MASTER OF SCIENCE

(AGRICULTURE)

IN

GENETICS AND PLANT BREEDING

BY

URMILA MAIBAM

B.Sc. (Agri.)

(Registration No. 04-2669-2015)

B. A. COLLEGE OF AGRICULTURE

ANAND AGRICULTURAL UNIVERSITY

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"Induced mutagenesis in sesame (*Sesamum indicum* L.)"

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ABSTRACT

The present investigation "Induced mutagenesis in sesame (*Sesamum indicum* L.)" was undertaken to find out the variability induced by different doses of Ethyl Methane Sulfonate (EMS). The study was carried out at College Farm, B. A. College of Agriculture, Anand Agricultural University, Anand. The seeds of three entries *viz.* Gujarat Til-4 (GT-4), Gujarat Til -10 (GT-10) and Patan-64 were treated with 0.5%, 1.0%, 1.5%, 2.0% and 2.5% doses of EMS. The M_1 generation was raised during summer season (2016) and harvested in bulk whereas M_2 generation was raised during *kharif* season (2016) in Randomized block Design (factorial) with three replications. Mutagenic effect of EMS on seed germination with respect to different doses was recorded in M_1 generation, where gradual reduction of germination per cent was noted with the increase in dose. In M_2 generation observations were recorded for twelve characters *viz.* days to 50 per cent flowering, plant height, number of primary branches, number of capsule per plant, number of seed per capsule, capsule length, days to maturity, 1000 seed weight, yield per plant, harvest index, oil content and protein content. The objective of present investigation was to study the effect of chemical mutagen (EMS) on three genotypes, to estimate genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance (GA) and also the genotypic and phenotypic correlations among different traits.

The analysis of variance revealed significant differences among genotypes for all the characters except for capsule length, indicating the presence of great deal of genetic variability for different traits. Wide and narrow ranges of mean values were observed for the characters under study.Genetic variance contributed major proportion of total variance for days to 50 per cent flowering, plant height, number of capsules per plant, days to maturity,1000 seed weight, yield per plant, harvest index, oil content and protein content suggesting that these characters were largely under genetic control.

High values of genotypic (GCV) and phenotypic coefficient (PCV) of variation were observed for plant height, number of capsules per plant, 1000 seed weight, yield per plant and harvest index indicating that sufficient variability existed in the experimental material for these traits.

High heritability coupled with high genetic advance as percent of mean were observed for days to 50 per cent flowering, plant height, number of capsules per plant,

days to maturity, yield per plant and harvest index indicating that these characters were predominantly governed by additive gene action and hence, there would be better scope for improvement of these characters by selection. Characters like number of primary branches, number of seed per capsule and capsule length showed moderate to low magnitude of heritability and moderate to high genetic advance, hence there would be little scope of improvement of these characters through selection. For characters like 1000 seed weight and oil content the per cent genetic advance was low accompanied by high heritability which indicates predominance of non additive gene action in the inheritance of character. Hence for the improvement of this character population improvement approach would be remunerative.

The estimates of correlation coefficients revealed the importance of characters like plant height, primary branches, capsule per plant, 1000 seed weight and harvest index for increasing the yield. Yield per plant also exhibited a positive and significant correlation with capsule length at genotypic level and a positive and highly significant correlation with oil content at phenotypic level. Protein content recorded negative and highly significant correlation with yield at both genotypic and phenotypic levels. Based on *per se* performance for improving seed yield, high performing genotypes GT-10 with control dose (D_5), GT-4 with control dose (D_5) and GT-10 with D_3 *i.e* (1.5%) EMS were identified as elite genotypes. However, their potentiality should be confirmed by testing them over space and time.

From the present investigation therefore it can be concluded that the different effects of the EMS on the three genotypes and that the induction of mutation by EMS did create variability but did not give improved result with respect to yield in M_2 generation. However, selection of mutants can only begin in the M_2 generation as the mutant genes mostly are present in heterozygous condition and it needs many generations of selfing to achieve homozygosity. It is also possible that mutations may result in chromosomal aberrations leading to deletions and inversions; this in turn may cause loosing of important genes which would have contributed to high yield. This can be one of the reasons for the fact that mutations generally do not enhance yield but can be a tool for achieving special traits of importance.

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CERTIFICATE

This is to certify that the thesis entitled **"Induced mutagenesis in sesame (*Sesamum indicum* L.)"** submitted by **Urmila Maibam (Reg. No. 04-2669-2015)** in partial fulfillment of the requirements for the award of the degree of **"Master of Science (Agriculture) in Genetics and Plant Breeding"** of the Anand Agricultural University is a record of bonafide research work carried out by her under my guidance and supervision and the thesis has not been previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand
Date: / /2017

(Dr. SNEHA MACWANA)
Major Advisor

DECLARATION

This is to declare that the whole of the research work reported here in this thesis for the partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Genetics and Plant breeding** by the undersigned is the result of investigation done by her under the direct guidance and supervision of **Dr. Sneha Macwana**, Associate Professor Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand-388110 (Gujarat) and no part of the work has been submitted for any other degree so far.

Place: Anand
Date: / /2017 (**Urmila Maibam**)

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CERTIFICATE

This is to certify that I have no objection for supplying a copy of my thesis or any part of it to scientists or workers for rendering service either in library or documentation centre.

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ACKNOWLEDGEMENT

It’s my honor to pay thanks to all those who have guided, supported and encouraged me to complete my work.

I am very much grateful to my major advisor **Dr. Sneha Macwana**, Associate Professor, Department of Genetics and Plant breeding, B.A. College of Agriculture, Anand Agricultural University for her constant attention and affectionate guidance at every stage of my work. Her constructive suggestions and smooth criticism always supported my work atmosphere. My thesis has no shape without her treasured kindness and ever remembered affection on me.

I take this opportunity to render sincere gratitude and regards to the members of my advisory committee, **Dr. Sashidharan N**., Professor and Head Department of Genetics and Plant breeding, B.A.C.A., A.A.U., **Dr. A. D. Kalola**, Associate Professor Department of Agricultural Statistics, B.A.C.A., A.A.U., **Dr. Arna Das**, Assistant Professor Department of Genetics and Plant breeding, B.A.C.A., A.A.U. and **Dr. Sushil kumar**, Assistant Professor Department of Agricultural Biotechnology, B.A.C.A., A.A.U. for their genuine encouragement and constructive suggestions throughout my study period.

I am equally thankful to **Dr. D.J. Parmar**, Associate Professor Department of Agricultural Statistics, **Dr. J. S. Patel**, former Professor and Head, Department of Agricultural Statistics, **Dr. Kalyanrao Patil**, Department of Seed science and technology, B.A.C.A., A.A.U. for their kind help and guidance during my research work.

I would like to acknowledge and extend my heartfelt gratitude to **Dr. N. C. Patel,** Vice Chancellor, AAU, Anand, **Dr. K. B. Kathiriya**, Directorate of Research and Dean P.G. Studies, AAU, Anand and **Dr. K. P. Patel,** Principal & Dean, B. A. College of Agriculture, AAU, Anand for keen awareness of academic values. I am also thankful to the university authority to provide me an opportunity to proceed for higher study leading to M. Sc. (Agri) degree as a student.

I thank my parents **Maibam Panchom** and **Maibam Premlata** for their faith in me and giving me liberty to choose what I desired. Their support has been unconditional all these years.Their blessings, love, care and sacrifice influenced me immensely for completing this huge task. The encouragement and support provided by my dear brother **Jotin** and sister **Eton** have been bestowing confidence and zeal at every stair of my life.

It’s my fortune to gratefully acknowledge the support of my seniors **Thupten Tsumu, Pitambara, Roopal, Dipal** and my dear friends **Nimitha, Niva, Sonaka** and **Yaiphabi** for their love, untiring support, encouragement and cooperation.

Above all, I would like to thank the almighty, for his blessings made this venture, a successful one.

Place: Anand

Date: / /2017 (**Urmila Maibam)**

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LIST OF ABBREVIATIONS

Symbols	
=	Is equal to
X	Cross
:	Colon
( )	Bracket
;	Semi colon
Abbreviations	
G	Gram
et al.	And others
%	Per cent
viz.	Namely
C.D.	Critical difference
cm	Centimeter
C.V.	Co-efficient of variation
Max.	Maximum
Min.	Minimum
No.	Number
FCRD	Factorial Completely Randomized Design
FRBD	Factorial Randomized Block Design
S.Em.	Standard error of mean
M_1	First generation following the mutagenesis treatment
M_2	Second generation following the mutagenesis treatment
EMS	Ethyl Methane Sulphonate
H.I.	Harvest Index
GCV	Genotypic coefficient of variance

NMU	Nitroso - N-methylurea
ENU	N-Nitroso, N-Ethylurea
PCV	Phenotypic coefficient of variance
GA	Genetic Advance
$\boldsymbol{\sigma^2_g}$	Genotypic variance
$\boldsymbol{\sigma^2_p}$	Phenotypic variance
h^2_b	Heritability in broad sense
$\overline{X}$	Mean of the character

CONTENTS

CHAPTER I

INTRODUCTION

Sesame (*Sesamum indicum* L.) 2n = 2*x* = 26 is a self pollinated oilseed crop, of the family Pedaliaceae. The origin of the crop has been a major subject of discussion, with proposals for an African or Indian domestication but based on various lines of evidence Bedigian has concluded that this species was first domesticated on the Indian subcontinent (2003, 2004). It is one of the most ancient and important oilseed crops, majorly cultivated in tropical and sub-tropical regions of the world. It is variously known as til, gingelly, simsim, gergelim and is one of the nine major oilseed crops in India. It is also called the "Queen of oil seeds" because of its excellent qualities of the seed, oil and meal. Brown or black seeded are valued more for oil whereas, white seeded are rich in iron. Sesame seeds are digestive, rejuvenative, anti-aging and rich in vitamins E, A and B complex and minerals like calcium, phosphorus, iron, copper, magnesium, zinc, and potassium coupled with high-unsaturated fatty acid. Sesame oil is also highly resistant to oxidative deterioration as compared to other edible oils.

India is a major producer of sesame followed by China, Nigeria and Myanmar (Anon., 2017). Recent data indicates that about 1.7 million hectares area is under sesame cultivation in India with a total production of 0.82 million tonnes and an average yield of 474 kg/ha. The major sesame producing states in India are West Bengal, Madhya Pradesh, Rajasthan, Gujarat and Uttar Pradesh. Highest yield was observed in West Bengal *i.e.* 952 kg/ha followed by Meghalaya 932 kg/ha. In Gujarat, sesame is cultivated in an area of about 0.18 million hectares with the total production of about 0.10 million tonnes and an average productivity of about 564 kg/ha (Anon., 2015).

The major problem of sesame in India is its low productivity as compared to the other major sesame producers. The cause of low productivity may be due to non adoption of irrigation, fertilizer and pesticide in appropriate doses, high risk and uncertainty factors in production, tendency to raise pulses mixed with other crops, low yield potential of improved cultivars, seed shattering, indeterminate growth habit, poor managerial attention, and inadequate extension activities. Since there is a limitation of available area due to urbanization, increasing productivity is the only

approachable way to augment sesame production in India. This will eventually need variability for selection or hybridization for breeding high yielding varieties, however germplasm of sesame is not as large as in other crops (Ashri, 1982) Secondly, the genetic architecture of sesame is poorly adapted to mechanized farming system due to its indeterminate growth habit, sensitivity to wilting under intensive management and seed shattering at maturity (Uzun and Cagirgan, 2006). Hence, creation of variation for improvement of one or two traits becomes a necessity for this crop.

Mutation breeding is one possible alternative to conventional breeding for crop improvement. Exposing plant genetic material to mutagens enhances the chance of isolating unique genetic material. In the past, induced mutations have effectively been utilized in development of new and valuable alterations in plant characteristics that have contributed to increased yield potential. It is an effective tool for crop improvement and an efficient mean to supplement existing germplasm for cultivar improvement in breeding programmes. It has been employed successfully to foster additional variability for qualitatively and quantitatively inherited traits in a number of crop plants e.g. rice (Talebi *et al.*, 2012), chickpea (Kharkwal *et al.*, 2005), sesame (Begum and Dasgupta, 2014) etc. Mutation breeding not only creates variability in crop species, but also shortens the time taken for the development of cultivars via induced mutation compared to those via hybridization. Primarily the advantage of mutation breeding is the probability of improving one or two characters without amending the rest of the genotype.

Induced mutations have great potentials and serve as a complimentary approach in genetic improvement of crops (Mahandjiev *et al*., 2001). The basic strategy in mutation-based breeding has been to upgrade the well adapted plant varieties by altering one or two major traits, which limit their productivity or enhance their quality. In several mutation-derived varieties, the changed traits have resulted in synergistic effect on increasing the yield and quality of the crop, improving agronomic inputs, crop rotation and consumer acceptance. Many mutants have made transnational impact on increasing yield and quality of several seed-propagated crops and will continue to have an increasing role in creating crop varieties with traits such as modified oil, protein, deeper rooting system, and resistance to abiotic and biotic stress.

Both physical and chemical mutagens have been used either singly or in combination for inducing mutation. Physical method includes ionising radiation, UV radiation and chemical method includes Ethyl Methane Sulfonate (EMS), colchicine etc. EMS is a chemical mutagen and alkylating agent. It produces random mutations in genetic material by nucleotide substitution; particularly by guanine alkylation. This typically produces point mutations. The original G:C base pair can become an A:T pair. EMS is also used for many other crops like in cowpea (Gnanamurthy *et al.*,2014), finger millet (Muduli and Mishra, 2007) in creating variability successfully.

The assessment of variability shall be carried out through biometrical techniques namely, Genotypic coefficient of variation (GCV) and Phenotypic coefficient of variation (PCV). Small differences between GCV and PCV indicate less environmental influence. Variability in terms of GCV and PCV is not sufficient to determine the amount of heritable variability, so heritability has to be estimated to provide more precise information to the extent, to which a particular genetic character can be transmitted to successive generations. Again the information on heritability may sometimes be misleading also therefore, an estimation of heritability, coupled with genetic advance estimates, is also required to assess the heritable portion of total variation. Only a few references are available for variability assessment through induced mutagenesis in sesame. Hence estimation of induced variability will be of great importance for carrying out further breeding for improvement in sesame.

Selection directly based on the performance of yield may not be very effective because of the complexity of the trait under control of polygenes, oligogenes, intergenic interaction with varying degree, unless other yield attributing traits are taken into consideration. Knowledge of correlation also provides information about the degree of relationship between important plant traits and is good index to predict the yield response in relation to the change of a particular character. In this regard, correlation studies would be effective in identification of component traits.

The present investigation “Induced mutagenesis in sesame (*Sesamum indicum* L.)” was therefore planned to create variability in three selected genotypes of sesame with chemical mutagen (EMS) which eventually will help to plan further breeding programmes for improvement of sesame in Anand as well as in Gujarat condition. The above facts on sesame cultivation and prospects have led to identify the objectives for the current research work as mentioned below.

1. To study the effect of chemical mutagen (EMS) on three genotypes, namely, Gujarat Til- 4 (GT-4), Gujarat Til- 10 (GT-10) and Patan 64.
2. To work out genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV).
3. To estimate heritability and genetic advance (GA).
4. To calculate correlation estimates between various quantitative traits to identify major yield components.

CHAPTER II

REVIEW OF LITERATURE

Genetic variability is the pre-requisite for crop improvement which helps in selection, recombination and isolation of superior genotypes. The genetic variability available today in plant collection is the result of past evolution involving spontaneous mutation, recombination and exposure to the forces of natural selection. There are indications that a major part of domestication of crop plants occurred in the form of discrete steps mediated by single gene mutations (Gottlieb, 1984). Although high yielding crops of better quality can be achieved by hybridization it's a time consuming process. This goal can however be achieved by induced mutation breeding which creates genetic variability among plants in a shorter period of time. Mutagenesis is highly fundamental in plant biology to induce genetic variability to a great number of crops, mainly due to the fact that the technology is simple, relatively cost effective to perform, applicable to all plant species and equally usable on a small and large scale (Swaminatan, 1995, Siddiqui and Khan, 1999).

Mutations can be induced by treating with chemical or physical mutagens. Induced mutations have a greater advantage over the spontaneous mutations as they occur at a higher frequency and can be utilized for crop improvement programmes. The ability to produce mutations artificially attracted the attentions of several workers and considerable efforts have been diverted towards utilization of this technique in crop improvement. A detailed knowledge of nature and magnitude of genetic variability, its heritable portion for economic traits, information regarding inter-relationship among various component characters and their direct and indirect contributions to economic characters are prime requisites to decide efficient crop improvement programme.

2.1 DISCOVERY OF MUTAGENESIS

De vries (1909), who first recognized clearly the role of mutation in evolution, had naturally hoped that if man learns to command the origin of mutations and thereby generate the allelic variability upon which recombination and selection could operate, speedy result like the goal of creating superior strains of domesticated plants and animals could be achieved. The term mutation was first used for the appearance

of new types in evening primrose (*Oenothera*). Muller (1927) was first to induce mutation in Drosophila using X-rays, however Stadler (1928) started working simultaneously for inducing variability on barley and maize using mutation.

2.2 MUTAGENIC AGENTS

Mutagenesis can be promoted through chemical, physical and biological agents (Koornneef, 2002). Both physical and chemical mutagens are known to act in different ways to cause DNA lesions (Chopra, 2005). They are known to induce a high frequency of mutations at random locations across the genome (Waugh *et al*., 2006).

2.3 NATURE OF MUTAGENS

Mutagens can be divided into different categories according to their effect on DNA replication.

2.3.1 PHYSICAL MUTAGENS

Physical mutagens include various types of radiation, *viz*., X-rays, gamma rays, alpha particles, beta particles, fast and thermal (slow) neutrons and ultra violet rays.

2.3.2 CHEMICAL MUTAGENS

The chemical mutagens can be divided into four groups, viz. 1) alkylating agents, 2) base analogues, 3) acridine dyes, and 4) others. A brief description of some commonly used chemicals of these groups is presented below.

Table 2.1 Chemical mutagens and their mode of action

Sl .No.	Group of mutagen	Name of chemical	Mode of action
1.	Alkylating Agents	Ethyl Methane Sulphonate Methyl Methane Sulphonate Ethyl Ethane Sulphonate Ethylene Imines	AT ⟷ GC Transitions Transitions GC ⟷ AT Transitions Transitions
2.	Base	5 Bromo Uracil	AT ⟷ GC Transitions

	Analogues	2 Amino purine	AT ⟷ GC Transitions
3.	Acridine Dyes	Acriflavin, Proflavin	Deletion, addition and frame shifts.
4.	Others	Nitrous Acid Hydroxylamine Sodium Azide	AT ⟷ GC Transitions GC ⟷ AT Transitions

Out of all the chemical mutagens that have been applied Ethyl Methane Sulfonate (EMS), Nitroso - N-methylurea (NMU), N-Nitroso, N-Ethylurea (ENU) and sodium azide are preferred agents in plant mutation induction (Medrano *et al*., 1986). Alkylating agents are the most important chemical mutagens used in mutation breeding. They add ethyl or methyl groups to bases in the nucleotide structure, which leads to activating a silent gene, silencing an active gene, or altering a particular gene action (Snustad and Simmons, 2006). The relevant literature on sesame and other crops is reviewed below.

2.4 EFFECT OF MUTAGENIC AGENTS

Nayar and George (1969) treated NP6 a white seeded sesame variety with doses ranging from 25 kR to 100 kR to know the effect of gamma rays. They have not reported any morphological deviations in M_1. In one of the M_2 families derived from 50 kR treatment a few plants showed faster growth rate than the rest and they were taller. These plants had larger internodes and most of them were non-branching. The tall mutant (TM) attained a height of about 1 ½ times that of NP6.

Sarafi (1978) obtained more variability following hybridization than mutation for yield and yield components in *sesamum*. Further 5 per cent selection from F_2 to F_6 and M_2 to M_6 generations were followed.

Chavan and Chopde (1979) treated three sesame varieties with four doses of gamma rays, and reported mutants with hairy capsules, early maturing and basally branched dwarf mutants in M_2. Hairy capsules were frequent in 58-2, early mutants in D7-11-1 and 85, basally branched dwarf mutants in D7-11-1. The maximum frequency of mutation varied according to the variety and dose.

Rangaswamy (1980) observed in the M_2 and M_3 generation a decrease in mean for plant height, number of capsules, capsule length, seeds per capsule and yield in Si-

3500; for capsule girth, seeds per capsule, 1000 seed weight and oil content in TMV-2 and for capsule length in hybrid progenies. Further the decreased mean in M_2 and increased mean in M_3 for capsule girth and seeds per capsule in the hybrid and for capsule girth in Si3500 were also noticed.

Chavan and Chopde (1982) evaluated eighty two M_2 progenies derived from gamma irradiation of three varieties for twelve yield component traits. Number of primary branches, height up to first branch and number of capsules on the main shoot showed higher variability

Kamala and Sasikala (1985) reported four high yielding mutants developed by gamma irradiation from 'TMV 5' and IS 103 varieties of sesame, recorded 3-30 per cent more seed yield and 5-13 per cent more oil content. However, the protein content remained unchanged. Four high yielding mutants from gamma ray treatments were detected in the 2 varieties in the M_2. Two high yielding mutants in 'IS 103' were screened from 20 kR and 40 kR treatments. In 'TMV 5' one of the mutants from 5 kR had whorled capsule phyllotaxy and another from 40 kR had normal alternate capsule set-up.

Jeya Mary and Jayabalan (1995) treated the seeds of sesame with EMS ranging from 10 µM to 50 µM at an interval of 10 µM each, induced variability in morphological characters. Some of the variants observed in response to EMS treatment are height mutants, branching mutants, leaf mutants, plant colour and texture mutants, mutants for maturity period, floral and sterile mutants, capsule mutants and seed mutants. The analysis of their breeding behaviour showed dose dependent increase in the frequency of such mutations.

Kang *et al.* (1996) released a variety Yangbackkae developed from Danbackkae seeds treated with 2 mM Sodium azide for 3 hrs. Yangbackkae has not only a higher yield than its control variety but also improved oil quality.

Wongyai *et al.* (2001) carried out a study on improvement of non-shattering capsule in sesame through seed treatment with 0.5% and 1.0% EMS for 4 hours. Growth characteristics, delayed shattering and shatter resistance of capsule were investigated in M_2 through M_8 lines. Most of the mutant lines gave higher seed yield than the check variety. All the tested mutant lines had a longer growth period during flowering. However, three promising lines had a shorter flowering period. The mutant

lines had a determinate growth habit. Delayed shattering and shatter resistant capsule were also obtained.

Sheeba *et al*. (2003) found enhanced genetic variability for seed yield and its component characters in M_2 generation from their study on sesame varieties namely, SVPR 1 and Co1 treated with doses 0.8%, 1.0%, 1.2%, 1.4%, and 1.6% of EMS.

Boranayaka *et al.* (2010) carried out a study in sesame varieties, SVPR 1 and Cardeboriga with EMS doses 0.8%, 1.0%, 1.2%, 1.4% and 1.6%. The frequency of viable mutant (mutants with alteration in branching habit, plant height, phyllotaxy, flower character, nodal distance of the first capsule, capsule and seed characters) was high in M_1 plants as well as in M_2 plants. Economically important mutants, determinate plant type, early flowering, increased number of branches and capsules, altered phyllotaxy, main stem with shorter inter nodes, multi-capsules per axil, multi-locular capsules were also isolated.

Khan and Tyagi (2010) studied the variability induced by gamma rays for quantitative traits in *Glycine max* (L.) varieties *viz.*, Pusa-16 and PK-1042. Seeds were irradiated with 15, 30 and 45 kR of gamma rays and reported an increased 100 seed weight over that of control except at 45 kR gamma rays. Increase or decrease in the mean values of the plant height was not linear to the doses in both varieies. In Pusa-16, the mean plant height showed an increase upto an intermediate dose. On the other hand, in PK-1042, decrease in plant height was associtaed with increase in dose level. The mean 100-seed weight showed a little variation to that of control due to various mutagenic treatments. In Pusa-16, the mean values in gamma rays were higher over the control population except at 45 kR gamma rays. In PK-1042, an increase in the mean values was exhibited at lower dose of gamma rays. An increase in 100 seed weight in both the varieties in treatments was observed over that of control except at 45 kR gamma rays.

Kumar and Yadav (2010) used IC413205 of sesame with dose of 0.5% for duration of 3,5 and 7 hours and reported that abnormality per cent increase with dose, while a decrease in the traits, namely, germination per cent, plant height, survival per cent, number of capsules per plant, seed weight, pollen fertility was found with increasing treatment durations.

Pavadai *et al.* (2010) studied the effectiveness and efficiency of gamma rays for yield parameters in M_2, M_3 and M_4 generation of *Glycine max* (L.) Merr. (soybean) variety CO 1. Seeds were irradiated with 10, 20, 30, 40, 50 and 60 kR doses of gamma rays with ^{60}CO, the gamma source. Reduction in plant height increased with the increase of dose, from 10 kR to 60 kR. Study revealed increased effectiveness and efficiency of gamma ray at low dose level which decreased at high dose level (50 kR and 60 kR). Effectiveness and efficiency were high in 40KR than the other mutagenic treatments.

Nura *et al.* (2011) reported a study on chemical mutagenesis (colchicines) on the seeds of two varieties of sesame (Ex-Sudan and E-8) with the aim of inducing variability. The sesame seeds were treated with colchicines at four different concentrations 0.1 mM, 0.5 mM, 1.0 mM, 2.0 mM and control for two mutant generations M_1 and M_2. Highly significant variation was observed in quantitative traits, like germination per cent, height at maturity, number of leaves/plant, internodes length, leaf area, number of pods/plant, number of seeds/pod and 1000 seed weight. The magnitude of such traits decreased with increase in colchicine concentrations.

Savant *et al.* (2011) treated seeds of sesame variety JLT-7 with different concentrations of EMS at room temperature. The concentrations of mutagenic solutions were 0.05%, 0.10% and 0.15%. Studies in M_2 and M_3 generation found an enhancement in seed oil level after mutagenic treatment. The mutant with late maturing, tall stature and indeterminate growth habit also recorded higher oil content. The dwarf with determinate growth and long capsule mutants were also found to contain better oil level than control.

Birara *et al.* (2013) studied sesame varieties Abasena and Kelafo 74, they were treated with sodium azide at 0.01, 0.02, 0.03, 0.04 and 0.05%. Highly significant differences were noticed in the varieties and treatment in traits like plant height, days to maturity, capsule length, number of capsules per plant, number of seeds per pod and 100 seed weight. For the variety Abasena plant height, number of seed per pod, capsule length and capsule per plant were stimulated at 0.02% sodium azide whereas days to maturity and flowering were reduced at the same concentration. For Kelafo 74 plant height were stimulated at 0.02 and 0.03% whereas days to flowering was reduced at 0.02%

Muhammad *et al.* (2013) studied the level of tolerance of sesame (*Sesamum indicum* L.) to Fast Neutron Irradiation (FNI) as well as induction of valuable mutants in two sesame cultivars (Ex-Sudan and Kenana-4) and irradiated with 4, 8, 12 and 16 µSv doses of FNI. Parameters investigated include number of capsules per plant, length of capsule, number of seeds per capsule and oil content. No significant differences were observed for all the yield parameters of sesame plants after exposure of seeds to different doses of FNI except for length of capsule and number of seeds per capsule in Ex-Sudan. Similarly, the two varieties showed significant differences in oil content at different doses of FNI.

Natikar *et al.* (2013) recorded that induced mutant lines exhibited higher magnitude of genetic variability.

Begum and Dasgupta (2014) used three sesame genotypes - Rama, SI 16666, IC 21706 with doses 0.5%, 1.0%, 1.5% and 2.0% EMS. Mutants surpassed the magnitude of variability over the control population in M_1 and M_2 generations. It was found that lower doses of mutagens were more effective in induction of desirable mutations. The genotype IC 21706 at 0.5% concentration exhibited best results for induced variability in M_2 generation. A considerable increase in genetic estimates for all the metric traits, as compared with that in the M_1 was also noted.

Ramadoss *et al.* (2014) studied the genotypes of sesame TTVS 51 and TTVS 19 and irradiated at 250, 359, 450, 550 and 650 Gy. A large number of viable mutants were isolated from all the mutagenic treatments. This includes mutants with alteration in branching habit, plant height, phyllotaxy *etc.* Mutants with wider spectrum of variation were found at 250Gy and 350Gy of gamma rays. Mutants for plant height occurred in the mutagenic treatments in both the varieties. In TTVS 51and TTVS 19, mutants for branched plant type with altered phyllotaxy and branched determinate type with normal phyllotaxy and mutants for curved branch were observed. A high yielding mutant with seed yield of more than 50 gram per plant was identified from 550Gy gamma irradiated population in TTVS 51 and from 650Gy in TTVS 19. These mutants have more number of branches (five primary and four secondary branches) and more number of capsules which in turn increase the yield.

Anbarasan *et al.* (2015) carried out a study in which the seeds of sesame variety TMV3 were treated with different doses of EMS 0.6, 0.8, 1.0 1.2 and 1.4 mM

and combined treatments of both EMS and gamma rays. In M_1 generation, germination percentage on 15th day, seedling survival (lethality) and seedling height (injury) on 30th day were recorded. The study revealed that in M_1 generation the seed germination percentage decreased with higher doses of mutagen. Highest percentage of reduction in seed germination was observed for combined treatment of EMS and gamma ray followed by 1.4 mM of EMS. The reduction in seedling survival (lethality) and seedling height (injury) was observed in all the mutagenic treatments.

Gunasekaran and Pavadai (2015) treated groundnut with different concentration of physical and chemical mutagen namely gamma rays 10, 20, 30, 40, 50 and 60 KR and EMS of concentration 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6% and found that the increasing doses/concentration of gamma rays and EMS decreased in phenotypic and yield characters in M_1 generation. The mutagenized populations showed significantly higher variability in the M_2 generation. Mutant lines showing higher yield per plant than the respective parents and checks were isolated in M_2 and subsequent generation were significantly more pod yield and yield components than the untreated plants.

Gopinath and Pavadai (2015) treated soybean var. Co-1 seeds with different concentrations of gamma rays 10, 20, 30, 40, 50 and 60 KR, EMS (0.1, 0.2, 0.3, 0.4, 0.5 and 0.6%) and Diethyl Sulphate (DES) (0.1, 0.2, 0.3, 0.4, 0.5 and 0.6%). The morphological parameters such as days to first flower, plant height, number of cluster per plant, number of pod per plan, seed yield per plant, number of branches per plant, protein content and oil content increases with increasing level of some doses of gamma rays, EMS and DES treatment in M_2 and M_3 generation. A number of mutants were recorded in M_2 and M_3 generations for one or more traits viz., plant height, maturity, branching, fruit size and yield. Mean for various characters increased at mutagenic treatment than control. The yield parameters like plant height, number of cluster per plant, number of seeds per plant and seed yield per plant were recorded as moderated and high mean value in the 50 KR of gamma rays, 0.5% of EMS and 0.4% of DES treated population when compared to control plants.

Investigation by Kumar and Shunmugavalli (2015) revealed that, in general, the frequency of viable mutants in M_2 generation varies with the dosage of the mutagens. It was also observed that the mutation frequency was independent of genotype and mutagens. When five varieties *viz* TMV4, TMV7, VRI2, Thilak and

TNY local of sesame were treated with 0.7, 1, 1.4, 1.6% of EMS the maximum number of viable mutants were isolated in the treatments *viz*., 1.0% EMS in the variety VRI 2 followed by 0.7% in the varieties TMV 7 and VRI 2 and 1.0% EMS in the variety TMV 4.

Pavadai (2015) studied the effect of gamma rays on Soybean var. Co-1 for three generations *viz*., M_1, M_2 and M_3. The yield parameters like plant height, number of clusters per plant, number of seeds per plant and seed yield per plant were recorded moderate and high mean value in the 50 KR of treated population of all generations when compared to control plants.

Ravichandran and Jayakumar (2015) reported the mutagenic effect of EMS 1.0, 1.5 and 2.0 mM dose in M_2 and M_3 generation on sesame variety VRI-1. The characters studied include, days to first flower, plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule and seed yield per plant in M_2 and M_3 generations. Both negative and positive shifts in mean values over the control population were recorded. The results indicated the possibilities of higher yield variants through proper selection.

Kumari *et al.* (2016) conducted a research on high yielding variety of sesame 'LTK-4' treated with EMS concentration of 0.5%, 1.0% and 1.5% and gamma radiation of doses *viz*., 150Gy, 300Gy, 450Gy, 600Gy and 750Gy . They observed highest number of viable mutants in 150Gy dose followed by 300>450>600>750>900 Gy. In chemical mutagen, mutants were higher in 0.5% followed by 1.5% and 1.0% EMS. Viable mutations decreased with increase in dose. Lower doses of physical and chemical mutagens have proved to be more effective and beneficial in inducing mutations in sesame.

2.5 GENOTYPIC COEFFICIENT OF VARIATION (GCV) AND PHENOTYPIC COEFFICIENT OF VARIATION (PCV)

Rangaswamy (1980) reported an increase in genotypic coefficient of variation (GCV) in the treated populations compared with that of the control. The hybrid as well as the varieties under the treatments showed significant differences for GCV. However, the GCV for plant height and number of capsules per plant in the hybrid under treatment was on par with that of the untreated.

Seeds of four local cultivars were irradiated with 20, 40, 60 and 80 kR by Kamala (1990). Data from seven yield components were recorded in the M_1, M_2 and M_3. The highest level of genotypic and phenotypic variance was noted for seed yield followed by number of capsules per plant, number of branches per plant, plant height and seeds per pod.

Sheeba *et al.* (2004) reported that in SVPR 1, maximum GCV was observed at EMS, 1.0 per cent for plant height, number of capsules per plant and capsule length, whereas high GCV for number of branches per plant, number of seeds per capsule and plant yield was recorded by 1.4 per cent. For CO1, 0.8 per cent EMS for plant height and number of branches per plant and 1.2 per cent for capsule length, number of seeds per capsule and single plant yield were found to have maximum GCV. The highest GCV was reported for capsule length followed by number of seeds per capsule in both the varieties, 1000 seed weight in CO 1 and single plant yield in SVPR 1. In the case of EMS, 1.0 per cent in CO 1 for number of capsules per plant and 1.2 per cent in SVPR 1 for single plant yield exhibited high GCV and high mean values.

Sarwar *et al.* (2008) conducted a study in which twenty eight genotypes in M_4 generation evolved through gamma irradiation were evaluated for characters like days to flowering, days to maturity, plant height, number of branches, number of capsules per plant, capsule length and seeds per capsule. Maximum values of GCV were estimated in seed yield followed by branches per plant and capsules per plant. Similar trends were also observed in case of PCV.

Natikar *et al.* (2013) conducted a study in sunflower and found that the values of PCV and GCV were highest for plant height, seed yield per plant and oil yield, and moderate for stem diameter, head diameter, seed filling percentage, hundred seed weight, hull content and oil content in M_3 generation of the variety Morden. In case of DSF 15B mutants GCV and PCV were high for seed yield and oil yield and moderate for plant height, stem diameter, head diameter, hundred seed weight and oil content.

Variability studies on yield and yield components of sesame genotype TMV 4 (mutated with EMS - 0.6, 0.8 and 1.0% and Sodium azide - 5,10 and 15 mM.) in M_2 generation was carried out by Anitha and Manivannan (2014). Observations on characters like days to flowering, plant height, number of branches, number of capsules per plant and seed yield per plant were recorded. High GCV and PCV were

observed for number of branches, number of capsules per plant and seed yield per plant. Low and moderate PCV and GCV respectively were observed for days to flowering and plant height in the mutated population.

Begum and Dasgupta (2014) reported highest GCV for plant height in M_1 at 0.5% EMS treatment on Rama. In M_2 generation, it was from 0.5% treated population IC 21706. For number of branches, highest GCV was observed in M_1 generation at 0.5% EMS treated population of IC 21706, and in M_2 generation, it was at 0.5% EMS treated population of SI 1666. For number of capsules and seed yield in both the generations, it was recorded at 0.5% EMS treated population of IC21706.

Usharani and Ananda Kumar (2015) found that in black gram variety VBN 4, treated with combination of both gamma rays (400, 500 and 600 Gy) and EMS (50, 60 and 70 mM) moderate and high phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were recorded in yield component characters such as plant height, number of primary branches, number of clusters per plant and number of pods per plant.

Ariraman *et al.* (2016) reported a study on pigeon pea (CO-7) treated with various concentrations of EMS (20mM, 25mM and 30mM) and gamma rays (15, 20, and 25KR). Highest PCV, GCV were observed at 25mM of EMS and 20KR of gamma when compared to control and other dose/conc. PCV and GCV were high at all the quantitative characters. Among the concentration of mutagenic treatments, quantitative and qualitative traits showed high, moderate and low phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) in M_2 generations.

Ariraman *et al.* (2016) found high PCV and GCV for all the quantitative characters like plant height, number of branches per plant, number of pods per plant, seed yield per plant, hundred seed weight per plant and seed protein content in pigeon pea when studied at a dose of 25 mM of EMS and 20 KR of gamma in M_2 generation

A study was done by Aristya and Taryono (2016) to evaluate characteristic associations and determine factor wise contribution on sesame seed yield of several M_4 lines. Seventeen sesame mutant lines of M_4 generations from two types (black and white) were used in this study. Homogeneous seeds of each of the two types were

treated with eight doses (0.1 kGy- 0.8 kGy) of Co-60 individually. Seed yield per plant registered high coefficient of variation.

2.6 GENOTYPIC CORRELATION AND PHENOTYPIC CORRELATION

Ibrahim *et al.* (1983) studied twelve homozygous M_6 mutants of Giza-24 obtained through gamma irradiation, which revealed positive correlation for number of days to flowering, number of capsules per plant and negative correlation for 1000 seed weight and seed yield per plant.

Ramanathan & Rathinam (1983) observed negative association between number of pods and pod yield in M_3 generation due to the induction of EMS in two varieties of groundnut. Combining all, it affirmed that plant height, number of branches per plant, number of capsules per plant, capsule length and number of seeds per capsule were important yield contributing characters consistently in all mutant populations.

Govindarasu and Ramamoorthi (1998) irradiated nine F_1crosses in sesame with gamma rays at 20 and 30 kR doses using cobalt-60 gamma source. They studied the progenies of both irradiated and non irradiated segregating populations for association of characters in the third generation. Only two component traits viz., branch number and capsule number maintained strong positive correlation with seed yield as well as among themselves in both the populations. They also had high positive direct effects on seed yield in the progenies of irradiated and non irradiated hybrids, revealing that these two are the most important traits in the determination of seed yield. The other character pairs viz., plant height, capsule length, seed number per capsule and 1000 seed weight expressing significant correlation in the untreated segregating progenies did not maintain the same level of association in gamma irradiated segregating progenies.

Khatri *et al.* (2005) carried out a study on seeds of *Brassica juncea* L. cv. S-9, treated with different doses of gamma rays (750 and 1000 Gy) and EMS (0.75% and 1.0%) and found that days to maturity was positively correlated with height, but negatively correlated with grain yield. Plant height showed negative correlation with seed yield revealing that dwarf strains would be high yielding.1000 grain weight illustrated highly positive correlation with grain yield per unit area.

Sarwar *et al.* (2008) reported highly significant and positive genotypic correlation for days to flower with days to maturity, plant height, number of branches and seeds per capsule. Days to maturity showed highly significant positive correlation with plant height and number of branches, whereas highly significant and negative correlation with seeds per capsule and capsules per plant were also found. At phenotypic level days to maturity showed highly significant and positive correlation with days to flower, plant height and branches per plant. Significant and positive correlation between plant height and number of branches was observed while it was highly significant but negatively correlated with capsules per plant. Number of branches showed significant negative correlation with capsule length and seeds per capsule. Capsules per plant showed positive and significant correlation with seeds per capsule and seed yield, but at phenotypic level capsules per plant exhibited negative association with days to flower, days to mature and plant height. Capsule length showed highly significant and positive correlation with seeds per capsule and seed yield. Seeds per capsule showed positive and highly significant correlation with capsule length and positive correlation with seed yield. Capsule length showed almost negative relationship with all attributes except capsules per plant. Seed yield exhibited positive and significant association with capsules per plant and positive but non significant with number of branches, capsule length and seeds per capsule

Ong'injo and Ayiecho (2009) reported variability studies on yield and yield components of sesame mutant lines in M_7 generation. Seed yield per plant registered the highest coefficient of correlation. Seed yield also exhibited positive and significant correlation with biomass yield, harvest index and 1000 seed weight. It showed a weak positive association with plant height, oil content, number of capsules per plant and number of days to flowering.

Begum and Dasgupta (2011) found significant positive correlation of seed yield with plant height, number of branches per plant, number of capsules per plant, capsule length and number of seeds per capsule, consistently in the mutated population of three genotypes namely Rama, SI 16666, IC 21706. The highest magnitude of positive correlation coefficient was found between seed yield per plant and number of capsules per plant.

Birara *et al.* (2013) reported that an increase in the number of capsules at 0.01, 0.02, 0.03% concentration of sodium azide when compared to control, had a positive correlation with the yield of seed in the sesame varieties Abasena and Kelafo 74.

Muhammad *et al.* (2013) found none of the correlation coefficients significant, they were generally positive in Ex-Sudan and negative in Kenana-4 suggesting that the two varieties respond to FNI in different ways. 12 and 16 µSv were the most potent dose to induce viable mutants in sesame especially in Ex-Sudan accession since it resulted in better yield parameters.

Correlation coefficients studied by Aristya and Taryono (2016) for eleven characteristics indicated that sesame seed yield per plant had positively and significantly correlated with plant height, the number of primary branches, the number of secondary branches, the number of nodes per plant, the number of nodes to the first flower, the number of capsules per plant, biomass yield per plant, and 1000-seed weight.

2.7 HERITABILITY AND GENETIC ADVANCE (GA)

Heritability and genetic advance tended to increase in the treated population, similar to that of GCV as reported by Rangaswamy (1980). The heritability and genetic advance for plant height was not improved by the treatments in the hybrid progenies.

Chavan and Chopde (1982) reported high heritability estimates accompanied by high expected genetic advance for number of capsules per plant, number of primary branches, height up to first capsule and number of capsules on the main shoot. Number of days to 50 per cent flowering had high heritability with moderate genetic advance.

Sheeba *et al.* (2003) reported maximum heritability for number of capsules per plant at 1.0% EMS in Co-1. 1.4% of EMS registered maximum heritability for number of branches per plant and also for capsule length. 1.4% in SVPR 1 and 1.6% in Co1 exhibited maximum genetic advance for the characters, namely, plant yield and capsule length respectively. High heritability and genetic advance combined with increase in genetic variability for capsule length, revealed scope of improving yield through effective selection based on this character.

Sarwar *et al.* (2008) found that more than 50 per cent heritable values were computed in all the characters studied except seed yield. The highest value of heritability was noted in days to flower, days to maturity, plant height and number of branches. Genetic advance as percent of mean was maximum in case of seed yield followed by branches per plant and capsule per plant.

Natikar *et al.* (2013) found that the heritability estimates in sunflower were high for all the characters studied, except for days to fifty per cent flowering. In case of mutants of Morden and mutants of DSF 15B, heritability estimates were high for all the characters, except for days to fifty per cent flowering, seed yield per plant, seed yield per ha and oil yield per ha but seed yield per plant, seed yield per ha and oil yield per ha recorded moderate heritability.

Variability studies on yield and yield components of sesame genotype TMV 4 in M_2 generation was carried out by Anitha and Manivannan (2014). Characters like plant height, number of capsules per plant and seed yield per plant exhibited high heritability coupled with high genetic advance revealing that these characters were controlled by additive gene action.

Begum and Dasgupta (2014) reported highest heritability and genetic advance for plant height at 0.5% EMS for Rama and IC21706 in M_2 generations. For capsule number 0.5% EMS (lowest dose) induced highest genetic advance for IC 21706, whereas the highest heritability was found in the populations of SI 1666 treated with 0.5% and 1.0% EMS. For seed yield, the highest values of genetic advance was shown by the mutant population of IC 21706 at 0.5% EMS dose .The treated populations of IC 21706 and SI 1666 recorded the highest heritability at 1.5% and 0.5% EMS, respectively.

A high amount of heritability and GA as per cent of mean was noted for plant height, number of clusters per plant, number of primary branches per plant, number of pods per plant, pod length, number of seeds, 100 seed weight and single plant yield as reported by Usharani and Ananda Kumar (2015).

Ariraman *et al.* (2016) found highest heritability and genetic advance at 25mM of EMS and 20KR of gamma in M_2 generation for parameters like plant height, number of branches per plant, number of pods per plant, seed yield per plant, hundred seed weight per plant and seed protein content**.**

CHAPTER III

MATERIALS AND METHODS

The details of the materials used, experimental methods followed and procedures for analyses adopted during the course of present investigation are described in this chapter.

3.1 EXPERIMENTAL SITE

The present study entitled "Induced mutagenesis in sesame (*Sesamum indicum* L.)" was under taken at agronomy farm, B. A. College of agriculture, Anand Agricultural University, Anand during summer season (2016) for M_1 generation and *kharif* 2016 for M_2 generation. The farm is located in Agro-climatic zone-III (Middle Gujarat) of Gujarat state. Geographically Anand is situated at 22°35' North Latitude and 72°55' East longitude with an altitude of 45.1 meters above the mean sea level. The soil of experimental site was sandy loam, the typical "Goradu" soil (alluvial in origin and belonging to the alifisol) of "Charotar" tract. It is light brown in colour, deep, well drained and fairly moisture retentive. The climatic condition of the area represents the tropical condition with semi-arid climate. Details of the weather parameters for the experimental period are presented in Appendix-I. These were recorded at the observatory, Department of Meteorology, B. A. College of Agriculture, AAU, Anand.

3.2 EXPERIMENTAL MATERIAL

3.2.1 Variety

Experimental plant material selected for the present investigation was sesame (*Sesamum indicum* L.). Three varieties of sesame namely Gujarat Til- 4 (GT-4), Gujarat Til – 10 (GT-10) and Patan 64 were used in the present study. Seeds of all the varieties were procured from Main oilseed research station, J.A.U., Amreli.

3.2.2 Mutagen

Chemical mutagen, Ethyl Methane Sulphonate (EMS), a mono-functional alkylating agent with chemical formula $C_3H_8SO_3$, having molecular weight 124.16 was used in the present investigation to induce mutations in the selected plant material

and to achieve genetic variability. The concentrations of EMS used were 0.5%, 1.0%, 1.5%, 2.0% and 2.5% along with a control.

3.3 PREPARATION OF EMS AND PROCESS OF APPLICATION

Seeds of GT-4, GT-10, Patan 64 were soaked overnight in distilled water at room temperature. Next morning, seeds were removed from water and treated with EMS solution (0.5%, 1.0%, 1.5%, 2.0%, 2.5%) prepared in phosphate buffer of pH 7 for 5 hrs. Intermittent shaking, followed by decantation of the EMS and rinsing with tap water and later by distilled water for ten times were carried out.

3.4. TREATMENT DETAILS

Table 3.1 Dose and symbols in M_1 and M_2 generation

Variety	**Dose and symbols in M_1 generation**					
GT-4	V_1D_1 (0.5%)	V_1D_2 (1.0%)	V_1D_3 (1.5%)	V_1D_4 (2.0%)	V_1D_5 (2.5%)	V_1D_6 (Control)
GT-10	V_2D_1 (0.5%)	V_2D_2 (1.0%)	V_2D_3 (1.5%)	V_2D_4 (2.0%)	V_2D_5 (2.5%)	V_2D_6 (Control)
Patan 64	V_3D_1 (0.5%)	V_3D_2 (1.0%)	V_3D_3 (1.5%)	V_3D_4 (2.0%)	V_3D_5 (2.5%)	V_3D_6 (Control)

V = Variety, D =Dose, Control = For each variety, seeds were pre soaked in distilled water for 6 hours to serve as control.

Table 3.1 contd…

Variety	**Dose and symbols in M_2 generation**				
GT-4	V_1D_1 (0.5%)	V_1D_2 (1.0%)	V_1D_3 (1.5%)	V_1D_4 (2.0%)	V_1D_5 (Control)
GT-10	V_2D_1 (0.5%)	V_2D_2 (1.0%)	V_2D_3 (1.5%)	V_2D_4 (2.0%),	V_2D_5 (Control)
Patan 64	V_3D_1 (0.5%)	V_3D_2 (1.0%)	V_3D_3 (1.5%)	V_3D_4 (2.0%)	V_3D_5 (Control)

V = Variety, D =Dose, Control = non treated seeds harvested in bulk from M_1.

No germination of D_5 (2.5% EMS) in M_1 so in M_2 control is D_5

3.5. M1 GENERATION

M_1 generation was raised during 24th February (2016). Seeds were planted treatment-wise and harvested in bulk for each treatment separately, which were used to raise M_2 generation. In the laboratory, the treated and controlled seeds were spread over moist germinating paper in petriplates and germination of seeds was observed on 7th day and 15th day.

3.6. M_2 GENERATION

Sowing was done on 20th August, 2016. M_2 was raised in Randomized Block Design in three replications with fifteen treatments per replication. Each plot consisted of single rows of 3m with a spacing of 45 cm and 10 cm and observations were recorded.

3.7. PARAMETERS STUDIED IN M_2 GENERATION

Observations were recorded on the following characters in M_2 generation.

3.7.1 Days to 50 Per Cent Flowering

Day to 50 per cent flowering was recorded by visual observation when about 50 per cent of plant population had attained flowers.

3.7.2 Plant Height (cm)

Plant height was recorded in centimeters from the base of plant to the tip of main axis at maturity

3.7.3 Number of Primary Branches

Numbers of primary branches borne on main axis were counted.

3.7.4 Capsule Length (cm)

Five capsules from each selected plant were selected and the length of capsule was measured from the base to the tip.

3.7.5 Number of Capsules Per Plant

Total number of capsules from average of five plants was counted.

3.7.6 Number of Seeds Per Capsule

Numbers of seeds were counted from five capsules selected randomly from the sample plant.

3.7.7 Days to Maturity

Calculated by counting the days from the date of sowing to the date of 90 per cent of capsule maturity and drying.

3.7.8 Seed Test Weight (g)

1000 dried seeds were counted from average of five plant samples and weighed.

3.7.9 Yield Per Plant (g)

The weight of seeds harvested from each of the randomly selected plant was recorded.

3.7.10 Harvest Index (%)

It is the ratio of economic yield to biological yield of the plant on dry weight basis and expressed as percentage. This was worked out from randomly selected five plants from each plot at the time of harvest and their average was recorded.

$$H.I. = \frac{\text{Seed yield per plant}}{\text{Biological yield per plant}} \times 100$$

3.7.11 Protein Content (%)

Clean seeds with 10-12 per cent moisture were used for protein estimation through NIR (Near infrared Resonance).

3.7.12 Oil Content (%)

Clean seeds with 10-12 per cent moisture were used for oil estimation through NIR (Near infrared Resonance).

3.8. STATISTICAL PROCEDURE

3.8.1 M_1 Generation

The observed data was statistically analyzed by appropriate statistical procedures as suggested for Completely Randomized Design (Factorial) by Steel and Torrie (1960).

Statistical model:

$Y_{ijk}=\mu + V_i + D_j + (VD)_{ij} + e_{ijk}$

Where,

μ = General mean

V_i= Effect of i^{th} variety

D_j= Effect of j^{th} dose

VD_{ij} = Effect of ij^{th} interaction of variety and dose

eijk = Random error associated with y_{ijk} observation

3.8.1.1 Standard error of mean (S.Em.)

Standard error of mean was calculated by the following formula:

$S.Em. = \sqrt{MSE/r}$

Where, MSE = Error mean square

3.8.1.2 Critical difference (CD)

Critical difference was calculated by the following formula:

$C.D = t_{(0.05)}(e.df) \times \sqrt{2} \times S.Em$

3.8.1.3 Coefficient of variation

It is the measure of variability evolved. Coefficient of variation is the ratio of standard deviation of a sample to its mean and expressed in percentage.

$$C.V.\% = \frac{\sqrt{\sigma^2_e}}{\overline{X}} \times 100$$

Where,

σ^2_e = Error mean square

$\overline{X}$ = Mean of the character.

Table 3.2 Analysis of variance for FCRD.

Source of variation (SV)	**Degree of freedom (DF)**	**Sum of square (SS)**	**Mean square (MS)**	**Cal F**
Variety (V)	(v-1)	SS_v	SS_v/DF	MSv /MS_E
Dose (D)	(d-1)	SS_d	SS_d/DF	MS_d/MS_E
V X D	(v-1) (d-1)	SS_{vxd}	SS_{vxd}/DF	MS_{vxd}/MS_E
Error	vd (r-1)	SS_E	SS_E/DF	

3.8.2 M_2 Generation

To test the biological effects of EMS on different characters of three varieties in M_1 and M_2 generation, the data recorded during the experiment were analyzed statistically following the analysis of variance for 2 factors experiment in FRBD (Gomez and Gomez, 2010).

In M_2 generation (Field) experiment was conducted in Factorial Randomized Block Design (FRBD). The data was collected on individual plant basis from five randomly selected plants from each replication and averaged. Mean value was calculated for days to 50 per cent flowering, plant height, number of primary branches, number of capsule per plant, number of seeds per capsule, capsule length, days to maturity,1000 seed weight, seed yield per plant, harvest index, oil percent and protein percent for each treatment. These mean values were subjected to following statistical analysis technique of ANOVA.

Model: $Y_{ijk} = m + r_i + V_j + D_k + VD_{ijk} + e_{ijk}$

Where,

Yijk = Observation on j^{th} variety in the i^{th} replication by k^{th} dose.

m = General mean

r_i = Effect of the i^{th} replications

V_j = Effect of the j^{th} variety

D_k= Effect of the k^{th} dose

V X D= Interaction effect of j^{th} variety in the i^{th} replication by k^{th} dose.

e_{ijk} = Random error associated with y_{ijk} observation

The total variation based on this model was partitioned into different components as under:

Table 3.3 Analysis of variance for FRBD.

Source of variation (SV)	**Degree of freedom (DF)**	**Sum of square (SS)**	**Mean square (MS)**	**Cal F**
Replication	(r-1)	SS_1	MS_1	MS_1/ MS_6
Treatment	(t-1)	SS_2	MS_2	MS_2/ MS_6
Variety	(v-1)	SS_3	MS_3	MS_3/ MS_6
Dose	(d-1)	SS_4	MS_4	MS_4/ MS_6
Variety x Dose	(v-1) (d-1)	SS_5	MS_5	MS_5/ MS_6
Error	(r-1)(vd-1)	SS_6	MS_6	

Where,

SS_1 = replication sum of square

SS_2 = treatment sum of square

SS_3 = variety sum of square

SS_4 = Dose sum of square

SS_5 = variety *x* dose sum of square

SS_6 = Error sum of square

MS_1 = Mean square due to replication

MS_2 = Mean square due to treatment

MS_3 = Mean square due to variety

MS_4 = Mean square due to dose

MS_5 = Mean square due to variety x dose

MS_6 = Mean square due to uncontrolled variation

r = number of replication

v = Number of varieties

m = Number of mutagens

d = dose

F test was applied to test the significance of difference among replications and among treatments, varieties and doses.

3.8.2.1 Mean

The mean value for each character was worked out by dividing the sum by corresponding number of observations.

$$\overline{X} = \frac{\Sigma X_{ij}}{n}$$

Where,

$\overline{X}$ = Mean

X_{ij} = Observation in i^{th} replication and j^{th} treatment and

n = Total number of observations.

3.8.2.2 Range

By examining the values of different plants within each plant progeny row, the lowest and the highest values in respective plant progeny row were considered as range.

3.8.2.3 Standard Error of Mean

Standard error of mean for different means was calculated as under with the help of error mean square from the analysis of variance table:

$$S.Em.V = \sqrt{\frac{\pm\ {}^{2}_{e}}{rd}}$$

Where,

S.Em.V = Standard error of mean for variety

σ^2_e = Error mean square

r = Number of replications

d = dose of mutagen

$$S.Em.C = \sqrt{\frac{\pm\ {}^{2}_{e}}{rv}}$$

Where,

S.Em.C = Standard error of mean for concentration

σ^2_e = Error mean square

r = Number of replications

v = variety

$$S.Em.\ VXd = \sqrt{\frac{\pm\ {}^{2}_{e}}{r}}$$

Where,

S.Em. VX D = Standard error of mean for interaction.

σ^2_e = Error mean square

r = Number of replications

v = variety of the plant.

3.8.2.4 Critical Difference (C.D.)

Critical difference for each character was calculated to compare the treatment mean as per the following formula.

$$C.D. = t_{(0.05,\ error\ \ df)} \times \sqrt{2} \times S.E.m$$

3.8.2.5 Coefficient of Variation

Coefficient of variation as a measure of variability among the individual plants of a treatment was calculated as under:

$$C.V.\% = \frac{\sqrt{\sigma_e^2}}{\overline{X}} \times 100$$

Where,

σ^2_e = Error mean square

$\overline{X}$ = Mean of the character.

3.8.2.6 Estimation of variance components

Total variation was partitioned into genotypic and phenotypic components of variances based on expectation of mean square for respective source of variation described in ANOVA.

3.8.2.6.1 Genotypic variance (σ^2_g)

It is the variance contributed by the genetic causes due to differences in their genetic make-up. This was calculated as:

$$\hat{\sigma}^2_g = \frac{MS_g - MS_e}{r}$$

Where,

$\hat{\sigma}^2_g$ = Genotypic variance.

M.S.g = Mean square for treatment.

r = Number of replications.

3.8.2.6.2 Phenotypic variance (σ^2_p)

It is the total variance and is the sum of the variances contributed by genetic as well as non-genetic factors among individuals. It was calculated as:

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

Where,

$\hat{\sigma}^2_p$ = Phenotypic variance

$\hat{\sigma}^2_g$ = Genotypic variance

$\hat{\sigma}^2_e$ = Error variance

3.8.2.6.3 Genotypic coefficient of variance (GCV)

It is the magnitude of genetic variation present for a character. It was calculated by the formula suggested by Burton and Devane, (1953).

$$GCV\% = \frac{\sqrt{\hat{\sigma}^2 g}}{\bar{X}} \times 100$$

Where,

$\hat{\sigma}^2 g$ = Genotypic variance.

$\bar{X}$ = Mean of the character.

3.8.2.6.4 Phenotypic coefficient of variance (PCV)

It is the magnitude of phenotypic variation present for a character. It was calculated by the formula suggested by Burton and Devane (1953).

$$PCV\% = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100$$

Where,

$\hat{\sigma}_p^2$ = Phenotypic variance

$\overline{X}$ = Mean of the character

GCV and PCV were classified as suggested by Shivasubramanian and Menon (1973) as follows

0-10% = low

10-20% =Moderate

20% and above = High

3.8.2.6.5 Heritability (Broad sense)

The phenotypic variability depicted by a character is composed of heritable and non-heritable components of variation. Heritability may be defined as the proportion of total genetic variance to phenotypic variance. It is contributed by genetic causes, whereas non-heritable variation is contributed by environmental factors and interaction.

Heritability in broad sense was calculated in percent by using the formula suggested by Allard (1960)

$$h_b^2(\%) = \frac{\pm_g^2}{\pm_p^2} \times 100$$

Where,

h_b^2 = Heritability in broad sense

σ_p^2 = Phenotypic variance

σ_p^2 = Genotypic variance

Heritability percentage was categorized as demonstrated by Robinson *et al*., (1949)

0-30% = low

30- 60 % = Moderate

60% and above = High

3.8.2.6.6 Genetic advance as percentage of mean (GA%)

The expected genetic advance (GA) was calculated for each character by adopting the procedure suggested by Allard (1960).

$$GA = K \times \frac{\sigma^2 g}{\sigma^2 p} \times \sigma p$$

Where,

K = Standardized selection differential,

(K = 2.06 at 5% selection intensity)

$\sigma^2 g/\sigma^2 p$ = Heritability in broad sense

σp = Phenotypic standard deviation

The genetic advance expressed as per cent of mean was estimated as follows:

$$GA\ (\%\ of\ mean) = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = Genetic Advance

$\bar{X}$ = mean of the character

The genetic advance as per cent mean was categorized as suggested by Johnson *et al.* (1955).

0-10 % = Low

10-20 % = Moderate

20 % and above = High

3.8.2.7 Correlations between characters

The form of analysis used for estimating co-variance components between different pairs of observations was the same as that for normal analysis of variance

except that sum of squares and mean squares were replaced by sum of products and mean products. The following estimates of co-variance were worked out as per Singh and Choudhary (1985).

Where,

$\hat{\sigma}_{gigj}$ = Genotypic covariance between i^{th} and j^{th} character

$\hat{\sigma}_{pipj}$ = Phenotypic covariance between i^{th} and j^{th} character

$(\hat{\sigma}_{pipj} = \hat{\sigma}_{gigj} + \hat{\sigma}_{eiej})$

$\hat{\sigma}_{eiej}$ = Environmental covariance between i^{th} and j^{th} character

The estimates of covariance and variance were utilized in computing genotypic and phenotypic correlation coefficients**.**

Table 3.4 Analysis of co-variance with expected mean sum of cross products.

Sources of variation	**Degree of freedom**	**Sum of cross products**	**Mean sum of cross products (MSCP)**	**Expected mean sum of cross products**
Replications	(r-1)	SCPr	MSCPr	$\sigma_{eiej} + g\sigma_{rirj}$
Treatments	(t-1)	SCPg	MSCPg	$\sigma_{eiej} + r\sigma_{gigj}$
Error	(r-1)(t-1)	SCPe	MSCPe	σ_{eiej}
Total	(rt-1)			

Genotypic covariance (gigj) was estimated as under

$$\sigma_{gigj} = (MSCP_g - MSCP_e) / r$$

Phenotypic covariance (pipj) was estimated as under

$$\sigma_{pipj} = \sigma_{gigj} + \sigma_{eiej}$$

3.8.2.7.1 Genotypic correlation coefficient (rgigj)

The genotypic correlation is chiefly caused by pleiotrophy and the linkage action of gene and r_{gigj} was estimated as suggested by Hazel *et al*. (1943).

$$r_{gigj} = \frac{\hat{\pm}_{gigj}}{\sqrt{\hat{\pm}^2_{gi} \times \hat{\pm}^2_{gj}}}$$

Where,

r_{gigj} = Genotypic correlation coefficient between i^{th} and j^{th} character.

$\hat{\pm}^2_{gi}$ = Genotypic variances of i^{th} character

$\hat{\pm}^2_{gj}$ = Genotypic variances of j^{th} character

3.8.2.7.2 Phenotypic correlation coefficient (r_{pipj})

The genetic and environmental causes of correlation combine together to give phenotypic correlation coefficient and r_{pipj} were estimated with help of following formula.

$$r_{pipj} = \frac{\hat{\pm}_{pipj}}{\sqrt{\hat{\pm}^2_{pi} \times \hat{\pm}^2_{pj}}}$$

Where,

r_{pipj} = Phenotypic correlation coefficient between i^{th} and j^{th} character,

$\hat{\pm}^2_{pi}$ and $\hat{\pm}^2_{pj}$ = Phenotypic variances of i^{th} and j^{th} character, respectively.

The genotypic and phenotypic correlation coefficients were tested against standardized tabulated significant values of r with (t-2) degree of freedom as per the procedure suggested by Fisher and Yates (1963).

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the present investigation on "Induced mutagenesis in sesame (*Sesamum indicum* L.)" were under taken at agronomy farm, B. A. College of agriculture, Anand Agricultural University, Anand during summer season (2016) for M_1 generation and *kharif* 2016 for M_2 generation. The results obtained from the study are presented and discussed under the following sub-headings.

4.1 M_1 GENERATION

4.1.1 Analysis of variance

4.2 M_2 GENERATION

4.2.1 Analysis of variance

4.2.2 Variance components

4.2.3 Estimation of Correlation coefficients

4.1 M_1 GENERATION

4.1.1 Analysis of variance

Analysis of variance for seed germination per cent revealed that the variance due to variety, dose and interaction between variety and dose were highly significant which indicated the existence of variability in the experimental material.

Mean data obtained on effect of different doses of EMS on seed germination per cent in control and mutagen treated sesame genotypes is presented in Table 4.2 and 4.3. From the table it is evident that the seed germination per cent in the genotype subjected to treatment with different doses of EMS is less than those of their respective controls. It clearly indicates that treatment with EMS have exerted an inhibitory effect on seed germination. It was observed that out of 18 treatments only 15 treatments were studied in M_2 because the dose D_5 (2.5% EMS) did not germinate in any of the variety in field as well as in laboratory condition. Hence, D_5 (2.5% EMS) was removed while carrying out study in M_2 generation. A dose dependent reduction of germination was clearly evident from the values recorded on 7^{th} and 15^{th} day.

Similar findings were earlier reported by Yadava and Chowdhury (1974), Boranayaka *et al.* (2010) and Anabarasan *et al.* (2013).

Table 4.1 Analysis of variance for germination per cent in M_1 generation of sesame.

Source of Variation	df	Mean square at 7th day	Mean square at 15th day
Variety (V)	2	85.99**	26.01**
Dose (D)	5	3263.78**	10790.00**
VXD	10	17.20**	14.79**
Error	36	0.18	0.49

* Significant at 5% level of significance

** Significant at 1% level of significance

Table 4.2 Mean values of genotypes for sesame in M_1 Generation (7th day).

Variety	Dose						
	D_1	D_2	D_3	D_4	D_5	D_6	Mean
V_1	46.00	34.00	28.00	18.00	0.00	54.00	30.00
V_2	48.00	40.00	34.00	18.00	0.00	56.00	32.66
V_3	42.00	34.00	26.00	20.00	0.00	48.00	28.33
Mean	45.33	36.00	29.33	18.66	0.00	52.66	10.11
For comparing the means of :-		SEm±			CD		
Variety (V)		0.10			0.29		
Dose (D)		0.14			0.41		
VXD		0.24			0.71		
CV%		4.19					

Table 4.3 Mean values of genotypes for sesame in M_1 generation (15^{th} day).

Variety	Dose						
	D_1	D_2	D_3	D_4	D_5	D_6	Mean
V_1	86.00	82.00	76.00	68.00	0.00	96.00	68.00
V_2	90.00	84.00	76.00	70.00	0.00	98.00	69.66
V_3	84.00	78.00	74.00	74.00	0.00	94.00	67.33
Mean	86.66	81.33	75.33	70.66	0.00	96.00	22.77
For comparing the means of :-		SEm±			CD		
Variety (V)		0.16			0.47		
Dose (D)		0.23			0.67		
VXD		0.40			1.17		
CV%		3.07					

4.2 M_2 GENERATION

4.2.1 Analysis of Variance

The analysis of variance for different characters studied in the present investigation of M_2 generation is given in table 4.4 The analysis of variance revealed significant differences of eleven characters, *viz*., days to 50 per cent flowering, plant height, number of primary branches, number of capsule per plant, number of seeds per capsule, days to maturity, 1000 seed weight, yield per plant, harvest index, oil and protein content which indicated the existence of variability in the experimental material. The estimates of genotypic (σ^2_g) and phenotypic variances (σ^2_p) of each character were obtained from analysis of variance.

4.2.2 Variance Components

Analysis of variance (ANOVA) may not reveal the absolute variability present in M_2 generation and this could be assessed through standardizing the phenotypic and genotypic variances by obtaining coefficient of variability. Further, it is essential to separate out the environmental influence from the total variability indicating the accuracy with which a genotype can be identified by its phenotypic performance. The estimates of heritability alone fail to indicate the response to selection. Therefore, the

heritability estimates coupled with estimates of genetic advance appeared to be more meaningful.

The mean performances of three sesame genotypes for different characters are presented in Table 4.5. The estimates of genotypic (σ^2_g) and phenotypic variance (σ^2_p) of each character were obtained from analysis of variance.

The other genetic parameters *viz.,* genotypic coefficient of variation (GCV%), phenotypic coefficient of variation (PCV%), heritability in broad sense (h^2_b) and genetic advance as per cent of mean (GA%) were computed from variance components and mean values. All these estimates are summarized in Table 4.6.

All the genotypes displayed wide range of variation in their mean performance with respect to all the characters. This had been exampled by the analysis of variances which showed highly significant mean differences for these characters indicating that the genotypes were genetically diverse (Table 4.4). The results also indicated that the different doses of EMS used have induced variability for most of the characters. Moreover, the wide range of variation provides ample scope for selection of superior and desired genotypes by the plant breeder for further crop improvement.

4.2.2.1 Days to 50 per cent flowering

4.2.2.1.1 Mean performance

Significant differences were observed among genotypes for days to 50 per cent flowering. It was observed that this trait had values ranging from 30.67 to 50.33 with mean value of 40.53 days. V_1D_4 (30.67) recorded early flowering while late flowering was recorded for V_3D_5 (50.33) followed by V_2D_5 (47.00) and V_3D_1 (46.00) but these values (V_3D_5, V_2D_5 and V_3D_1) were at par.

Days to 50 per cent flowering range from 34.73 (V_1) to 44.27 (V_3) for varieties while, dose effect had values ranging from 38.00 (D_4) to 43.00 (D_5).

4.2.2.1.2 Variance components and heritability

The results revealed that genotypic variance (26.60) contributed a major portion of phenotypic variance (33.88) in expression of the character, and thereby less influence of environment. The heritability was found high (78%).

The findings of Chavan and Chopde (1982) were in agreement with the above results as they also recorded high heritability.

The contradictory results were reported by Natikar *et al.* (2013) who reported that heritability estimates were high for all the characters studied, except for days to 50 per cent flowering.

4.2.2.1.3 Genotypic and phenotypic coefficients of variation

Moderate level of GCV (12.72%) and PCV (14.36%) indicated the existence of considerable variation for this trait in the population.

4.2.2.1.4 Genetic advance (per cent of mean)

The value of genetic advance was high (23.22%), coupled with high heritability (78%), which indicated the predominance of additive gene action in the expression of the character. Hence, there would be good response of the selection for improvement of the character.

The findings of Chavan and Chopde (1982) were in partial agreement with the above result as they found moderate genetic advance coupled with high heritability.

Table 4.4 Analysis of variance for various characters in M_2 generation of sesame.

Source of variation	d.f.	Mean squares for different characters											
		Days to 50 % flowering	Plant height	Number of primary branches	Number of pods per plant	Number of seeds per pod	Pod length	Days to maturity	1000 seed weight	Yield per plant	Harvest index	Oil	Protein
Replication	2	8.07	51.75	0.02	33.09	7.52	0.01	11.82	0.09	0.09	0.41	0.27	2.61
Treatment	14	87.08**	988.51**	0.35**	224.55**	85.62**	3.10	271.59**	0.86**	20.44**	296.80**	5.82**	24.75**
Variety	2	388.87**	2956.28**	1.33**	665.47**	255.97**	0.09	1577.76**	1.92**	14.16**	200.43**	19.02**	87.28**
Dose	4	28.86*	729.71**	0.21*	141.87**	89.27**	0.01	43.08**	1.28**	60.09**	872.61**	4.07**	26.63**
Var X Dose	8	40.76**	625.97**	0.19*	155.66**	41.22*	0.03	59.31**	0.40**	2.19**	33.00**	3.40**	8.18**
Error	28	7.28	60.76	0.06	10.68	17.84	0.02	7.06	0.10	0.10	1.91	0.33	1.70

* Significant at 5% level of significance

** Significant at 1% level of significance.

Table 4.5: Mean values of genotypes for different characters of sesame in M_2 generation.

Treatments	Days to 50 per cent flowering	Plant height (cm)	Number of primary branches	Number of pods per plant	Number of seeds per pod	Pod length (cm)	Days to maturity	1000 seed weight (g)	Yield per plant (g)	Harvest index (%)	Oil (%)	Protein (%)
	1	2	3	4	5	6	7	8	9	10	11	12
Varieties												
V_1	34.73	63.97	2.48	18.39	28.37	1.90	73.87	1.81	2.20	8.39	48.69	26.54
V_2	42.60	89.99	3.05	29.76	33.57	1.92	92.20	2.39	3.58	13.54	50.28	23.44
V_3	44.27	67.84	2.63	18.07	25.41	1.78	91.00	1.73	1.71	6.47	48.10	28.19
Min	34.73	63.97	2.48	18.07	25.41	1.78	73.87	1.73	1.71	6.47	48.1	23.44
Max	44.27	89.99	3.05	29.76	33.57	1.92	92.2	2.39	3.58	13.54	50.28	28.19
SEm±	0.69	2.01	0.066	0.84	1.09	0.03	0.68	0.08	0.08	0.35	0.14	0.33
CD (5%)	2.01	5.83	0.18	2.44	3.15	0.09	1.98	0.24	0.23	1.03	0.43	0.97
Dose												
D_1	40.89	72.70	2.67	20.04	29.33	1.88	87.67	1.87	1.32	4.97	49.46	25.56
D_2	40.67	66.57	2.64	18.16	25.82	1.83	86.67	1.92	1.14	4.29	48.11	27.46
D_3	40.11	70.73	2.78	23.44	34.24	1.84	83.56	1.98	1.89	7.14	49.41	24.59
D_4	38.00	70.11	2.56	20.40	27.64	1.86	83.11	1.54	1.05	3.99	48.50	28.24

	1	2	3	4	5	6	7	8	9	10	11	12
D_5	43.00	89.54	2.96	28.31	28.56	1.90	87.44	2.58	7.08	26.94	49.62	24.43
Min	38.00	66.57	2.56	18.16	25.82	1.83	83.11	1.54	1.05	3.99	48.11	24.43
Max	43.00	89.54	2.96	28.31	34.24	1.9	87.67	2.58	7.08	26.94	49.62	28.24
SEm±	0.89	2.59	0.08	1.08	1.40	0.04	0.88	0.10	0.10	0.46	0.19	0.43
CD (5%)	2.60	7.52	0.24	3.15	4.07	NS	2.56	0.31	0.30	1.33	0.55	1.25
VXD												
V_1D_1	38.00	61.66	2.13	14.00	25.67	1.99	75.67	1.27	0.45	1.70	49.06	25.54
V_1D_2	37.00	79.00	2.47	23.20	29.80	1.85	75.00	1.80	1.42	5.32	48.29	28.25
V_1D_3	36.33	43.93	2.53	10.53	30.07	1.82	73.33	1.73	0.61	2.26	48.81	25.78
V_1D_4	30.67	51.93	2.53	12.47	26.47	1.83	72.00	1.67	0.67	2.53	48.75	27.57
V_1D_5	31.67	83.33	2.73	31.73	29.87	1.99	73.33	2.60	7.84	30.15	48.57	25.54
V_2D_1	38.67	84.70	3.00	27.60	32.93	1.86	91.67	2.33	2.29	8.62	49.96	23.50
V_2D_2	43.00	66.70	2.87	17.80	27.67	1.91	95.67	2.33	1.45	5.45	49.51	23.58
V_2D_3	43.67	93.64	3.13	39.40	40.87	2.01	94.33	2.27	3.79	14.33	49.88	23.40
V_2D_4	40.67	89.47	2.67	31.73	30.93	2.01	90.00	2.27	2.16	8.16	50.87	24.31
V_2D_5	47.00	115.43	3.60	32.27	35.47	1.82	89.33	2.73	8.24	31.14	51.16	22.40
V_3D_1	46.00	71.75	2.87	18.53	29.40	1.80	95.67	2.00	1.21	4.58	49.38	27.63
V_3D_2	42.00	54.00	2.60	13.47	20.00	1.73	89.33	1.63	0.57	2.11	46.53	30.56

	1	2	3	4	5	6	7	8	9	10	11	12
V_3D_3	40.33	74.63	2.67	20.40	31.80	1.71	83.00	1.93	1.28	4.83	49.55	24.57
V_3D_4	42.67	68.93	2.47	17.00	25.53	1.74	87.33	0.68	0.34	1.28	45.89	32.85
V_3D_5	50.33	69.87	2.53	20.93	20.33	1.91	99.67	2.40	5.17	19.54	49.13	25.34
Mean	40.53	73.93	2.72	22.07	29.12	1.86	85.68	1.97	2.49	9.46	49.02	26.05
Min	30.67	43.93	2.13	10.53	20.00	1.71	72.00	0.68	0.34	1.28	45.89	22.40
Max	50.33	115.43	3.60	39.40	40.87	2.01	99.67	2.73	8.24	31.14	51.16	32.85
	**	**	*	**	*	NS	**	**	**	**	**	**
SEm±	1.55	4.50	0.14	1.88	2.43	0.07	1.53	0.18	0.18	0.79	0.33	0.75
CD (5%)	4.51	13.03	0.42	5.46	7.06	NS	2.56	0.54	0.52	2.30	0.96	2.17
CV(%)	6.6	10.5	9.3	14.8	14.5	7.0	4.4	16.3	12.4	14.5	1.1	4.9

* Significant at 5% level of significance

** Significant at 1% level of significance.

Table 4.6 Estimates of genotypic variance (σ^2_g), phenotypic variance (σ^2_p) genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2_b) and genetic advance (GA) in M_2 generation of sesame.

Character	σ^2_g	σ^2_p	GCV	PCV	h^2_b (%)	GA (%)
Days to 50% flowering	26.60	33.88	12.72	14.36	78.00	23.22
Plant height (cm)	309.25	370.01	23.79	26.02	83.00	47.79
Number of primary branches	0.09	0.15	11.47	14.79	60.00	17.59
Number of pods per plant	71.29	81.97	38.26	41.02	87.00	73.49
Number of seeds per pod	22.59	40.43	16.32	21.84	55.00	25.13
Pod length (cm)	1.02	1.04	3.64	7.93	21.00	110.77
Days to maturity	88.17	95.23	10.96	11.39	92.00	21.73
1000 seed weight (g)	0.25	0.35	25.54	30.33	70.00	0.49
Yield per plant (g)	6.78	6.88	104.26	105.00	98.00	213.84
Harvest index	98.29	100.20	104.74	105.75	98.00	213.82
Oil	1.83	2.16	2.76	3.00	84.00	5.23
Protein	7.68	9.38	10.64	11.76	81.00	19.82

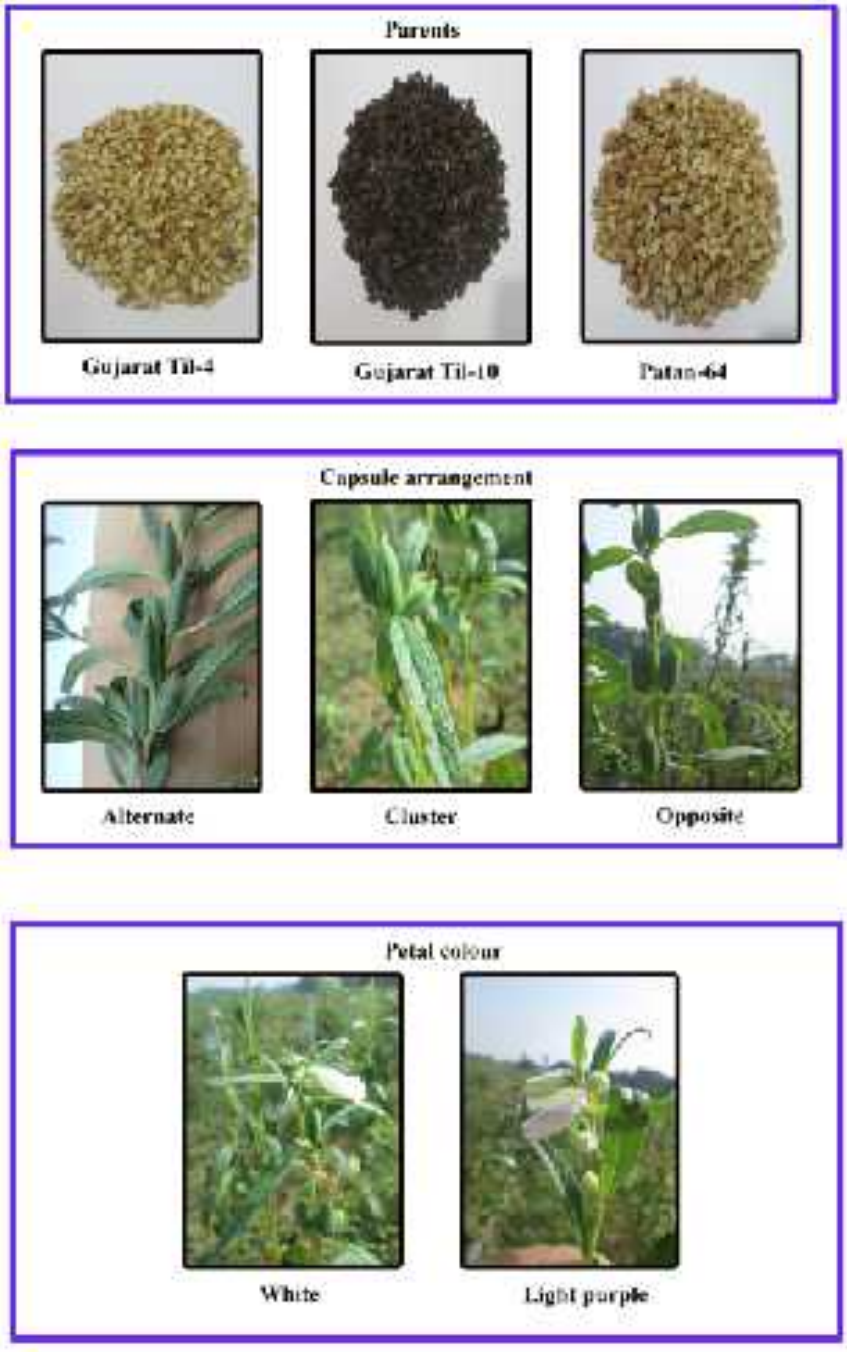


Plate 1: Photograph of parents and variability in capsule and petal colour arrangement in VI_2 generation

4.2.2.2 Plant height (cm)

4.2.2.2.1 Mean performance

The character showed high range of variability (43.93 to 115.43 cm) with general mean of 73.93. Significant differences were observed among genotypes for this trait. V_2D_5 (115.43) exhibited maximum plant height while V_1D_3 (43.93) recorded the lowest value for plant height.

Range varied from 63.97 (V_1) to 89.99 (V_2) for varieties whereas for dose effect it varied from 66.57 (D_2) to 89.54 (D_5)

This finding was in confirmation with Chavan and Chopde (1982) whose study also showed higher variability for plant height in sesame.

Birara *et al.* (2013) also found highly significant differences in the varieties and treatment for plant height.

4.2.2.2.2 Variance components and heritability

The estimates of genotypic and phenotypic variances were high. The genotypic variance (309.25) contributed a major portion of phenotypic variance (370.01), which indicated that the environment had little role in the expression of this trait. The estimate of heritability was also high (83%).

4.2.2.2.3 Genotypic and phenotypic coefficients of variation

The high estimates of GCV (23.79%) and PCV (26.02%) revealed sufficient variability in the population under investigation. The narrow difference between GCV and PCV values suggested less influence of environment in the expression of this trait.

Contradictory results were reported by Anitha and Manivannan (2014) who found low and moderate PCV and GCV respectively for plant height in the mutated population. Usharani and Ananda Kumar (2015) also reported moderate and high PCV and GCV for plant height.

4.2.2.2.4 Genetic advance (per cent of mean)

The per cent genetic advance was high (47.79%), accompanied with high heritability (83%), suggesting that genes with additive effect were largely responsible

for variation among genotypes for this trait. So there would be good response of the selection for improvement of the character.

The results were in confirmation with Anitha and Manivannan (2014) who also found high genetic advance accompanied with high heritability.

4.2.2.3 Number of primary branches

4.2.2.3.1 Mean performance

Significant differences were observed among genotypes for this trait, and it varied from 2.13 to 3.60 with mean value of 2.72. The genotype V_2D_5 recorded maximum number of branches per plant (3.60) while the genotype V_1D_1 had minimum number of branches per plant (2.13).

Range value varied from 2.48 (V_1) to 3.05 (V_2) for varieties whereas for dose effect, range value varied from 2.56 (D_4) to 2.96 (D_5).

This was in confirmation with findings of Chavan and Chopde (1982) whose study also showed higher variability for number of primary branches in sesame.

4.2.2.3.2 Variance components and heritability

The genotypic variance (0.09) contributed less in total variance (0.15), which indicated that the environment played important role in expression of this trait. The heritability was found moderate (60%).

Usharani and Ananda Kumar (2015) reported high amount of heritability for this trait which was similar as the above results.

4.2.2.3.3 Genotypic and phenotypic coefficients of variation

The estimates of GCV (11.47%) and PCV (14.79%) were moderate, indicating existence of variability in the population. The close estimates of GCV and PCV values suggested little contribution of the environment for the expression of the character.

The contradictory results were reported by Usharani and Ananda Kumar (2015) who found moderate and high PCV and GCV for number of primary branches.

4.2.2.3.4 Genetic advance (per cent of mean)

The genetic advance as per cent of mean was moderate (17.59%), coupled with moderate heritability (60%), indicating little scope for improvement of this trait.

Usharani and Ananda Kumar (2015) reported high amount of heritability and GA as per cent of mean for number of primary branches and this findings were not in agreement with the above results.

4.2.2.4 Number of capsule per plant

4.2.2.4.1 Mean performance

Higher values are desirable for number of capsule per plant as it is associated with yield. Differences among genotypes were significant for capsule per plant, which ranged from 10.53 to 39.40 with a mean value of 22.07. V_2D_3 recorded maximum number of capsule per plant (39.40) while V_1D_3 had minimum number of capsule per plant (10.53) i.e. mutation treatment in 1.5% EMS induced variability both in variety V_1 and V_2.

Range values varied from 18.07 (V_3) to 29.76 (V_2) for varieties whereas for dose effect it varied from 18.16 (D_2) to 28.31(D_5)

Nura *et al.* (2011) also reported significant variation for pods per plant in sesame. Birara *et al.* (2013) also found highly significant differences in the varieties and treatment for pods per plant which was similar to the above findings.

4.2.2.4.2 Variance components and heritability

The results revealed that genotypic variance (71.29) contributed a major portion of phenotypic variance (81.97) in expression of the character, and thereby less influence of environment. The heritability was found high (87%).

4.2.2.4.3 Genotypic and phenotypic coefficients of variation

The values of GCV (38.26%) and PCV (41.02%) were high and small difference between them indicated that the environment had little effect on the expression of this trait.

Similar findings were earlier reported by Anitha and Manivannan (2014) who observed high GCV and PCV while the findings of Usharani and Ananda Kumar

(2015) were in partial agreement with the results who found moderate and high PCV and GCV for number of pods per plant.

4.2.2.4.4 Genetic advance (per cent of mean)

The value of genetic advance was high (73.49%), coupled with high heritability (87%), which indicated the predominance of additive gene action in the expression of the character. Hence, there would be good response of the selection for improvement of the character.

The findings by Usharani and Ananda Kumar (2015) were in agreement who also found high genetic advance coupled with high heritability.

4.2.2.5 Number of seeds per capsule

4.2.2.5.1 Mean performance

Differences among genotypes were significant for this trait. The character showed high range of variability (20.00 to 40.87) with general mean (29.12). V_3D_2 (20.00) was found having lowest number of seeds per capsule while V_2D_3 (40.87) was found with maximum number of seeds per capsule but the values of V_2D_3 (40.87) and V_2D_5 (35.47) were at par.

Range value varied from 25.41(V_3) to 33.57 (V_2) for varieties whereas for dose effect it varied from 25.82 (D_2) to 34.24 (D_3), indicating that treating these seeds with 1.5% EMS increases the number of seeds.

Birara *et al.* (2013) also found highly significant differences in the varieties and treatment for seeds per capsule, while Muhammad *et al.* (2013) in sesame found no significant difference for this trait which was not in agreement with the above findings.

4.2.2.5.2 Variance components and heritability

The genotypic variance (22.59) contributed less in total variance (40.43), which indicated that the environment played important role in expression of this trait. The heritability was found moderate (55%).

4.2.2.5.3 Genotypic and phenotypic coefficients of variation

The estimates of GCV (16.32%) and PCV (21.84%) were moderate to high in magnitude, which indicated substantial variability in the population under investigation.

4.2.2.5.4 Genetic advance (per cent of mean)

The value of genetic advance for this trait was high (25.13%), coupled with moderate heritability (55%) indicated limited scope of improvement through selection.

The findings by Usharani and Ananda Kumar (2015) were not in agreement who reported high genetic advance coupled with high heritability.

4.2.2.6 Capsule length

4.2.2.6.1 Mean performance

For dose effect and interaction effect non significant differences were found. As for varieties, the values of V_1 and V_2 were at par and range value varied from 1.78 (V_3) to 1.92 (V_2) with mean value of 1.86.

Birara *et al.* (2013) and Muhammad *et al.* (2013) found significant difference for capsule length in sesame which contradicted the result above.

4.2.2.6.2 Variance components and heritability

The genotypic variance (1.02) contributed less to total variance (1.04), explaining the greater role of environment in the expression of this character. The estimate of heritability was also found low (21%)

Sheeba *et al.* (2003), Usharani and Ananda Kumar (2015) reported high heritability which contradicted the above results.

4.2.2.6.3 Genotypic and phenotypic coefficients of variation

Very low values of GCV (3.64%) and PCV (7.93%) indicated the presence of less variability for days to maturity in the population under investigation.

Contradictory results were found by Sheeba *et al.* (2004) who observed high GCV for pod length.

4.2.2.6.4 Genetic advance (per cent of mean)

The genetic advance as per cent of mean was high (110.77%) coupled with low heritability (21%) indicated limited scope of improvement of this trait through selection.

The findings by Sheeba *et al.* (2003), Usharani and Ananda Kumar (2015) contradicts the result as they reported high genetic advance coupled with high heritability.

4.2.2.7 Days to maturity

4.2.2.7.1 Mean performance

Significant differences were observed among genotypes for this trait, and it varied from 72.00 to 99.67 with mean value of 85.68. The genotype V_3D_5 recorded late maturity (99.67) while the genotype V_1D_4 had early maturity (72.00).

Range value varied from 73.87 (V_1) to 92.20 (V_2) for varieties whereas for dose effect it varied from 83.11 (D_4) to 87.67 (D_1).

Birara *et al.* (2013) in sesame found highly significant differences for days to maturity which was similar to the above results.

4.2.2.7.2 Variance components and heritability

The genotypic variance (88.17) contributed major portion of phenotypic variance (95.23). It indicated that this character was least influenced by environmental variation. Heritability estimate (92%) was high for this trait.

The results were in agreement with Sarwar *et al.* (2008) who also reported high value of heritability

4.2.2.7.3 Genotypic and phenotypic coefficients of variation

The estimates of GCV (10.96%) and PCV (11.39%) were moderate, indicating existence of variability in this trait. The close estimates of GCV and PCV values suggested little contribution of the environment for the expression of the character.

4.2.2.7.4 Genetic advance (per cent of mean)

The value of genetic advance was high (21.73%), coupled with high heritability (92%), which indicated the predominance of additive gene action in the

expression of the character. Hence, there would be good response of the selection for improvement of the character.

The results were in partial agreement with Sarwar *et al.* (2008) who also reported high value of heritability.

4.2.2.8 1000 seed weight

4.2.2.8.1 Mean performance

Significant differences were observed among genotypes for this trait, and it ranged from 0.68 to 2.73 with mean value of 1.97. V_2D_5 recorded maximum 1000 seed weight (2.73) while V_3D_4 (0.68) had the least value for 1000 seed weight.

Range value varied from 1.73 (V_3) to 2.39 (V_2) for varieties whereas for dose effect it varied from 1.54 (D_4) to 2.58 (D_5).

Nura *et al.* (2011) also reported similar findings where they found significant variation for 1000 seed weight in sesame.

4.2.2.8.2 Variance components and heritability

The results revealed that genotypic variance (0.25) contributed a major portion of phenotypic variance (0.35) in expression of the character, and thereby less influence of environment. The heritability was found high (70%).

4.2.2.8.3 Genotypic and phenotypic coefficients of variation

The high estimates of GCV (25.54%) and PCV (30.33%) revealed substantial variability in the population under investigation.

The findings were in partial agreement with Sheeba *et al.* (2004) who found high GCV for variety CO1 of sesame.

4.2.2.8.4 Genetic advance (per cent of mean)

The per cent genetic advance was low (0.44%) accompanied by high heritability (70%) which indicate predominance of non additive gene action in the inheritance of character. Hence for the improvement of this character population improvement approach would be advantageous and stable.

4.2.2.9 Yield per plant (g)

4.2.2.9.1 Mean performance

Significant differences were observed among genotypes for this trait, and it varied from 0.34 to 8.24 with mean value of 2.49g. The genotype V_2D_5 recorded maximum number of yield per plant (8.24) but it was at par with the values of V_1D_5 (7.84). The genotype V_3D_4 (0.34) recorded the least yield per plant.

Range values varied from 1.71 (V_3) to 3.58 (V_2) for varieties whereas for dose effect it varied from 1.05 (D_4) to 7.08 (D_5) indicating that none of the doses of EMS has increased the yield in any of the variety.

Contradictory findings were reported by kang *et al.* (1996) that had higher yield than its control.

4.2.2.9.2 Variance components and heritability

The genotypic variance (6.78) contributed major portion of phenotypic variance (6.88) in expression of the character so less influence by environmental variation. Heritability estimate (98%) was high for this trait.

The results were in confirmation with Usharani and Ananda Kumar (2015) who also reported high amount of heritability.

4.2.2.9.3 Genotypic and phenotypic coefficients of variation

The high estimates of GCV (104.26%) and PCV (105%) revealed sufficient variability in the population under investigation. The narrow difference between GCV and PCV values suggested less influence of environment in the expression of this trait.

Similar findings were reported by Sarwar *et al.* (2008) who recorded high value for GCV and PCV. Aristya and Taryono (2016) also registered high coefficient of variation.

4.2.2.9.4 Genetic advance (per cent of mean)

The per cent genetic advance was high (213.84%), accompanied with high heritability (98%) suggesting that genes with additive effect were largely responsible for variation among genotypes.

The results were in confirmation with Usharani and Ananda Kumar (2015) who also reported high amount of heritability and GA as per cent of mean.

4.2.2.10 Harvest index

4.2.2.10.1 Mean performance

Significant differences were observed among genotypes for this trait, and it was varied from 1.28 to 31.14 with mean value of 9.46. The genotype V_2D_5 (31.14) recorded maximum harvest index, while the genotype V_3D_4 had the least value for harvest index (1.28). The values of V_2D_5 (31.14) and V_1D_5 (30.15) were also found to be at par. Although different doses of EMS has induced variability in this character, but none of the dose has attended the higher value of harvest index than control.

Range varied from 6.47 (V_3) to 13.54 (V_2) for varieties whereas for dose effect it varied from 3.99 (D_4) to 26.94 (D_5).

4.2.2.10.2 Variance components and heritability

The genotypic variance (98.29) contributed major portion of phenotypic variance (100.20). It indicated that this character was least influenced by environmental variation. Heritability estimate (98%) was high for this trait.

4.2.2.10.3 Genotypic and phenotypic coefficients of variation

The high estimates of GCV (104.74%) and PCV (105.75%) revealed sufficient variability in the population under investigation. The narrow difference between GCV and PCV values suggested less influence of environment in the expression of this trait.

4.2.2.10.4 Genetic advance (per cent of mean)

The per cent genetic advance was high (213.82%) accompanied with high heritability (98%), suggesting that genes with additive effect were largely responsible for variation among genotypes.

4.2.2.11 Oil (%)

4.2.2.11.1 Mean performance

Significant differences were observed among genotypes for this trait, and it varied from 45.89 to 51.16 with mean value of 49.02. The genotype V_2D_5 (51.16)

recorded maximum oil content but V_2D_5 and V_2D_4 (50.87) were found to be at par, while the genotype V_3D_4 had the least oil content (45.89).

Range value varied from 48.10 (V_3) to 50.28 (V_2) for varieties whereas for dose effect it varied from 49.41 (D_3) to 49.62 (D_5)

Similar findings were earlier reported by Gopinath and Pavadai (2015) who reported an increase in oil content with increasing level of some doses of mutagen in soya bean.

4.2.2.11.2 Variance components and heritability

The genotypic variance (1.83) contributed to major portion of phenotypic variance (2.16). It indicated that this character was least influenced by environmental variation. Heritability estimate (84%) was high for this trait.

The contradictory findings were reported by Natikar *et al.* (2013) who recorded moderate heritability for oil yield per ha in sunflower.

4.2.2.11.3 Genotypic and phenotypic coefficients of variation

Low values of GCV (2.76%) and PCV (3.00%) indicated the presence of less variability for this trait in the population under investigation.

The above results are contradictory to the earlier findings of Natikar *et al.* (2013) as they found high value of PCV and GCV for oil yield.

4.2.2.11.4 Genetic advance (per cent of mean)

The per cent genetic advance was low (5.23%) accompanied by high heritability (84%) indicating predominance of non additive gene action in the inheritance of character hence for the improvement of this character population improvement approach would be remunerative.

The contradictory findings were reported by Natikar *et al.* (2013) who recorded moderate heritability for oil yield per ha.

4.2.2.12 Protein (%)

4.2.2.12.1 Mean performance

Significant differences were observed among genotypes for this trait, and it varied from 22.40 to 32.85 with mean value of 26.05. The genotype V_3D_4 (32.85)

recorded maximum protein content, while the genotype V_2D_5 had the least protein content (22.40).

All the three varieties i.e. V_1, V_2 and V_3 were at par and values ranged from 23.44 (V_2) to 28.19 (V_3). For dose effect, range varied from 24.43 (D_5) to 28.24 (D_4).

The contradictory results were reported by Kamala and Sasikala (1985) who found that protein content remained unchanged after mutagenic treatment.

4.2.2.12.2 Variance components and heritability

The genotypic variance (7.68) contributed major portion of phenotypic variance (9.38) indicating that this character was least influenced by environmental variation. Heritability estimate (81%) was high for this trait.

The result above was in agreement with the findings of Ariraman *et al.* (2016) who recorded high heritability for this trait.

4.2.2.12.3 Genotypic and phenotypic coefficients of variation

The estimates of GCV (10.64%) and PCV (11.73%) were moderate, indicating existence of variability in the population. The close estimates of GCV and PCV values suggested very little contribution of the environment for the expression of the character.

The result above contradicted the findings of Ariraman *et al.* (2016) who reported high PCV and GCV for protein content in Pigeon pea.

4.2.2.12.4 Genetic advance (per cent of mean)

The per cent genetic advance was moderate (19.82%) accompanied by high heritability (81%) indicating higher magnitude of additive gene action in the inheritance of this trait.

Similar findings were recorded by Ariraman *et al.* (2016) found high heritability and genetic advance for this trait.

4.2.3 Correlation Coefficients

In estimating the association between characters, correlation analysis has been used to determine the type and magnitude of association between a pair of characters. These associations provide a better understanding of the contribution of one trait in building up the genetic makeup of the other traits of a crop. The knowledge about correlations between economically important traits and characters contributing to that in all combinations can be helpful to decide the parameters for selection, so that improvement in the associated characters can be done.

The association between characters that can be directly observed is the phenotypic correlation. The knowledge about phenotypic correlation between yield contributing characters helps in selection programme for yield improvement of a crop. The genotypic correlations permit the prediction of correlated response and evaluation of the relative influence of one character on other. Genotypic correlations in particular are helpful in the construction of selection indices. The phenotypic and genotypic correlation coefficients were estimated among twelve characters of three sesame genotypes, to find out the association of seed yield and other yield contributing characters (Table 4.7)

The data showed that correlation at genotypic and phenotypic levels had the same trend. Values of genotypic correlation coefficients were higher than those of their respective phenotypic correlation coefficients in most of the cases, suggesting that there was a strong and inherent association between two characters. In some cases, however, the phenotypic correlation was slightly higher than their genotypic counterpart, which implied that the non-genetic causes inflated the value of genotypic correlation because of the influence of environmental factors.

4.2.3.1 Days to 50 per cent flowering

Days to 50 per cent flowering showed highly significant and positive correlation with days to maturity at both genotypic and phenotypic levels and with plant height and primary branches at phenotypic level only.

4.2.3.2 Plant height (cm)

Plant height exhibited highly significant and positive correlation with number of primary branches, capsule per plant, seeds per capsule, 1000 seed weight, yield per

plant and harvest index at both the levels. It was positively and highly significantly associated with oil content at phenotypic level and significantly associated with oil content at genotypic level. There was also a presence of significant positive correlation with days to 50 per cent flowering and days to maturity at phenotypic level. On the other hand, it was negatively and highly significantly associated with protein content at phenotypic level and negatively and significantly associated with protein content at genotypic level.

The findings of Sarwar *et al.* (2008) were in partial agreement as they found significant and positive correlation between plant height and number of branches and also negative correlation of plant height with capsule per plant.

4.2.3.3 Number of primary branches

Number of primary branches exhibited highly significant and positive correlation with plant height, capsule per plant, seeds per capsule, 1000 seed weight, yield per plant and harvest index at both the levels. It was positively and highly significantly associated with oil content at phenotypic level and significantly associated with oil content at genotypic level. It also recorded significant and positive correlation with days to 50 per cent flowering and highly significant positive correlation with days to maturity at phenotypic level. On the other hand, it was negatively and highly significantly associated with protein content at phenotypic level and significantly associated at genotypic level.

Contradictory findings were recorded by Sarwar *et al.* (2008) who found that the number of branches showed significant negative correlation with capsule length and seeds per capsule.

4.2.3.4 Number of capsule per plant

Number of capsule per plant exhibited highly significant and positive correlation with plant height, primary branches, seeds per capsule, 1000 seed weight, yield per plant and harvest index at both the levels. It was highly significantly associated with oil content at phenotypic level and significantly associated with oil content at genotypic level. It was also significantly associated with capsule length at phenotypic level and highly significantly associated with capsule length at genotypic level. On the other hand, it was negatively and highly significantly associated with

protein content at phenotypic level and negatively and significantly associated with protein content at genotypic level

The findings by Sarwar *et al.* (2008) were in partial agreement with the results who found capsule per plant showing positive and significant correlation with seeds per capsule and seed yield. It also exhibited negative association with days to flower, days to mature and plant height

4.2.3.5 Number of seeds per capsule

Number of seeds per capsule exhibited highly significant and positive correlation with plant height, primary branches, capsule per plant and oil content at both the levels. It was positively and significantly associated with capsule length and 1000 seed weight at phenotypic levels.On the other hand, it was negatively and highly significantly associated with protein content at phenotypic and genotypic level.

The findings of Sarwar *et al.* (2008) were in partial agreement as they found that seeds per capsules showed positive and highly significant correlation with capsule length and also positive correlation with seed yield.

4.2.3.6 Capsule length

Capsule length exhibited highly significant and positive correlation with capsule per plant and oil content at genotypic level. It was significantly associated with 1000 seed weight, yield per plant and harvest index at genotypic level and significantly correlated with capsule per plant, seeds per capsule and oil content at phenotypic level. On the other hand, it was negatively and highly significantly associated with protein content at phenotypic and genotypic level.

The findings of Sarwar *et al.* (2008) were in partial agreement as they found

capsule length showing almost negative relationship with all attributes except capsule per plant.

4.2.3.7 Days to maturity

Days to maturity exhibited highly significant and positive correlation with days to 50 per cent flowering at both levels it also exhibited highly significant and positive correlation with primary branches and significant and positive correlation with plant height and 1000 seed weight at phenotypic levels.

The findings of Sarwar *et al.* (2008) were in partial agreement as they found days to maturity showing highly significant positive correlation with plant height and number of branches whereas highly significant and negative correlation with seed per capsule and capsule per plant

4.2.3.8 1000 seed weight

1000 seed weight exhibited highly significant and positive correlation with plant height, primary branches, capsule per plant, yield per plant, harvest index and oil content at both the levels. It was significant and positively correlated with seed per capsule and days to maturity at phenotypic level, there was also a significant and positive correlation with capsule length at genotypic levels. Further it was negatively and highly significantly associated with protein content at phenotypic level and negatively and significantly associated with protein content at genotypic level.

In the study by khatri *et al.* (2005) it was found that thousand grain weight recorded highly positive correlation with grain yield per unit area which was similar to the findings above.

4.2.3.9 Yield per plant (g)

It was found that yield was positive and highly significantly correlated with plant height, primary branches, capsule per plant, 1000 seed weight and harvest index at both genotypic and phenotypic levels. It exhibited a positive and significant correlation with capsule length at genotypic level; it also exhibited a positive and highly significant correlation with oil content at phenotypic level while, protein content recorded negative and highly significant correlation with yield at both genotypic and phenotypic levels.

The results were in partial agreement with the findings of Sarwar *et al.* (2008) as they found positive and significant correlation of seed yield with harvest index and 1000 seed weight. But they also found weak positive association with plant height, oil content, number of capsules per plant and number of days to flowering

Similar findings were reported by Aristya and Taryono (2016) who found that seed yield/plant had positive significant correlation with plant height, the number of primary branches, the number of secondary branches, the number of capsules/plant and 1000-seed weight.

Table 4.7 Genotypic and phenotypic correlation coefficient for twelve characters of sesame.

Characters		Days to 50 % flowering	Plant Height	Primary Branches	Pod per plant	Seed Per pod	Pod length	Days to Maturity	1000 seed weight	Yield per plant	Harvest index	oil	Protein
Days to 50% flowering	Rg	1.00	1.35	0.43	0.18	-0.11	-0.25	0.93**	0.21	0.20	0.19	0.19	-0.14
	Rp	1.00	0.34*	0.31*	0.18	0.05	-0.02	0.76**	0.17	0.17	0.17	0.14	-0.07
Plant Height	Rg		1.00	0.83**	0.94**	0.75**	0.36	0.37	0.65**	0.74**	0.72**	0.62*	-0.55*
	Rp		1.00	0.63**	0.81**	0.53**	0.25	0.30*	0.51**	0.65**	0.66**	0.53**	-0.46**
Primary Branches	Rg			1.00	0.70**	0.77**	-0.15	0.51	0.76**	0.67**	0.68**	0.60*	-0.60*
	Rp			1.00	0.57**	0.51**	0.11	0.39**	0.58**	0.54**	0.51**	0.52**	-0.47**
Pod per plant	Rg				1.00	0.79**	0.80**	0.32	0.71**	0.71**	0.71**	0.565*	-0.561*
	Rp				1.00	0.61**	0.32*	0.27	0.55**	0.65**	0.65**	0.51**	-0.51**
Seed Per pod	Rg					1.00	0.19	0.01	0.41	0.36	0.36	0.69**	-0.67**
	Rp					1.00	0.35*	0.03	0.42*	0.26	0.26	0.51**	-0.48**
Pod length	Rg						1.00	0.02	0.59*	0.52*	0.52*	0.64**	-0.76**
	Rp						1.00	0.00	0.27	0.23	0.24	0.36*	-0.38**
Days to Maturity	Rg							1.00	0.33	0.14	0.14	0.23	-0.20
	Rp							1.00	0.31*	0.14	0.13	0.22	-0.18
1000 seed weight	Rg								1.00	0.80**	0.80**	0.80**	-0.80**
	Rp								1.00	0.67**	0.66**	0.65**	-0.66**
Yield per plant	Rg									1.00	1.00**	0.44	-0.52**
	Rp									1.00	0.98**	0.41**	-0.46**
Harvest index	Rg										1.00	0.44	-0.51*
	Rp										1.00	0.40**	-0.46**
oil	Rg											1.00	-0.92**
	Rp											1.00	-0.90**
Protein	Rg												1.00
	Rp												1.00

* Significant at P = 0.05 and ** Significant at P = 0.01 levels.

4.2.3.10 Harvest index

Harvest index exhibited highly significant and positive correlation with plant height, primary branches, capsule per plant, 1000 seed weight and yield per plant at both levels. It exhibited highly significant and positive correlation with oil content at phenotypic level and significant and positive correlation with capsule length at genotypic levels. It was negatively and highly significantly associated with protein content at phenotypic level whereas negatively and significantly associated at genotypic levels.

4.2.3.11 Oil (%)

Oil (%) exhibited highly significant and positive correlation with plant height, primary branches, capsule per plant, seeds per capsule and 1000 seed weight at both levels. It exhibited highly significant and positive correlation with capsule length and yield per plant at genotypic level and highly significant and positive correlation with harvest index and significant positive correlation with capsule length at phenotypic levels. It was negatively and highly significantly associated with protein content at phenotypic level and positively and highly significantly associated with protein content at genotypic level

4.2.3.12 Protein (%)

Protein (%) exhibited highly significant and negative correlation with seeds per capsule, capsule length, 1000 seed weight, yield per plant, harvest index and oil content at both levels. It exhibited highly significant and negative correlation for plant height, primary branches, capsule per plant and oil content at phenotypic level and significant and negative correlation for plant height, primary branches and capsule per plant at genotypic levels.

Early flowering cultivars are desirable for a crop. From the above results it was recorded that the treatment V_1D_4 (2.00% EMS) flowered earlier than control thereby suggesting a superior nature than control for this specific trait which was a desirable effect from mutagenesis.

Generally medium plant height (75-125 cm) is preferred for sesame crop. From the above results it was found that for variety GT-4, V_1D_2 and control (V_1D_5) showed desirable plant height, while the rest of the treatment recorded undesirable plant height. As for variety GT-10, V_2D_1, V_2D_3 and V_2D_4 along with control showed

desirable plant height. Patan 64 is generally a short plant and from the above results no improvement in plant height for this variety was recorded after mutagenesis. Thus suggesting that mutagenesis did not help in the improvement of this character.

Number of primary branches is an important morphological character that helps in determining the capsule bearing ability which in turn may contribute to yield. Among all the genotypes studied the non treated population of V_2D_5 *i.e* control recorded maximum number of primary branches as compared to the treated population. Thus no improvement in the treated population was found after mutagenesis

For number of capsule per plant and number of seed per capsule treatment V_2D_3 (1.5% EMS) recorded high values suggesting their superiority than control which is a desirable characteristic and a positive result from mutagenesis.

Early maturing cultivars are desirable for a crop. From the above results it was recorded that the treatment V_1D_4 (2.00% EMS) matured early thereby suggesting a superior nature than control for this specific trait which was an improved effect from mutagenesis.

1000 seed weight is an important yield contributing character. From the above result it was recorded that treatment V_2D_5 *i.e* control exhibited maximum mean value among all the treatments. Thus no improvement was found for this character from mutagenesis.

Higher seed yield is a major breeding goal and characters like yield per plant and harvest index is an important yield contributing character. They were found having maximum mean value in non treated population of V_2D_5 *i.e* control. It was also found that the mean values of V_2D_5 were at par with V_1D_5 for both the characters. Mean values of yield and harvest index of treated population was comparatively lower than the non treated population indicating no improvement even after mutagenesis

Oil content is the most important economic product in sesame. Therefore high oil content is a desirable trait. Treatment V_2D_5 recorded maximum mean value for oil content while the treated population had generally lower mean value except for V_2D_4

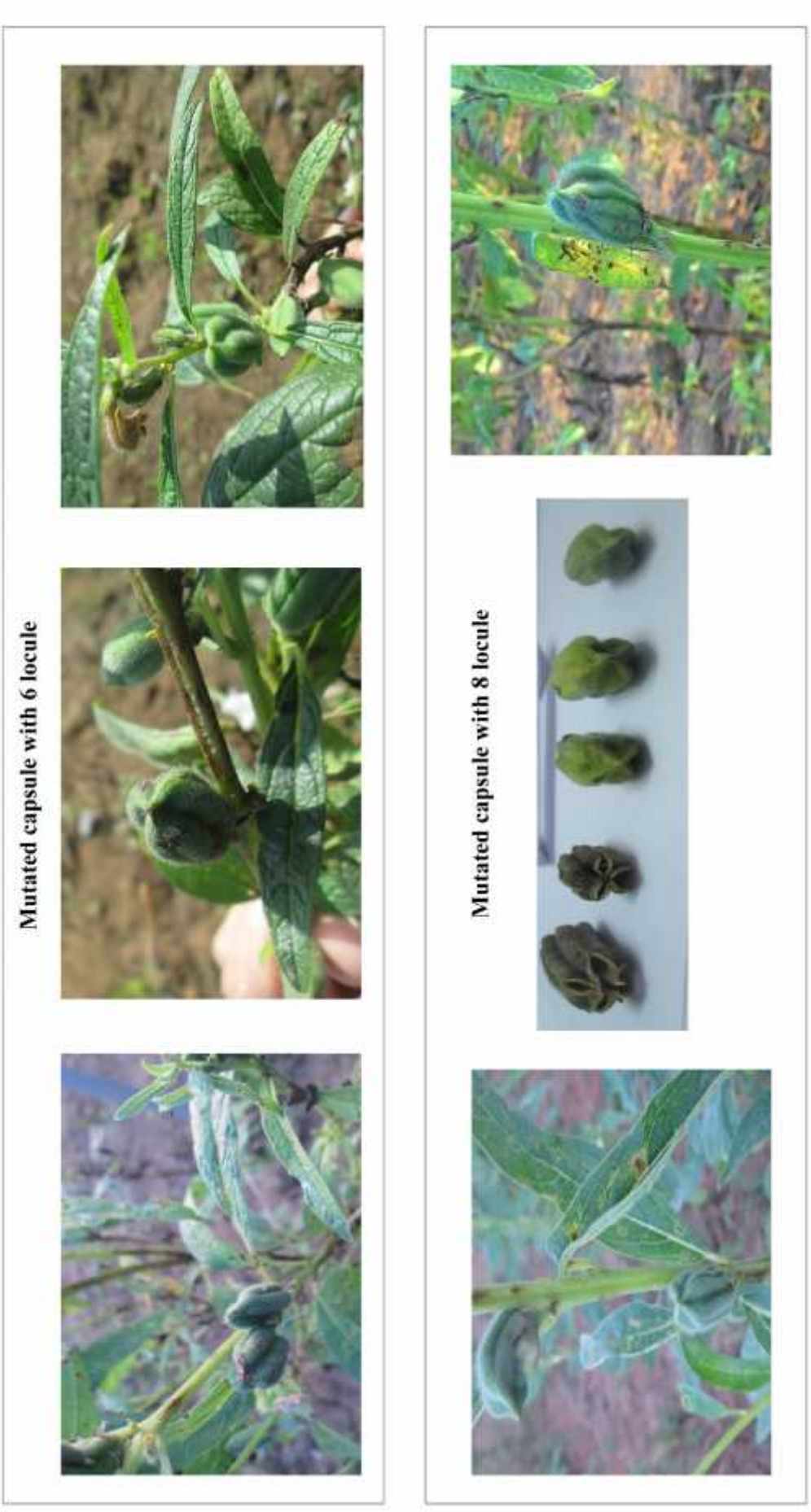
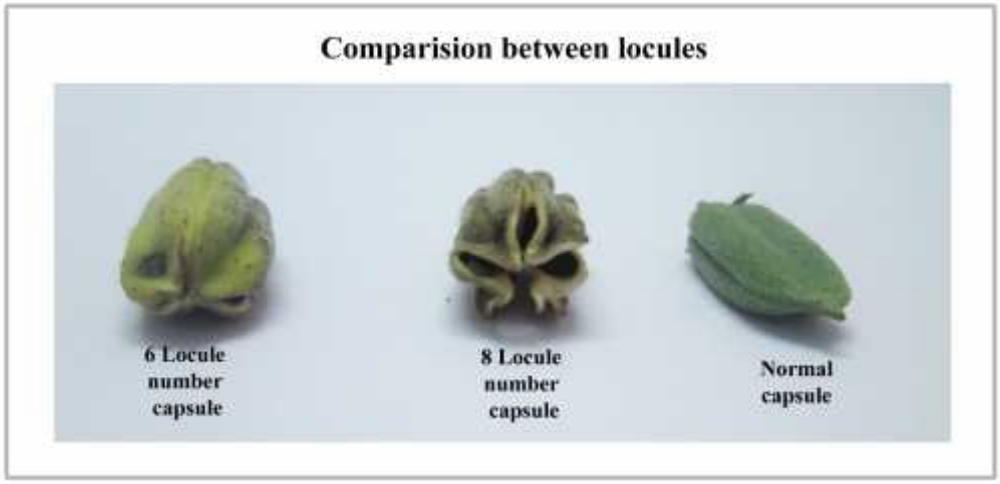


Plate 2: Variation of locule number in M_2 generation



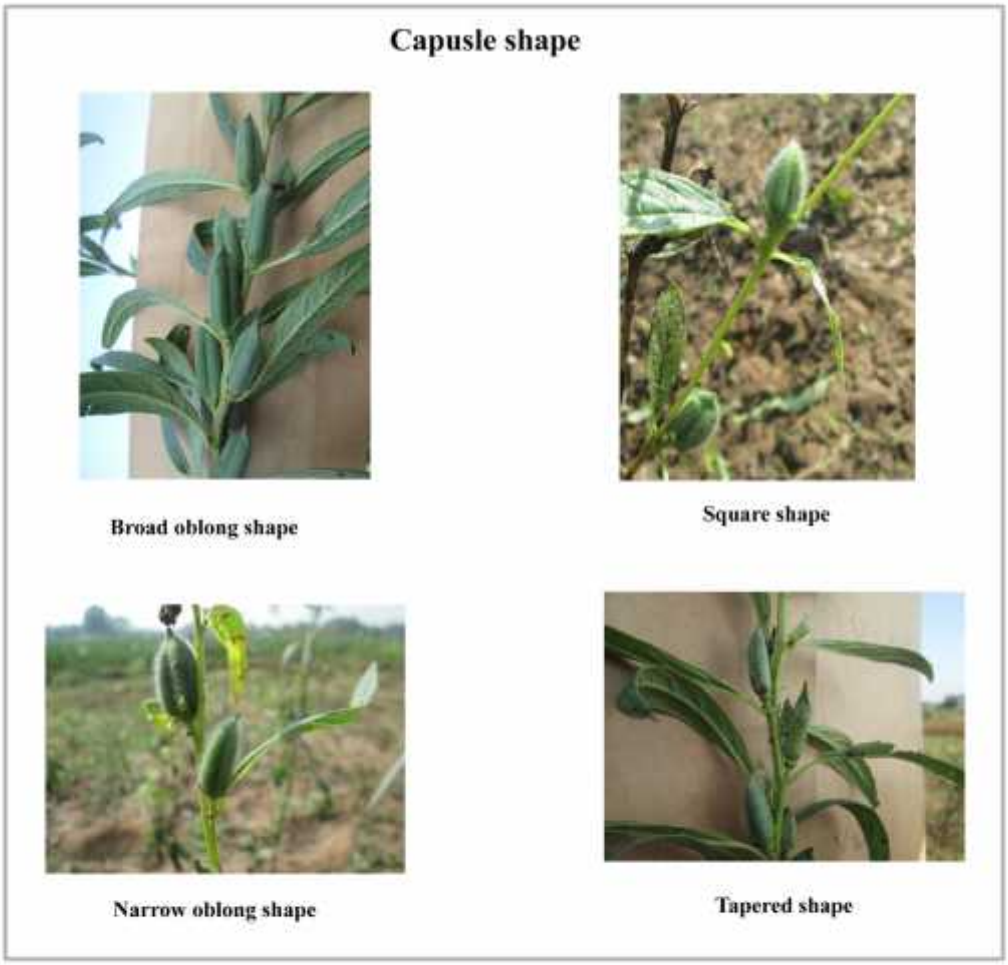


Plate 3: Photograph showing comparision in locule number and variability in capsule shape

(2.00% EMS) which was at par with V_2D_5 *i.e* control. Thus no improvement of oil content was found from the effect of mutagenesis.

Apart from being an important oilseed source, sesame seed is a potential source of proteins. From the above results it was recorded that treatment V_3D_4 (2.00% EMS) exhibited maximum mean value as compared to the non treated population which was a positive outcome from mutagenesis.

The estimates of variance component revealed that the characters like days to 50 per cent flowering, plant height, number of capsules per plant, days to maturity, 1000 seed weight, yield per plant, harvest index, oil per cent and protein per cent showed larger contribution of genotypic variance to total variance and also expressed high magnitude of heritability, which revealed less influence of environmental factors on the expression of these characters. Rest of the characters showed low to moderate heritability, indicating high influence of environmental factors on expression of these characters. Extent of variability in the experimental material was high for characters like plant height, number of capsules per plant, 1000 seed weight, yield per plant and harvest index as indicated by high estimates of GCV; while rest of the characters had low to moderate GCV per cent.

The estimates of genetic advance as per cent of mean were high coupled with high heritability for days to 50 per cent flowering, plant height, number of capsules per plant, days to maturity, yield per plant and harvest index indicating the predominance of additive gene action in the inheritance of these traits, hence, simple selection would be effective for genetic improvement of the said characters in desired direction. For number of seed per capsule and capsule length genetic advance as per cent of mean were high coupled with moderate to low heritability indicating limited scope of improvement.

The correlation study in the treated population of M_2 generation revealed the importance of characters like plant height, primary branches, capsule per plant, 1000 seed weight and harvest index for increasing the yield. Yield per plant also exhibited a positive and significant correlation with capsule length at genotypic level and a positive and highly significant correlation with oil content at phenotypic level. Protein

content recorded negative and highly significant correlation with yield at both genotypic and phenotypic levels. The genotypic correlations were higher in magnitude than the phenotypic correlations in most of the cases of treated and untreated population, indicating the masking effect of the environment in the total expression of the genotype.

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation entitled “Induced mutagenesis in sesame (*Sesamum indicum* L.)” was carried out to obtain information on genetic variability, correlation coefficient in the mutated population of sesame. The experiment was conducted at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand during 2016. The seeds of these genotypes were obtained from Main oilseed research station, J.A.U., Amreli. The experimental material comprised of three diverse genotypes of sesame which were exposed to five different doses of chemical mutagen EMS. The three genotypes were analyzed in Factorial CRD for M_1 generation and Factorial RBD for M_2 generation. The experimental material was evaluated for twelve characters *viz.*, days to 50 per cent flowering, plant height, number of primary branches, number of capsules per plant, number of seed per capsule, capsule length, days to maturity,1000 seed weight, yield per plant, harvest index, oil content and protein content.

In M_1 generation highly significant differences in the genotypes were observed. Seed germination per cent in the genotype subjected to treatment with five different doses of EMS was lower than those of their respective controls. Gradual reduction of germination per cent was noted with the increase in dose. Hence, a dose dependent reduction in germination per cent was clearly evident from the values recorded.

For M_2 generation the analysis of variance revealed significant differences among genotypes. Out of twelve characters under study, eleven of them showed significant difference which indicated that experimental material had sufficient variability for different traits.

Based on mean performance the following results can be summarised as follows:-

Variety GT-4 with dose D_4 *i.e.* 2.00% EMS recorded early flowering while late flowering was recorded by Patan 64 with D_5 *i.e* control dose for days to 50 per cent flowering. For plant height GT-10 with D_5 *i.e* control exhibited maximum value while GT-4 with dose D_3 *i.e* 1.5% EMS recorded the lowest value. The genotype GT-

10 with D_5 *i.e* control recorded maximum number of primary branches while the genotype GT-4 with dose D_1 *i.e*. 0.5% EMS had minimum number of primary branches.

GT-10 with dose D_3 *i.e* 1.5% EMS recorded maximum number of capsules per plant while GT-4 with dose D_3 *i.e.* 1.5% EMS had minimum number of capsules per plant. Patan 64 with dose D_2 *i.e.* 1.00% EMS was found having lowest number of seed per capsule while GT-10 with dose D_3 *i.e* 1.5% EMS was found with maximum number of seeds per capsule. No significant difference was found for the character of capsule length.

The genotype Patan 64 with control dose (D_5) recorded late maturity while the genotype GT-4 with dose D_4 *i.e.* 2.00% EMS had early maturity.

GT-10 with control dose (D_5) recorded maximum 1000 seed weight while Patan 64 with dose D_4 *i.e.* 2.00% EMS had the least 1000 seed weight. The genotype GT-10 with control dose (D_5) recorded maximum yield per plant while Patan 64 with dose D_4 *i.e.* 2.00% EMS recorded the least yield per plant. The genotype GT-10 with control dose (D_5) recorded maximum harvest index, while the genotype Patan 64 with D_4 *i.e.* 2.00% EMS had the least value for harvest index.

The genotype GT-10 with control dose (D_5) recorded maximum oil content, while the genotype Patan 64 with D_4 *i.e.* 2.00% EMS had the least oil content. The genotype Patan 64 with D_4 *i.e.* 2.00% EMS recorded maximum protein content, while the genotype GT-10 with control dose (D_5) had the least protein content.

The estimates of variance component revealed that the characters like days to 50 per cent flowering, plant height, number of capsules per plant, days to maturity, 1000 seed weight, yield per plant, harvest index, oil per cent and protein per cent showed larger contribution of genotypic variance to total variance and also expressed high magnitude of heritability, which revealed less influenced of environmental factors on the expression of these characters. Rest of the characters showed low to moderate heritability, indicating high influence of environmental factors on expression of these characters. Extent of variability in the experimental material was high for characters like plant height, number of capsules per plant, 1000 seed weight, yield per plant and harvest index as indicated by high estimates of GCV; while rest of the characters had low to moderate GCV per cent.

The estimates of genetic advance as per cent of mean were high coupled with high heritability for days to 50 per cent flowering, plant height, number of capsules per plant, days to maturity, yield per plant and harvest index indicating the predominance of additive gene action in the inheritance of these traits, hence, simple selection would be effective for genetic improvement of the characters in desired direction. For number of seed per capsule and capsule length genetic advance as per cent of mean were high coupled with moderate to low heritability indicating limited scope of improvement

Seed yield per plant showed significant and positive correlation with plant height, primary branches, capsule per plant, 1000 seed weight, harvest index at both genotypic and phenotypic levels. Therefore, the possibility for simultaneous improvement of seed yield through improvement in the said component attributes by selection. Yield per plant exhibited a positive and significant correlation with capsule length at genotypic level while it also exhibited a positive and highly significant correlation with oil content at phenotypic level. Protein content recorded negative and highly significant correlation with yield at both genotypic and phenotypic levels. The genotypic correlations were higher in magnitude than the phenotypic correlations in most of the cases, indicating the masking effect of the environment in the total expression of the genotype.

The findings of present investigation lead to the following conclusions:-

1. In M_1 generation there was a gradual reduction in germination per cent with the increase in dose indicating the inhibitory effect on seed germination by EMS.
2. Based on mean performance of genotypes in M_2 generation for various traits like early flowering, it was recorded that the treatment V_1D_4 (2.00% EMS) flowered earlier than control thereby suggesting a superior nature than control which was a desirable effect from mutagenesis.
3. Generally medium height (75-125 cm) is preferred for sesame crop. From the above results it was found that for variety GT-4, V_1D_2 (1.00% EMS) and control (V_1D_5) showed desirable height, as for variety GT-10, V_2D_1 (0.5% EMS), V_2D_3 (1.5% EMS) and V_2D_4 (2.00% EMS) along with control showed desirable height indicating the positive outcome from mutagenesis.

4. For number of capsule per plant and number of seed per capsule treatment V_2D_3 (1.5% EMS) recorded high values suggesting their superiority than control which was a positive result from mutagenesis.

5. Early maturing cultivars are desirable for a crop. From the above results it was recorded that the treatment V_1D_4 (2.00% EMS) matured early thereby suggesting a superior nature than control which was an improved effect from mutagenesis.

6. Apart from being an important oilseed source, sesame seed is a potential source of proteins. From the above results it was recorded that treatment V_3D_4 (2.00% EMS) exhibited maximum mean value as compared to the non treated population which was a positive outcome from mutagenesis.

7. In M_2 generation the characters *viz.*, days to 50 per cent flowering, plant height, number of capsules per plant, days to maturity, yield per plant and harvest index displayed substantial variability, high heritability and high genetic advance. Hence, these characters could be improved by selection. The characters like number of primary branches, number of seed per capsule and capsule length showed moderate to low magnitude of heritability and moderate to high genetic advance, hence there would be little scope for improvement of these characters through selection. For characters like 1000 seed weight and oil content the per cent genetic advance was low accompanied by high heritability which indicated predominance of non additive gene action in the inheritance of character. Hence for the improvement of this character, population improvement approach would be remunerative.

8. The correlation study revealed the importance of characters like plant height, primary branches, capsule per plant, 1000 seed weight, harvest index, for increasing the yield. Yield per plant also exhibited a positive and significant correlation with capsule length at genotypic level and a positive and highly significant correlation with oil content at phenotypic level. Protein content recorded negative and highly significant correlation with yield at both genotypic and phenotypic levels. Based on *per se* performance for improving seed yield, high performing genotypes GT-10 with control dose (D_5), GT-4 with control dose (D_5) and GT-10 with 1.5% EMS (D_3) dose were identified as

elite genotypes. However, their potentiality should be confirmed by testing them over space and time.

9. From the present investigation therefore it can be concluded that the different effects of the EMS on the three genotypes and that the induction of mutation by EMS did create variability but did not give improved result with respect to yield in M_2 generation. However, selection of mutants can only begin in the M_2 generation as the mutant genes mostly are present in heterozygous condition and it needs many generations of selfing to achieve homozygosity. It is also possible that mutations may result in chromosomal aberrations leading to deletions and inversions; this in turn may cause loosing of important genes which would have contributed to high yield. This can be one of the reasons for the fact that mutations generally do not enhance yield but can be a tool for achieving special traits of importance.

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*Original not seen

APPENDIX I

Gographic and edaphic details of Anand centre

	PARTICULAR	DETAILS
	GEOGRAPHIC SITUATION	
	Elevation	45.1 Meters
	Latitude	22°-36' N
	Longitude	72°-55' E
	CHARACTERISTICS OF SOIL	
A.	**MECHANICAL PROPERTIES**	
	1) Coarse sand (%)	0.90
	2) Fine sand (%)	85.59
	3) Silt (%)	6.25
	4) Clay (%)	4.75
	5) Texture class	Loamy sand
B.	**PHYSICAL PROPERTIES**	
	1) Bulk density (g/cc)	1.51
	2) Particle density (g/cc)	2.65
	3) Porosity (%)	43.40
	4) Field capacity (%)	20.00
	5) Permanent wilting point	9.80
C.	**CHEMICAL PROPERTIES**	
	1) Organic carbon (%)	0.15
	2) Total nitrogen (%)	0.36
	3) Available P (kg/ha)	88.20
	4) Available K (kg/ha)	209.00
	5) pH	7.7
	6) EC ds/m (at 25 °C)	0.11

APPENDIX II

Meteorological data for the experimental period of crop season from August 2016 to November 2016

Month-Year and week		Temperature (ºC)			Relative humidity (%)			Rain fall (mm)	Sunshine (hr/day)	Wind speed (kmph)
Month	**Week**	**Max.**	**Min.**	**Mean**	**Morning**	**Evening**	**Mean**			
August-16	31	31.5	25.2	28.4	97.4	79.4	88.4	73.2	1.8	5.7
	32	30.0	24.5	27.3	95.6	85.0	90.3	96.8	1.0	6.0
	33	32.5	24.7	28.6	92.1	66.1	79.1	2.8	5.6	6.4
	34	29.5	24.9	27.2	94.7	90.1	92.4	49.6	1.1	5.5
	35	31.7	25.4	28.5	97.4	77.7	87.6	19.6	2.7	4.3
September-16	36	32.4	23.7	28.1	94.6	60.4	77.5	8.2	8.8	5.8
	37	34.5	24.9	29.7	90.7	54.1	72.4	0	8.7	4.4
	38	32.3	23.7	28.0	93.6	76.9	85.2	159.6	4.1	4.0
	39	33.3	24.2	28.7	93.6	64.9	79.2	0	9.1	5.7
October-16	40	32.1	24.0	28.1	98.3	79.9	89.1	44.2	3.6	4.2
	41	32.6	23.5	28.1	95.0	61.4	78.2	0	5.3	2.7
	42	35.0	19.6	27.3	89.3	35.4	62.4	0	9.0	2.3
	43	34.1	18.9	26.5	76.4	35.0	62.2	0	9.3	2.1
November-16	44	34.4	15.1	24.8	89.3	28.3	58.8	0.0	9.3	1.9
	45	33.9	13.0	23.4	96.4	27.4	61.9	0.0	8.9	1.4
	46	32.6	13.2	22.9	89.6	30.6	60.1	0.0	9.4	2.2
	47	33.3	12.7	23.0	92.7	27.9	60.3	0.0	9.5	1.7