# ESTIMATION OF INDUCED VARIABILITY IN CHILLIES

*By*

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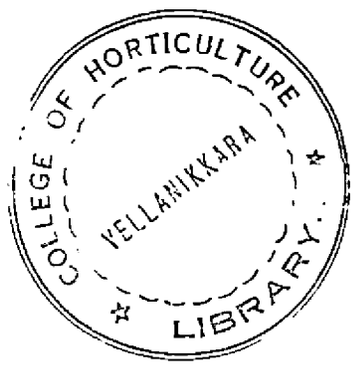


**THESIS**

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**1985**

# DECLARATION

I hereby declare that this thesis entitled "Estimation of induced variability in chillies" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Lekha Rani C.

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Vellayani,

22-1-1985.

# C E R T I F I C A T E

Certified that this thesis entitled "Estimation of induced variability in chillies" is a record of research work done independently by LEKHA RANI C under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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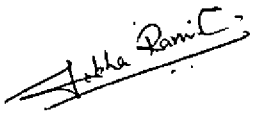

LEKHA RANI C.

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# INTRODUCTION

# INTRODUCTION

The utilisation of radiations and chemical mutagens as potent tools for inducing alterations in the genetic make up of organisms is one of the most important lines of contemporary breeding research. As far as crop improvement is concerned, it has been conclusively proved that mutagens can be beneficially utilised for tailoring better varieties of crop plants. Extensive studies have been conducted on artificially induced variations in crop plants, especially seed propagated plants. The reports conclusively prove that all sorts of morphological and physiological variations already existing within the species, as well as those not found in nature, can be induced by mutagens.

When genetic variability for the trait concerned is available within the species, crop improvement becomes considerably easy. But when genetic variation present in the population is exhausted, further progress through the conventional breeding methods becomes more and more difficult. In such situations, creation of further genetic variations through the use of mutagenic agents assumes special interest. Mutations can createvarieties for direct use or for indirect use in conventional breeding programmes.

It has been clearly stated by many workers including Gregory (1956) and Pate and Duncan (1963) that radiation is as efficient as hybridisation in supplementing genetic variability for selection. In certain situations induced mutations are the only solution for the problems faced by the breeders.

Majority of the economically important characters in crop plants such as number of fruits, fruit weight, yield etc. are controlled by polygenic systems. Hence for the improvement of such characters, assessment of the extent of created variability and the frequency distribution of variants is important. For quantitative characters, studies have to be conducted at the population level and mutants which transgress the prescribed range of the parents, though they occur at very low frequency, can still provide the necessary base for the desired direction of selection. Study of mutagen sensitivity is a pre-requisite for initiating practical mutation breeding programmes in any crop plant, as there is a positive correlation between sensitivity and yield of positive variants. The higher doses of mutagens lead to drastic changes at the genotypic level and consequently, majority of the variants are screened off. But lower doses produce only a very low frequency of deleterious effects. Hence

medium-doses of EMS (0.5% & 1.0%) and gamma rays (20 kR and 30 kR) were chosen for the present investigation.

Chillies - the attractive red condiment, is now an important commercial crop in India although it is a native of Latin America. Today India is the largest producer and consumer of chillies in the world, producing about 5.24 lakh tonnes of dried chillies from nearly 8 lakh hectares. It is now cultivated in all parts of the country either as a major crop or in home-steads. Majority of the types grown in India are of medium pungency. Many research stations in India have evolved several high yielding varieties in this crop. But almost all the varieties released and recommended for cultivation are highly susceptible to leaf curl complex in all the seasons. The lack of genes responsible for resistance reactions give a scope for induced alteration in the existing genotype of this particular crop variety.

The present investigation was taken up as a preliminary trial in the broad area of 'Induction of mutations for leaf curl resistance in chillies'. The objectives of the investigation were the following:

1. to study the effects of gamma rays and EMS in relation to genic status in chillies.
2. to find out the differential response of the varieties to moderate doses of EMS and gamma rays.
3. to study the general effect of gamma rays and EMS on induced variability in various polygenic traits in $M_2$ generation and
4. to study chimerism diplontic selection and elimination of mutated sectors as initiated by EMS and gamma rays on seed treatment.

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

The significance of artificially induced mutations in cultivated plants has long been a point of controversy among plant breeders. The utilisation of artificially induced mutations for breeding purposes was started as early as 1901 by De vries. But it was the classic discovery of Muller (1927) that x-ray could induce genetic changes in Drosophila that marked the beginning of the era of induced mutagenesis. The utilisation of radiation as a tool for inducing variability in crop plants was first reported by Stadler (1928). Since then, all kinds of radiations have been examined. In recent years, genetically effective radiations like x-rays, gamma rays and neutrons are widely used for induction of mutations. Radiations affect biological events such as germination, survival, growth and fertility in the immediate generation. They act at the chromosomal level causing structural and numerical changes as well as spindle abnormalities, or at the molecular level, causing changes in the macromolecular structure of DNA.

Sparrow et al. (1958) reviewed the investigations relating to the effects of radiations during 1896 to 1955. Detailed accounts of studies conducted with the help of ionizing radiations have been published by

many scientists including Gregory, 1956a, b; 1968; Gaul, 1959, 1961, 1964a, b; Sparrow, 1961; Evans and Sparrow, 1961, Sparrow et al., 1965, 1968; Sparrow and Pond, 1956; Gustafsson, 1963; Yamaguchi, 1964; Brock, 1965a, b; Nilan et al., 1965; Gottschalk, 1965, 1969; Gottschalk and Baquar, 1973; Iqbal, 1969, 1970, 1972: Tanaka, 1968; Mikaelsen, 1968; Mikaelsen et al., 1968; Broertjes, 1969, 1972 and Harten et al., 1972;1973.

Soon after the discovery of the mutagenic effects of radiation, search was made for chemicals that would produce cytogenetic changes. Auerbach et al. (1947) presented definite data on the mutagenic activity of mustard gas substances. With this discovery workers all over the world started surveying different chemicals for their mutagenic activity. Rapoport (1946; 1948) established the high mutagenicity of epoxides and epimines in Drosophila. Investigators have probed the relative advantages and disadvantages of different mutagens and alkylating agents have been found to be the most efficient in inducing mutations in a wide range of organisms from bacteria to mammals (Auerbach, 1961). Within the alkylating group, monofunctional agents in general and ethyl methane sulphonate (EMS) in particular appear to be more efficient in producing mutations in several organisms including higher plants (Swaminathan et al.

1962). The mutagenic efficiency of EMS was demonstrated by Ehrenberg (1960).

In seed propagated plants, chemical mutagens have yielded very high mutation frequencies, and in most cases, they were more efficient than ionizing radiations (Kamra and Brunner, 1970). The effect of alkylating agents and their mechanism of action on the biological system have been reviewed by Ross (1962), Loveless (1966), Lawley (1973) and Sun and Singer (1975). High mutagenicity of EMS in barley has been demonstrated by Heslot et al. (1959) and it has been corroborated by Gustafsson (1960) and others. Rao and Natarajan (1965) reported that compared to NMU and MMS, EMS induced higher rates of chlorophyll and viable mutations, in the $M_2$ plant basis.

The outstanding works of Gustafsson (1963), Yamaguchi and Mieh (1964), Kawai and Sato (1965), Bhatia and Vander Veen (1965), Konzak et al., (1965), Gaul et al. (1966 b), Sato (1966), Sato and Gaul (1967), Siddiq et al. (1968), Soriano (1968), Kawai (1969) and Mikaelson et al. (1971) gave a clear picture of the research work carried out to study the effectiveness and efficiency of chemical mutagens in various plant species.

Physical Vs Chemical mutagens

For the induction of mutations in plant materials, two groups of mutagenic agents, namely physical and chemical mutagens are available to the breeder. The former has been used for many decades whereas the use of chemicals is relatively later, starting approximately in 1940 (Broertje and Van Harten, 1978). Some encouraging results were obtained by Shiemann (1912) with chemical mutagens. Friese (1963) classified chemical mutagens as base analogue substitutes, dyes, acids, metals and alkylating agents. In higher plants, the last group especially EMS has proved to be very effective. The relatively low toxicity and high genetic effects of EMS (Gaul, 1961) and its high mutagenic effectiveness and efficiency in higher plants (Konzak et al. 1965) demand attention for endured practical application.

Formerly, it was believed that mutagens particularly affect specific genes and change them in a desired direction, and hence search was made for such mutagens. But later, it was reported that ionizing radiations act in a more or less random fashion, affecting both the eu-and heterochromatic regions of chromosomes and so the hope for gene specificity was directed to chemical mutagens (Micke, 1970). With physical and

chemical mutagens, three types of effects of specific interest in genetics and breeding which are easy to measure are produced. They are (1) gene mutations (2) chromosomal aberrations and (3) physiological disturbances. Aberrations and physiological disturbances produce undesirable damaging effects leading to reduced germination, decreased survival, seedling injury and reduced fertility in $M_1$ generation.

The absorption of ionizing radiations in a living cell causes a variety of structural aberrations in chromosomes which are visible under the microscope. Chemical mutagens on the other hand, enter into chemical reactions with the gene, which would then result in a particular genetic change depending on the nature of the mutagen. In support to the above fact, it has been made clear that the spectrum of induced mutations and recoverable mutations varies depending on the mutagens used (Nilan, 1966; Smith, 1961). Nilan and Konzak (1961); Ehrenberg et al. (1961) and Gustafsson (1963) reported that the spectrum of chlorophyll deficient mutants may depend on the type of mutagens employed. This shows that the mutation rates of specific loci may also vary depending on the type of mutagens used in addition to other modifying factors. So it is considered worthwhile

using several mutagens in mutation work, as the chances of getting particular desirable mutants are then increased.

As reported by Kamra and Brunner (1970), chemical mutagens have yielded very high mutation frequencies and in most cases, they were more efficient than ionizing radiations, especially in sexually propagated crop plants. However, most of the varieties developed by mutation breeding have arisen from materials irradiated with ionising mutations only (Sigurbjarnsson and Micke, 1969). It will be premature to assess the merits of chemical mutagens on the basis of the number of varieties to which they have given rise, since extensive work with chemical mutagens has begun only in 1960, following the introduction of EMS. As such, there is no definite indication that preference should be shown to either physical or chemical mutagens.

2. Genic status in relation to mutation frequency:

In recent years, the role of nuclear volume and chromosome content (DNA value) in determining the radiosensitivity of plant species has received a great deal of attention. It has been clearly demonstrated that there is an inverse relationship between radiosensitivity and DNA content. Data for the prediction of radio-

sensitivity of seeds in relation to total DNA content have been published by Osborne et al. (1963) and by Lunden (1964). Genetic differences even though they are as small as single gene differences, can induce significant changes in radiosensitivity. Gustafsson (1944, 1947, 1965), Gustafsson and Tedin (1954), Nilan (1956), Lamprecht (1956 and 1958), Gelin et al. (1958), Smith (1961), Sparrow (1961), Konzak et al. (1961 a) and Sparrow et al. (1965) clearly reported that any change in genotypic level can induce significant changes in radiosensitivity which influence not only the total rate, but also the spectrum of recoverable mutations. Ramalingam (1980) reported that spectrum of mutations differed according to variety and mutagen and interaction between variety and dose of a particular mutagen. A variety-dependent variation was observed in the sensitivity to physical and chemical mutagens. Considerable differences in the early yield and chemical composition were found between the dES induced mutants in different varieties (Dikii et al., 1979).

A clear and specific prediction on the influence of a particular genotype on the mutation spectrum is not available as reported by Mackey (1960 a,b). Jagathesan and Swaminathan (1961) and Swaminathan (1965) reported a differential effect of mutagen between species of the

same ploidy level and between varieties within the same species in various crops.Radiosensitivity of haploid plants was found to be higher than that of diploids by Tanaka (1970). The diploids in turn were reported to be more sensitive than the respective auto tetraploids (Yamaguchi and Kobayashi, 1960, Yamaguchi, 1964, Sree Rangaswamy 1970). Enken (1966a,b) concluded that the closer the varieties are in their genotypes, greater is the similarity in their spectra and frequency of mutation.

Gregory (1960) stated that "the chief limiting factor in mutation production and mutation recovery is the genic constitution of the experimental organism and not the type of mutagen used. Thus for the plant breeder, a knowledge of what might be called mutant expectations in his material may be made important than a resolution of the mechanism of mutational changes at the submicroscopic level".

Comparison among varieties of tomato (Bianchi et al. 1963) barley (Mikaelson and Brunner, 1968) and pea (Mukeeb and Siddiqui, 1973) showed variation in respect to radiation response among different genotypes indicating the influence of genetic factors on radiosensitivity. Krishnaswami and Rathnam (1982) reported differential sensitivity to EMS exhibited by ten greengram cultivars.

Gamma irradiation of greengram varieties indicated variation in the mutagenic sensitivity in the $M_1$ generation (Ratnaswamy et al. 1978).

Davies (1962) studied the genetic control of radiosensitivity in tomato using growth measurements and other characters. Bianchi et al. (1963) have also conducted experiments with tomato varieties. Sahib and Abraham (1970) studied the biological effect of x-rays on $K_1$ variety of chillies and studied the morphological abnormalities and chromosomal aberrations induced in $M_1$. Marked intervarietal differences in radiosensitivity were recorded by Matsuo et al.(1958), Fuji (1962). Ukai (1967) and Nikaelsen and Navaratna (1968) in rice. The varietal differences in radiosensitivity were also reported to be due to differences in chemical composition (Myttenaere et al. 1965) or due to differences in endogenous levels of auxin and ascorbic acid (Goud et al. 1967).

3) Mutagen affected $M_1$ fertility

Siddiq and Swaminathan (1968) reported that chemical mutagens induce more sterility compared to radiations. Decrease in fertility in sorghum following physical mutagen treatments had been observed by Goud et al.(1970) and Ramulu (1974). An inverse relationship between grain fertility in $M_1$ and doses of gamma rays was reported in

sorghum (Reddy and Smith, 1975) and rice (Yamaguchi et al. 1976).

EMS was superior to gamma rays as a mutation inducing factor and at the same time caused much less reduction in fertility (Ehrenberg et al. 1959); Sharma and Bensal, 1970). Linear relationship of reduction in fertility following EMS treatment was observed in rice (Soriano, 1968; Rahman and Soriano, 1972). Singh et al. (1978) observed decrease in pollen fertility as doses of mutagens increased, especially with EMS in barley. Similar result was obtained by Proskurnin (1971) at higher doses in barley.

Singh (1970) observed that gamma rays induced a high frequency of translocation and this might be correlated with pollen sterility, whereas with chemical mutagens such as EMS, there was a marked reduction in pollen and seed fertility though the extent of chromosomal aberrations was negligible. Zubrzycki and Pahlen (1973) compared the effects of EMS and X-rays in the induction of mutations in chillies. Bensal and Singh (1972) studied a polypetalous mutant of NP-46A, which breeds true and which was induced by X-rays. Bensal (1973) discovered a mutation in C. annuum variety NP-46A, in which reproductive parts were transformed to vegetative by treatment with EMS NMU.

4. Chimera and diplontic selection:

Most mutation breeding experiments have been initiated with complex multicellular tissues, either with seeds in sexually propagated plants or with buds or cuttings in asexually propagated species. In all cases, plants will develop which are composed of genetically different tissues, called "chimeras", which will lead to diplontic selection and finally elimination of the mutated sectors as reported by several workers. Therefore in order to reduce the diplontic selection and to obtain mutated sectors not too small for detection, the treatment should be given when the primordia in question consists of a few undifferentiated cells (Gaul, 1959 a & b). Swaminathan (1970) and Goud et al. (1970) reported that the plants with drastic changes have been eliminated due to a rigorous diplontic selection and naturally, the surviving plants had less abnormalities.

Radiobiological studies present a new line of approach in investigations on the structure of the embryo and development of plant organs, through the differential effects on primordial cells. Swaminathan (1966a) inferred that the dormant rice seed when exposed to mutagenic treatment had eight to ten initials which would give rise to tillers. Kawai (1963 a) reported that following

treatments with heavy doses of radiations, the same mutation was distributed over almost all the ears in certain $M_1$ plants, indicating that all the ears originated from a single primordium. It was inferred that all primordia except one might have been killed by severe radiation injury.

Gelin (1956) and Gaul (1959 b) analysed the chimerism by means of translocation studies in barley metaphase 1 PMC (Pollen mother cells). However, the investigations were complicated by the fact that spikes containing more than one or a few spikelets in the proper stage of development are rare. The incidence of chlorophyll deficient sectors on the leaves of $M_1$ plants in cereals after mutagenic treatment had been observed by several workers. Frequency of plants with chlorophyll deficient sectors did not show a clear dependence on dose in rice (Nayar, 1971). Hsieh (1959) suggested that variegations induced by radiations in the $M_1$ generation were due to plastid mutations. Prasad (1972) coincided with the above observation in sorghum. On the other hand, Kaplan (1954) observed that the number of leaf spots increased exponentially with the dose and concluded that chromosomal aberrations were responsible for the induction of the spots. This interpretation was supported by the findings of Zacharias and Ehrenberg

(1962) that X-rays produced leaf spots in proportion to the square of the dose, whereas fast neutrons induced spots in proportion to the dose. D' Amato et al. (1962) reported high frequency of chlorophyll deficient chimeras with chemical mutagen in wheat. Rao and Natarajan (1965) and Varghese and Swaminathan (1968) reported the same in barley and wheat respectively. Some workers including Varghese and Swaminathan (1968) have explained it as due to the result of strong alkylation. Kapoor (1967) in sorghum observed chlorotic streaks in about 35 per cent of $M_1$ population.

Siddiq (1968) and Siddiq and Swaminathan (1968) found lower segregation ratios with *EMS* than with gamma rays. Swaminathan et al. (1970) had concluded that chemical mutagens generally yielded a lower segregation ratio than radiations, probably due to operation of a less rigorous somatic sieve. Yamaguchi (1962) reported that following gamma irradiation, the segregation ratios increased with increasing doses in rice. Similar results were obtained in rice by Kawai and Sato (1965) and Ando (1968). A dependence of mutated sector size on the dose of the mutagen was reported by Bekendam (1961), Yamaguchi (1962 a) Osone (1963), Kawai and Sato (1965), Siddiq (1968) and Singh (1970). Kawai and Sato (1965) and Siddiq (1968) observed that the size of mutated

sectors in $M_1$ ears was smaller in treatment with chemical mutagens than with radiations. The sector size was found to increase with increasing doses of chemical mutagens and radiations. This increased sector size at higher doses was probably due to a proportionate reduction in the number of initial cells involved in the development of the panicle.

In general, the number of initial cells in the material exposed effect the mutation frequency and segregation ratio. The smaller the number of initial cells, the lesser the probability for mutation to occur in them and the larger the size of mutated sector, implying that the later formed tillers or branches would have low mutation frequency but high segregation ratios. This inference was confirmed by the observations of Frydenberg et al. (1964) in barley.

5. Induced micro-mutations

The expression "Micro-mutation" is used to mean mutations in polygenes governing quantitative characters, leading to small changes in phenotypes. Majority of the economically important characters in crop plants are polygenic in nature. As pointed out by East (1935), the deviations forming the fundamental materials of evolution are the small variations mentioned by Darwin.

Baur (1924) in his paper on the means, origin and inheritance of racial differences in Antirrhinum introduced the term "Klein-mutationen" which Gregory (1968) interpreted as synonymous with micro-mutations. The first convincing report that physical mutations like X-ray can induce new variability in quantitative traits was presented by Buzzati Traverso (1955) in Drosophila.

Following the successful experiences of Gregory (1955) in the usefulness of mutation tool for groundnut improvement, breeders in different crop plants resorted to the micro-mutation technique to improve quantitatively inherited characters like yield and its components. Sax (1955) reported that yield can be increased by certain stimulatory doses of radiations, which may be due to higher mitotic activity of mutants (Tedoradze et al., 1977, Javeed Iqbal, 1979). Radiations produce more chromosome mutations which are sieved off during meiosis while EMS is known to produce comparatively more point mutations (Ehrenberg et al. 1959).

Experiments of Humphrey (1954) and Rawlings et al. (1958) on induced mutations in soybean clearly showed that the estimates of genetic variations for yield, plant height, maturity time and seed size on the average

were five times as large as those of the controls, giving a better chance for selection. Scossiroli (1966a) reported that it would be normal to observe some decrease in mean values on quantitative traits measured in normal looking plants as compared with control, since the majority of the small mutations induced would be detrimental. Aastveit (1966) opined that induced polygenic mutations don't follow any particular direction and that they are at random.

Rao and Sears (1964) working with wheat, concluded that alkylating agents, EMS and NMU are capable of inducing functional alterations of genes in polyploid plants. A general reduction of mean and a significant skewness of distribution after mutagenic treatments was reported by Scossiroli (1965), Goud (1967a) and Minocha et al. (1977). Kumar and Das (1977) have also agreed with the above report and explained the cause as the action of ionizing radiations on chromosomal and extra-chromosomal parts of the cell.

Increase in variance following mutagenic treatment was a common feature observed in quantitative characters as reported by several investigators (Oka et al. 1958; Bateman, 1959; Kao et al., 1960 and Matsuo and Onozawa, 1961). Oka et al. (1958) and Oka et al. (1962) reported

an increase in variance with increasing doses of mutagens, but Yamaguchi (1960) observed an opposite effect. Yamaguchi (1964) confirmed that variance did not increase linearly with the radiation dose. On the other hand, Miah and Bhatti (1968) reported that the variance decreased at higher doses. Sakai and Suzuki (1964) and Tanaka (1968) found that distribution of variance for certain characters was skewed and therefore, stated that the mutation of polygenes occured mostly in a negative direction. Swaminathan (1966 a) was of opinion that the directions of incidence of micro mutations was strongly influenced by the previous selection history of the variety.

Brock et al. (1972) had reported that the increased variability in mutagen treated population was found to be largely due to increase in genetic components. X-ray and neutron treatments on soybeans by Humphrey (1954) and Rawlings et al. (1958) resulted in an increase in genetic variability for yield, plant height, maturity and seed size, oil and protein content. Borojevic and Borojevic (1968) reported that genetic variability for several quantitative characters increased in irradiated population of Triticum aestivum.

The induced genetic variability proved also to be suitable for artificial selection on specific quantita-

tive traits. The experimental work initiated by Scossiroli (1954) and followed by Clayton and Robertson (1955 and 1964), Yamada and Kitagawa (1961), Kitagawa (1967) proved to be fundamental to this point of view. Improved yield due to selections in irradiated populations have been reported in barley by Gaul (1961a, 1965a) and in durum wheat by Bogyo et al. (1969).

The classical works of Brock (1957) and Gregory (1968) on improvement of yield and Gustafsson (1965) on adaptability, Brock (1970) on maturity and Sigurbjornasson and Micke (1969) on numerous other traits gave a clear picture of the role and importance of induced mutations in different crop plants from a plant breeding point of view.

# MATERIALS AND METHODS

# MATERIALS AND METHODS

The present investigation to assess the created variability in chillies due to $^{60}$Co-gamma rays and ethyl methane sulphonate (EMS) was carried out in the College of Agriculture, Vellayani, during 1983-84. Three varieties of Capsicum annuum were chosen, one each from the low, medium and high mutagen sensitivity groups (Asha,1983).

## Selection of seed material:

The three varieties of chillies selected were CA-30, Blue Pendent and CA-12. Pure and well developed seeds obtained from fully ripened fruits of healthy plants were used for the study. Sun-dried, healthy-looking seeds having uniform size and colour were selected for mutagenic treatment.

## Gamma irradiation:

Two hundred seeds of each variety were exposed to 20 and 30 kR gamma rays, using a $^{60}$Co-gamma shine unit installed at the Department of Botany, University of Kerala, Kariavattom, Trivandrum. The dose rate employed was 70.4 kR/hr. The irradiated seeds were soaked in distilled water for about 20 hours and sown in pots on the following day of treatment.

EMS treatment:

EMS solutions of 0.5 and 1.0 per cent concentrations were prepared in double glass distilled water immediately before use. Two hundred seeds of each variety were used for each concentration. Seeds pre-soaked in distilled water for 12 hours were treated with the above two concentrations of EMS. Before treatment, superficial water on the pre-soaked seeds were removed by gently pressing them within the folds of a blotting paper, so as to prevent further dilution of the mutagenic solution.

The pre-soaked seeds were immersed in the mutagen solution at room temperature for six hours with intermittent shaking. To facilitate uniform absorption of the mutagen by the seeds, 20 ml of the solution was used, approximately ten times the volume of the seeds. The solution was maintained at room-temperature throughout the period of treatment.

After treatment, the seeds were washed thoroughly in double glass distilled water, and then kept in running water for two hours. Corresponding controls were kept in distilled water for the same period and were handled the same way as the treated ones.

Raising $M_1$ generation:

The gamma-ray and EMS treated and control seeds were sown in two replications of 100 seeds each. Uniform potting mixture prepared with cowdung, river sand and soil was filled in the pots. Seedlings randomly selected from these pots were transplanted on to the main field on the 35th day of sowing. A spacing of 40 cm between rows and 30 cm within rows was given to the seedlings which is closer as compared to the normal recommendation. This was provided to avoid excessive vegetative growth of the $M_1$ plants. Special care was taken to provide uniform field conditions for these plants till harvest.

Fertilizer application was done at the rate of 35.5 kg, 20 kg and 12.5 kg of NPK per hectare, being half the recommended dose. Half the dose of N & K and full dose of P and cowdung was given at the time of transplanting and the rest, one month after transplanting. All the field experiments in this study relating to $M_1$ and $M_2$ were conducted in the experimental area attached to the Department of Agricultural Botany, College of Agriculture, Vellayani.

Collection of seed material from $M_1$ generation:

The flowers of ten selected $M_1$ plants from each treatment were selfed and the seeds extracted from fully

ripened fruits. To have detailed analysis on diplontic selection, branch-wise fruit collection was done from five of the selected plants. The branches were numbered based on the sequence of emergence from the base. Five healthy, selfed fruits were collected from each of the first three branches. Fruits collected from the remaining branches as well as the main axis were bulked, thus making four different lots. For the remaining five sample plants fruits were collected from the main axis and branches and bulked. Plant-wise fruit collection for each variety was done from five control plants also. First formed flowers from each plant and branch were selfed, and ripe fruits were harvested about 1 to 1½ months later. The ripe fruits were properly labelled and collected as separate lots as described above, and stored in paper covers till the seeds were extracted.

Seed extraction from $M_1$ fruits:

The ripe fruits collected and stored in paper covers were dried in the sun for a few days prior to seed extraction. Seeds were extracted only from healthy fruits and all shrunken, discoloured and under-sized seeds were discarded. The seeds were sun-dried and kept in paper covers in dry places in order to avoid fungal attack.

Raising $M_2$ generation:

$M_1$ seeds were uniformly dried and sown in one metre broad beds, each lot sown as separate rows, 30 cm apart, one month after extraction. From the branch-wise collections, seeds from the first three branches were sown as separate rows, and those from the remaining branches as another row. A single row from each plant was considered as sufficient to represent the plant-wise collections. Five rows of control seeds per variety were also raised.

As the seedlings had not attained sufficient growth for transplanting on the 30th day, an additional dressing of Ammonium sulphate was applied. A maximum of 30 seedlings per treatment, per replication, randomly selected from these rows were transplanted to the main field, on the 40th day of sowing in two replications with a spacing of 45 cm between rows and between plants. Two seedlings per pit was planted and thinned down to one on establishment. Necessary gap filling was also done. As far as possible, uniform field conditions were given to the plants till harvest. The crop was maintained following the Package of Practices recommended by the Kerala Agricultural University. Fertilizer applications were done at the rate of 75 kg, 40 kg and 25 kg of NPK per hectare. Half the dose of N & K and full dose of P was given at

the time of transplanting, and the remainder one month afterwards. Optimum spacing and fertilizer application was given for maximum character expression in the segregating generations.

Observation in $M_2$ generation:

The following observations were taken in $M_2$.

1) Chlorophyll mutation frequency:

The chlorophyll deficient mutants were screened out on the 20th day of sowing and their frequency calculated. Due to lack of different types of chlorophyll mutants the spectrum was not taken into consideration. Chlorophyll deficient mutants were screened in the early hours of the day and the percentage segregation calculated on branch-wise and seedling basis.

2) Viable mutations:

Gamma ray treated and control plants were subjected to periodical observations and the visual variants were scored.

3) Quantitative mutations:

Detailed observations on the following quantitative traits were made and data collected.

1) Plant height at transplanting stage and on the 30th, 60th and 90th day of planting.
2) Number of branches per plant.

3) Number of fruits per plant

4) Weight of fruits

5) Length of fruits

6) Yield per plant and

7) Number of seeds per fruit

Seedling height:

The height of seedlings on the 30th day of sowing was measured. Fifteen seedlings were randomly chosen from each row and the height was taken from the soil level to the tip of the shoots and expressed in cm. The average height for each dose was calculated.

Plant height:

Plant height was taken at 3 stages of growth at an interval of 30 days, namely 30th, 60th and 90th day after transplanting. Here also the height was taken from the soil level to the shoot tip.

Number of branches:

Number of branches produced per plant was also studied at maturity. The primary branches arising from the main axis alone were taken into consideration. Number of fruiting branches were also taken.

Number of fruits per plant:

Data on the total number of fruits produced per plant was also studied in the $M_2$ generation.

Weight of fruits:

Fruit weight was determined from fresh, fully mature fruits in the $M_2$ generation. Five fruits per plant were weighed from ten randomly selected plants in each treatment and the mean fruit weight per plant was calculated in g.

Length of fruits:

The length of fruits was measured as the distance from the point of attachment to the tip. As above, a sample of five fruits per plant was measured from ten sample plants per treatment and the mean expressed in cm.

Yield per plant:

Yield per plant was found out by multiplying mean fruit weight per plant with the number of fruits per plant and expressed in g.

No. of seeds per fruit:

The seeds were extracted from five ripe fruits from each of the ten sample plants per treatment and the number of seeds per fruit was counted.

Classification of $M_2$ phenotypes:

$M_2$ phenotypes were classified under three different classes namely positive variants, control group and negative variants. As the range of control group varied in

different varieties, classification was done independently for each variety.

Based on height of plants, classification was done as follows:-

1. Dwarf (below 20 cm height, plants in the negative group for CA 30)

( " 25 cm " " in the negative group for (Blue Pendent)

( " 20 cm " " " (CA-12)

2. Medium ( 20-30 cm height-- control group (CA-30)

( 25-35 cm " -- " (Blue Pendent)

(20-30 cm " -- " (CA-12)

3. Tall (above 30 cm height plants in the positive group - (CA-30)

(above 35 cm " " (Blue Pendent)

(above 30 cm " " (CA-12)

Based on branches per plant, they were grouped under three different classes:

1) Low branching { Less than 2 branches per plant -Negative group for (CA-30)
{ no branches/plant - negative group for (Blue Pendent)
{ no branches/plant - negative group (CA-12)

2) Medium branching

(2-4 branches per plant-control group (CA-30)

(1-2 " " " (Blue Pendent)

(1-2 " " " (CA-12)

3) High branching

(More than 4 branches per plant= positive group (CA-30)

(More than 3 " - " (Blue Pendent)

(More than 2 " - " (CA-12)

Similarly, in the case of all other characters, the $M_2$ plants were classified under 3 heads, ie.

1) Plants falling in the positive group

2) Plants falling in the control group

3) Plants falling in the negative group

The frequency of each group per treatment was calculated in percentage and significance tested following proper statistical procedures.

## Statistical analysis

Analysis of variance of the $M_2$ data was done following Fischer (1935). Percentage values were transformed by the angular transformation as proposed by Snedecor (1956). Analysis of mean tables was done as a factorial in RBD with 3 varieties and five treatments, namely two doses each of gamma rays, EMS and control, with two replications. The outline of analysis of variance table showing the source of variations and corresponding degrees of freedom is given below:

| Source | degrees of freedom |
|---|---|
| Replication | 1 |
| Treatment | 4 |
| Between varieties (V) | 2 |
| Between Treatments (T) | 4 |
| Between mutagens | 1 |
| Between levels of mutagen 1 | 1 |
| Between levels of mutagen 2 | 1 |
| Treated Vs Control | 1 |
| V x T | 8 |
| Error | 14 |
| Total | 29 |

From the same experiment, in order to study the effect of seed collection from different branches on character expression, analysis was done as that of a split plot design, treating the modes of seed collection as minor treatment. In this experiment, control was not taken into consideration as branch-wise seed collection was not followed there. So the experiment consists of three varieties and four treatments, being taken as the 12 major treatments and five modes of seed collection as the minor treatment, with two replications. The outline of analysis of variance is as follows:

| Source | degrees of freedom |
|---|---|
| Replication | 1 |
| Major treatment | 11 |
| V | 2 |
| T | 3 |
| V x T | 6 |
| Error (1) | 11 |
| Minor treatment (M) | 4 |
| V x M | 8 |
| T x M | 12 |
| V x T x M | 24 |
| Error (2) | 48 |
| Total | 119 |

Analysis of the $M_2$ phenotypic classes was done in the form of a split-plot design. The three phenotypic classes namely positive variants, control group and negative variants are treated as a third split up in the original data. The various combinations of varieties (3) and doses of mutagens (4) from the 12 main plot treatments, the five modes of seed collection from $M_1$ plants as sub-plot treatments, and the three phenotypic classes forming the sub-sub plot treatments. The split up of the degrees of freedom due to various sources of variation is given below:

| Source | Degrees of freedom |
|---|---|
| Block | 1 |
| Treatment | 11 |
| V | 2 |
| T | 3 |
| V x T | 6 |
| E (1) | 11 |
| M | 4 |
| V x M | 8 |
| T x M | 12 |
| V x T X M | 24 |
| E (2) | 48 |
| S | 2 |
| V x S | 4 |
| T x S | 6 |
| M x S | 8 |
| Higher order interaction | 100 |
| E (3) | 120 |
| Total | 359 |

# RESULTS

# RESULTS

## 1.1. Mean plant height as influenced by genotypes and mutagens

The mean plant height as influenced by varieties, mutagens and their doses is presented in Table 1-1. The statistical analysis of the data showed significant variation among varieties and between mutagens. But the differences is mean value between levels of mutagens and the treatments compared to control and variety into dose effect interactions were not significant. The mean plant height in $V_1$ for the different doses ranged from 25.58 cm in 20 kR gamma rays to 30.58 cm in 1.0 per cent Ethyl Methane Sulphonate, the control being 26.69 cm. In the variety $V_2$ mean plant height for the different doses ranged from 31.7 cm in 20 kR gamma rays to 38.95 cm in 1.0 per cent EMS, with a control value of 34.9 cm. In $V_3$ the range was from 28.01 cm in 30 kR to 31.66 cm in 0.5 per cent, with a mean plant height of 29.06 cm in control population. An insignificant negative or positive shift compared to control was noted, depending on varieties, mutagens and doses employed.

A variety dependent significant variation in plant height was noticed. Variety $V_2$ had the maximum mean

Table 1-1 Mean plant height (cm) as influenced by genotypes and mutagens

| Varieties | Control | EMS | | Gamma rays | | General mean |
|---|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20kR | 30kR | |
| $V_1$ | 26.69 | 27.41 | 30.58 | 25.58 | 26.48 | 27.35 |
| $V_2$ | 34.9 | 32.26 | 38.95 | 31.70 | 32.22 | 34.01 |
| $V_3$ | 29.06 | 31.66 | 28.75 | 28.71 | 28.01 | 29.24 |
| General mean | 30.22 | 30.44 | 32.76 | 28.66 | 28.90 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Between varieties (V) | 15.08* | 2.68 |
| Between mutagens | 5.32* | 5.99 |
| Between levels of EMS | 2.06 | - |
| Between levels of gamma rays | 0.02 | - |
| Treated Vs Control | 0.01 | - |
| Varieties x Treatments | 0.88 | - |

* Significant at 5% level

plant height of 34.01 cm which was significantly superior to the other two varieties. In all the three varieties, mean plant height was higher in EMS treatments compared to gamma ray exposures. A reduction in mean value under both 20 and 30 kR gamma ray exposures as compared to the control was observed in all cases. In $V_1$ and $V_2$ maximum mean plant height was noted in 1.0 per cent EMS concentration while in $V_3$ it was noted under 0.5 per cent. The mean height was minimum under 20 kR exposure in all the three varieties. A significant difference in mean plant height between the two mutagens was observed in $V_2$ between 20 kR gamma rays (31.7 cm) and 1.0 per cent Ethylmethane sulphonate (38.95 cm).

1.2. Mean plant height under different $M_1$ branch categories:

Data regarding mean plant height as influenced by varieties, mutagens and their doses, as well as $M_1$ branch categories is presented in Table 1-2. Statistical analysis of the data showed significant variation among varieties, treatments, varieties into treatment interaction, among the five branch categories, varieties into branch categories interaction, treatments into branch categories interaction and in

Table 1-2 Mean plant height (cm) as influenced by varieties, $M_1$ branch categories and mutagens and their doses

| Varieties | Mutagens | Doses | $M_1$ branch categories | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| $V_1$ | EMS | 0.5% | 27.69 | 24.68 | 27.08 | 27.26 | 27.41 | 26.82 |
| | | 1.0% | 27.65 | 29.77 | 28.76 | 28.46 | 30.58 | 29.02 |
| | Gamma rays | 20 kR | 27.65 | 30.11 | 30.51 | 31.04 | 25.58 | 28.98 |
| | | 30 kR | 29.95 | 30.85 | 31.63 | 29.75 | 26.48 | 28.93 |
| $V_2$ | EMS | 0.5% | 31.74 | 36.42 | 31.32 | 34.34 | 32.26 | 33.21 |
| | | 1.0% | 32.48 | 30.19 | 29.39 | 34.36 | 38.95 | 33.07 |
| | Gamma rays | 20 kR | 34.36 | 35.09 | 41.03 | 35.39 | 31.70 | 35.51 |
| | | 30 kR | 39.29 | 37.65 | 36.90 | 33.99 | 32.22 | 36.01 |
| $V_3$ | EMS | 0.5% | 32.70 | 38.41 | 34.74 | 32.09 | 31.66 | 33.94 |
| | | 1.0% | 32.48 | 32.07 | 30.89 | 28.47 | 28.75 | 30.53 |
| | Gamma rays | 20 kR | 0 | 0 | 0 | 0 | 28.71 | 28.71 |
| | | 30 kR | 0 | 0 | 0 | 0 | 28.01 | 28.01 |
| Mean | | | 31.21 | 32.52 | 32.22 | 31.51 | 30.19 | |

Analysis of variance

| Source | F value | C.D. Value |
|---|---|---|
| Major treatments | 29.11* | 6.05 |
| Varieties (V) | 64.61* | 6.15 |
| Doses (T) | 15.47* | - |
| V x T | 24.09* | - |
| Minor treatments (M) | 7.28* | 1.78 |
| V x M | 9.67* | 6.15 |
| T x M | 91.32* | " |
| V x T x M | 21.51* | " |

* Significant at 5% level

the higher order interaction (varieties into treatments into branch categories).

Mean plant height in $V_1$ ranged from 24.68 cm in the first branch category under 0.5 per cent EMS to 31.63 cm in the third category under 30 kR. A range in value from 29.39 cm in third branch category under 1.0 per cent EMS to 41.03 cm in the same category under 20 kR was noted in $V_2$. In $V_3$ the range was from 28.47 cm in the fourth category under 1.0 per cent EMS to 38.41 cm in the second category under 0.5 per cent EMS.

The mean plant height ranged from 24.68 cm in the second branch category to 27.69 cm in the first branch category under 0.5 per cent EMS in $V_1$. Under 1.0 per cent concentration the lowest mean plant height was recorded in the first branch category (27.65 cm) and the highest in the fifth category ie. whole plant seed collection. But 20 kR gamma rays showed the minimum mean plant height of 25.58 cm in the bulk seed collection and the maximum (31.04 cm) in the fourth category. In the higher dose of the physical mutagen, the mean plant height ranged from 25.95 cm in the first category to 31.63 cm in the third category. It was noted that the higher doses of both physical and chemical mutagens recorded the lowest mean plant height in the first branch category.

The minimum mean plant height of 31.32 cm and 29.39 cm in $V_2$ under 0.5 and 1.0 per cent EMS respectively was observed in the third branch category. In 0.5 per cent the mean plant height ranged to 36.42 cm in the second branch category and in 1.0 per cent in the bulk seed collection (38.95 cm). But in physical mutagen treatment, the lowest mean values were observed in bulk progeny, being 31.70 cm in 20 kR and 32.22 cm in 30 kR. Third category recorded the highest value under 20 kR (41.03 cm) and the first category in 30 kR (39.29 cm). In $V_3$ the early formed branches showed the highest mean plant heights and the corresponding minimum values were in the bulk seed collection and in the fourth branch category.

The mean plant heights recorded under the different levels of mutagens in the varieties tried ranged from 26.82 cm under 0.5 per cent in $V_1$ to 36.01 cm under the same dose in $V_2$. The mean values recorded for $V_2$ under 20 and 30 kR gamma rays, 35.51 cm and 36.01 cm respectively, were found to be significantly superior to the $V_1$ means of 26.82 cm in 0.5 per cent EMS, 29.01 cm in 1.0 per cent 28.98 cm in 20 kR, 28.93 cm in 30 kR and the $V_3$ means of 28.71 cm and 28.01 cm under 20 and 30 kR respectively. The last two main plot means were found to be significantly inferior to all other main plot means recorded

under the same and the other two varieties. All the four $V_2$ means of 33.21 cm (0.5% EMS), 33.07 cm (1.0% EMS), 35.51 cm (20 kR), 36.01 cm (30 kR) and also the $V_3$ mean of 33.94 cm (0.5% EMS) were found to be significantly superior to the $V_1$ mean value under 0.5% EMS (26.82 cm).

The sub plot (branch categories) means ranged from 30.19 cm in the bulk progeny to 32.52 cm in the second branch category. Bulk seed collection was found to be significantly inferior to second and third branch category means.

No significant variation among sub plot (branch category) means at the same level of main plot (varieties and treatments) was noted in $V_1$. A significant variation in mean plant height was noted in $V_2$ under 1.0 per cent EMS between the third branch category (29.39 cm) and the first, second and fifth branch category means (32.48 cm, 30.19 cm and 38.95 cm respectively). Under 20 kR gamma rays, the mean plant height of 41.03 cm recorded in the third branch category was significantly superior to that noted in the fifth branch category (31.70 cm). In 30 kR also, mean plant height in the fifth branch category (32.22 cm) was significantly inferior to the mean plant height in the first category (39.27 cm). The mean plant height of 38.41 cm recorded

in the second branch category was significantly superior to those observed in the 4th and 5th categories, 32.09 cm and 31.66 cm respectively, under 0.5 per cent of $V_3$. Significant variation in mean value was not observed in the other doses tried in $V_3$.

1.3. Phenotypic frequency of Plant height variants:

The frequency distribution of plant height variants ( in percentage) as affected by Gamma rays and EMS in three varieties of chillies under five $M_1$ branch categories is represented in Table 1-3, and the results of statistical analysis in Table 1-3.A. Statistical analysis of the data showed significant variation among varieties, doses of mutagen, varieties into doses interaction, modes of seed collection, varieties into branch categories, treatments into branch categories and varieties into treatments into modes interactions, phenotypic categories, varieties into phenotypic classes, treatments into phenotypic categories and modes into phenotypic classes interactions.

Both positive and negative variants were created by the different doses of gamma rays and EMS. The frequency distribution was found to be dependant on varieties, exposures and $M_1$ branch categories. The minimum mean frequency of 5.58 per cent for negative variants in

plant height was observed under the second branch category in 20 kR gamma rays in $V_2$ and the maximum (56.41%) under the bulk progeny in 30 kR in the same variety. Positive variation was also found to be minimum under 20 kR in $V_2$ under the bulk progeny and it ranged to a maximum of 71.87 per cent under the second branch category of 0.5 per cent EMS in $V_3$. In most of the cases, the maximum and minimum values showed the general trend, positive variants being maximum in the second branch category and negative variants in the bulk progeny. Positive variants were at higher frequency under EMS treatment as compared to gamma rays, in the different branch categories and varieties. An increase in EMS concentration registered an increase in positive variants, at the expense of the control group whereas the increase was at the expense of the negative variants in the higher level of gamma ray exposure.

No significant difference in the number of plants falling under the three categories of phenotypes was noted with respect to plant height for $V_1$ and $V_2$ but a significant reduction was noted for $V_3$, as there was no branch-wise collection from $M_1$ owing to lack of branching from the two doses of physical mutagen. Frequency of plants coming under the three phenotypic classes in the

different varieties was found to be significant, positive variants (24.5%) being more than the negative variants (19.2%). In $V_1$ frequency of plants were not significantly different among positive and negative variants but in the other two varieties, significant difference was noted whereas variety $V_2$ showed maximum positive variation (36.7%) $V_1$ registered the maximum negative variation (24.5%).

Positive variants was maximum from plants treated with 1.0% EMS (45.2%) and negative variants under 20 kR gamma rays (33.3%). Minimum variation was shown by 0.5 per cent EMS treatment, with 47 per cent of the plants coming under the control group. Negative variants created by the higher doses of the two mutagens were comparable. Seeds collected from the second $M_1$ branches showed a high frequency of positive variants and a low negative value for the character concerned, the positive variants being significantly superior to that of all other branch categories except the third. Negative variants were maximum under the 5th branch category.

2. Number of branches per plant:

2.1. Mean number of branches per plant as influenced by genotypes and mutagens

Data regarding the effect of varieties, mutagens and their doses on number of branches per plant is presented in Table 2-1. Statistical analysis of the data showed no significant variation among varieties, between mutagens, between levels of mutagens, treatments compared to control and variety into dose effect interactions. The mean number of branches per plant in $V_1$ ranged from 1.46 in 0.5 per cent to 2.02 in 1.0 per cent EMS with a control value of 1.91. In $V_2$ the range was from 1.32 in 20 kR to 1.89 in 0.5 per cent EMS, the control being 1.41. It was noted that in $V_1$, 0.5 per cent EMS gave the minimum number of branches and in $V_2$ the same dose gave the maximum value. In the variety $V_3$, mean number of branches ranged from 1.03 in 20 kR to 1.80 in 1.0 per cent EMS. The control value of 1.40 showed a medium trend between the minimum and maximum values in the treated populations, as noted in varieties $V_1$ and $V_2$. In the number of branches per plant also depending on variety, mutagens and doses tested insignificant positive or negative shifts were noted.

Table 2-1 Mean No. of branches/plant as influenced by genotypes and mutagens

| Varieties | Control | EMS | | gamma rays | | General mean |
|---|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20kR | 30kR | |
| $V_1$ | 1.91 | 1.46 | 2.02 | 1.69 | 1.75 | 1.77 |
| $V_2$ | 1.41 | 1.09 | 1.37 | 1.32 | 1.61 | 1.52 |
| $V_3$ | 1.40 | 1.59 | 1.80 | 1.03 | 1.40 | 1.44 |
| General mean | 1.72 | 1.64 | 1.73 | 1.35 | 1.59 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Between varieties (V) | 0.09 | - |
| Between mutagens | 0.001 | - |
| Between levels of EMS | 0.0001 | - |
| Between levels of gamma rays | 0.001 | - |
| Treated Vs Control | 4.005 | - |
| Varieties x Treatments | 0.99 | - |

A variety dependent insignificant variation in mean value was noticed. Variety $V_1$ had the maximum mean number of branches in all the treatments including control.

It was noted that 1.0 per cent EMS treatments in all the varieties tested gave an increased ability for branching. The maximum reduction in number of branches was noted in 20 kR exposure in all the varieties studied.

In the profusely branching variety $V_1$ and the least branching variety $V_3$, 1.0 per cent EMS gave the maximum number of branches per plant whereas in $V_2$ it was shifted to the lower dose of EMS (0.5 per cent). In general, chemical mutagen treatment resulted in an increase in the mean number of branches per plant whereas physical mutagen treatment resulted in a reduction in branching. The effect of 30 kR gamma rays was comparable to that of the control.

2.2. Mean number of branches per plant under different $M_1$ branch categories

Mean number of branches per plant in $M_2$ as influenced by varieties, mutagens and their doses and five $M_1$ branch categories is depicted in Table 2-2. Statistical analysis of the data showed significant variation in mean values among the major treatments (varieties and

Table 2-2 Mean number of branches/ plant as influenced by varieties $M_1$ branch-categories and mutagens & their doses

| Varieties | Mutagens | Doses | $M_1$ branch categories | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| $V_1$ | EMS | 0.5% | 3.70 | 2.05 | 1.87 | 2.95 | 1.36 | 2.07 |
| | | 1.0% | 2.13 | 2.64 | 2.24 | 2.74 | 2.02 | 2.35 |
| | Gamma rays | 20 kR | 2.03 | 2.93 | 2.51 | 2.95 | 1.69 | 2.42 |
| | | 30 kR | 1.68 | 2.52 | 2.54 | 2.75 | 1.75 | 2.25 |
| $V_2$ | EMS | 0.5% | 1.63 | 1.63 | 1.36 | 1.93 | 1.89 | 1.59 |
| | | 1.0% | 1.07 | 1.01 | 1.31 | 1.17 | 1.37 | 1.18 |
| | Gamma rays | 20 kR | 1.35 | 2.25 | 1.80 | 1.39 | 1.32 | 1.62 |
| | | 30 kR | 2.17 | 2.28 | 3.12 | 1.62 | 1.61 | 2.16 |
| $V_3$ | EMS | 0.5% | 2.63 | 3.21 | 1.68 | 2.55 | 1.59 | 2.33 |
| | | 1.0% | 1.09 | 1.69 | 1.08 | 1.66 | 1.8 | 1.46 |
| | Gamma rays | 20 kR | 0 | 0 | 0 | 0 | 1.03 | 1.03 |
| | | 30 kR | 0 | 0 | 0 | 0 | 1.37 | 1.37 |
| | | Mean | 1.83 | 2.22 | 1.95 | 2.10 | 1.53 | |

Analysis of Variance

| Source | F value | C.D value |
|---|---|---|
| Major treatments | 10.88* | 0.73 |
| Varieties (V) | 26.41* | 0.98 |
| Doses (T) | 3.33 | - |
| V x T | 10.18* | - |
| Minor treatments (M) | 1.94 | 0.28 |
| V x M | 1.35 | - |
| T x M | 0.44 | - |
| V x T x M | 2.79* | 0.98 |

* Significant at 5% level

doses of mutagens), varieties, varieties into treatments interaction and varieties into treatments into branch category interaction. But the variation in mean values observed among doses of mutagens, $M_1$ branch categories, varieties into branch categories and treatments into branch categories interactions were observed to be insignificant.

In the variety $V_1$, mean number of branches ranged from 1.35 in 0.5 per cent EMS under the fifth branch category to 2.95 under 20 kR exposure in the fourth branch category. A range in value from 1.01 in the second branch category under 1.0 per cent EMS to 3.12 in the third branch category under 30 kR gamma rays was noted in the second variety. A wide range in value from 1.03 in the fifth branch category under 20 kR to 3.21 in the second branch category under 0.5 per cent EMS was noted in $V_3$.

Lowest mean number of branches in $V_1$ was observed in the bulk progeny under 0.5 and 1.0 per cent EMS and 20 kR gamma rays, the values being 1.36, 2.02 and 1.69 respectively. In 30 kR the same result was noted in the first category (1.68). The maximum mean number of branches were produced by the fourth category under 1.0 per cent EMS as well as 20 and 30 kR gamma rays (2.74, 2.95 and 2.75 respectively). Under 0.5 per cent EMS the maximum

of 2.7 branches per plant was observed in the first category.

When the later formed $M_1$ branches and the bulk seed collection gave the maximum mean number of branches under both the doses of EMS, the same was distributed among the early formed branches in gamma ray exposures in $V_2$. Lowest mean number of branches was recorded in the early formed $M_1$ branches by EMS and by whole plant seed collection under gamma ray exposures.

The doses of chemical mutagen exhibited marked differences in their effects in $V_3$ with the minimum values in bulk seed collection and the maximum in the early formed branches by 0.5 per cent concentration. Under 1 per cent concentration the minimum value was observed in the early formed branches and maximum in the bulk seed collection.

A considerably reduced value of 1.03 was noted under the bulk seed collection in 20 kR which was justifiable as no branching was observed in the $M_1$ plants under the two exposures of gamma rays. The mean value was also low in the case of 30 kR exposures.

The main plot means ranged from 1.03 in 20 kR in $V_3$ to 2.42 under the same treatment in $V_1$. On the whole, profuse branching was observed in $V_1$ as compared to the

other two varieties. The maximum mean number of branches of 2.42 recorded under 20 kR in $V_1$ was significantly superior to the meansobserved under the different treatments of the other two varieties, except 30 kR in $V_2$ and 0.5 per cent EMS in $V_3$. The mean values of 2.35 and 2.25 shown by the higher doses of EMS and gamma rays respectively were also significantly superior to the different treatments in $V_2$ and $V_3$.

The sub plot means ranged from 1.53 in the fifth branch category to 2.22 in the second branch category. The maximum value was significantly superior to the first and fifth sub-plot means.

Variety $V_1$ showed significantly superior branching in the first branch category as compared to bulk seed collection in 0.5 per cent EMS, in the second and fourth branch categories as compared to bulk in 20 kR and in the fourth branch category as compared to the first and bulk in 30 kR. No significant difference in branching among plants raised from seeds collected from different $M_1$ branch categories was noted in $V_2$. The first and second branch categories showed significantly superior branching as compared to the bulk seed collection in 05 per cent EMS of $V_3$. The second category was significantly superior to the third category.

2.3. Phenotypic frequency of branch number variants:

The frequency distribution of branch number variants as affected by the different doses of the 2 mutagens in 3 varieties under five $M_1$ branch categories is depicted in Table 2-3 and the results of statistical analysis in Table 2-3.A. On statistical analysis the data expressed significant variation in mean frequency distribution among varieties, doses of mutagen, varieties into doses interaction, modes of seed collection, varieties into branch categories, treatments into branch categories and varieties into treatments into branch categories interactions, phenotypic classes, varieties into phenotypic classes and treatments into phenotypic classes. Branch-categories into phenotypic classes interaction alone was found to be insignificant.

In $V_1$, both positive and negative variants were created by the different concentrations of EMS and gamma rays. The frequency of these variants was highly dependent on varieties, mutagens, their doses as well as the modes of collection.

Negative variation was found to be completely absent in $V_2$ and $V_3$ and the maximum negative variation of 20.55 per cent was registered in the second branch-category under 20 kR gamma rays in $V_1$. Mean frequency of

positive variants ranged from 1.63 to 39.32 per cent under 20 kR exposure in the fifth and second branch categories respectively. In $V_1$ negative and positive variants were produced in almost equal frequencies under the second brach category in 0.5 per cent and 30 kR whereas a two fold increase in positive variants (26.47%) as compared to negative variants (13.09%) was observed under the fifth branch category in 20 kR of the same variety. The effects produced by 1.0 per cent EMS and 20 kR gamma rays were comparable in the first, fourth and fifth branch categories of $V_2$.

Significant differences in the number of plants falling under the three phenotypic classes were noted among $V_1$, $V_2$ and $V_3$ due to lack of negative variants in $V_2$ and $V_3$ and the absence of branch wise collection from $M_1$ in the physical mutagen exposures in $V_3$. Frequency of plants coming under the three phenotypic classes was found to be significant, positive variants being more (20.07%) as compared to negative variants (7.23%). Frequencies in the positive and negative groups were not found to be significantly different in $V_1$, but in the other 2 varieties significant differences were observed due to the complete absence of negative variants. Variety $V_2$ produced maximum positive variants.

Positive variation was the highest for plants treated with 0.5 per cent EMS (23.46%) which was significantly superior to the lowest value of 16.52 per cent under 20 kR gamma rays. Frequency distribution of negative variants ranged from 6.29 per cent under 0.5 per cent EMS to 7.88 per cent under 20 kR gamma rays. Seeds collected from the second branches registered a high positive variation and the bulk progeny registered a high negative variation. But no significance was observed. Variation was comparatively low for the fifth branch category with nearly 68 per cent of the plants falling in the control group.

3. Length of fruits:

3.1. Mean fruit length as influenced by genotypes and mutagens

Fruit length, as influenced by varieties, mutagens and their doses is presented in Table 3-1. Statistical analysis showed significant variation due to different doses compared to control. But the differences in mean values among varieties, between mutagens, between levels of mutagens and variety into treatment interactions were not significant. The mean fruit length in $V_1$ ranged from 3.38 cm in 1.0 per cent EMS to 4.42 cm in control population. Hence in this variety mutagen treatment led to a general significant reduction in mean fruit length which

Table 3-1 Mean fruit length(cm) as influenced by genotypes and mutagens

| Varieties | Control | EMS | | Gamma rays | | General mean |
|---|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20kR | 30kR | |
| $V_1$ | 4.42 | 4.08 | 3.38 | 3.95 | 4.17 | 4.04 |
| $V_2$ | 4.28 | 4.23 | 4.41 | 4.18 | 4.88 | 4.38 |
| $V_3$ | 4.80 | 4.14 | 3.95 | 4.09 | 4.81 | 4.26 |
| General mean | 4.13 | 4.15 | 4.01 | 4.07 | 4.62 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Between varieties (V) | 0.05 | - |
| Between mutagens | 0.41 | - |
| Between levels of EMS | 0.06 | - |
| Between levels of gamma rays | 0.86 | - |
| Treated Vs Control | 5.43* | 0.98 |
| Varieties x Treatments | 0.69 | - |

* Significant at 5% level

was observed between 1.0 per cent EMS (3.37 cm) and control value (4.41 cm). In the variety $V_2$ mean fruit length ranged from 4.18 cm in 20 kR to 4.88 cm in 30 kR, with a control value of 4.28 cm. Here the minimum and maximum value distribution was on either side of the control in the case of physical mutagens the effect of chemical mutagens being comparable to the control. In $V_3$ the range was from3.95 cm in 1.0 per cent EMS to 4.81 cm in 30 kR which only slightly exceeded the control value of 4.80 cm. So here also, mutagen treatment had led to a reduction in the mean value of the character under study.

Fruit length in general was adversely affected by mutagen treatment.

3.2. Mean fruit length under different $M_1$ branch categories:

The effect of mutagens and their doses and $M_1$ branches categories on fruit length in the different varieties is presented in Table 3-2. Significant variation in mean values was noted among varieties, treatments, varieties into treatments interaction, among the modes of seed collection, varieties into modes, treatments into modes and varieties into treatments into modes interactions.

Table 3-2 Mean fruit length (cm) as influenced by varieties, $M_1$ branch-categories and mutagens & their doses

| Varieties | Mutagens | Doses | $M_1$ branch categories | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| $V_1$ | EMS | 0.5% | 4.08 | 4.32 | 3.86 | 4.35 | 4.08 | 4.14 |
| | | 1.0% | 4.04 | 4.09 | 4.57 | 3.77 | 3.38 | 4.03 |
| | Gamma rays | 20 kR | 4.26 | 5.07 | 3.21 | 3.77 | 3.95 | 4.05 |
| | | 30 kR | 4.13 | 4.09 | 4.05 | 5.20 | 4.17 | 4.33 |
| $V_2$ | EMS | 0.5% | 4.27 | 4.09 | 3.95 | 4.38 | 4.23 | 4.19 |
| | | 1.0% | 4.56 | 4.59 | 4.29 | 4.38 | 4.41 | 4.45 |
| | Gamma rays | 20 kR | 5.49 | 4.52 | 3.83 | 3.78 | 4.18 | 4.36 |
| | | 30 kR | 4.11 | 4.44 | 3.85 | 4.18 | 4.88 | 4.29 |
| $V_3$ | EMS | 0.5% | 4.34 | 4.52 | 5.38 | 4.4 | 4.14 | 4.56 |
| | | 1.0% | 4.29 | 5.92 | 4.61 | 4.74 | 3.95 | 4.70 |
| | Gamma rays | 20 kR | 0 | 0 | 0 | 0 | 4.09 | 4.09 |
| | | 30 kR | 0 | 0 | 0 | 0 | 4.81 | 4.81 |
| | | Mean | 4.36 | 4.57 | 3.77 | 4.29 | 4.21 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Major treatments | 2584.57* | 0.82 |
| Varieties (V) | 2999.29* | 1.28 |
| Doses (T) | 2101.43* | - |
| V x T | 2672.86* | - |
| Minor treatments (M) | 509.50* | 0.37 |
| V x M | 1075.00* | 1.28 |
| T x M | 549.25* | * |
| V x T x M | 142.25* | * |

* Significant at 5% level

Mean fruit length ranged from 3.21 cm under the third branch category in 20 kR to 5.20 cm under the 5th branch category in 30 kR in the variety $V_1$. In $V_2$ the highest (5.50 cm) the lowest (3.88 cm) values fell in the same mutagen dose in the first and 4th branch categories respectively. A range from 3.95 cm in the 5th branch category under 1.0 per cent EMS to 5.92 cm in the 2nd branch category under the same treatment was noted in $V_3$.

The mean values ranged from 3.86 cm under 0.5 per cent EMS in $V_1$ in the third branch category to 4.35 in the 4th category whereas in the higher concentration of the same chemical mutagen, it was from 3.38 cm in the bulk seed collection to 4.51 cm in the 3rd category. Exposures of gamma rays resulted in an increase in mean fruit length ranging from 3.21 cm in the third to 5.07 cm in the second category in 20 kR and from 4.05 cm in the third to 5.2 cm in the 4th branch category in 30 kR. Lowest mean fruit length under both the EMS concentrations in $V_2$ were met with in the 3rd branch category, whereas the highest values were observed in the fourth and second categories in 0.5 per cent and 1.0 per cent concentrations respectively. Here also, physical mutagen treatment led to an increase in mean fruit length ranging from 3.78 cm

in the 4th branch category to 5.50 cm in the first under 20 kR and from 3.85 cm in the third to 4.88 cm in the whole plant seed collection in 30 kR. In $V_3$ both the concentrations of EMS expressed the minimum mean values in the bulk seed collection and maximum means in the early formed branches.

When the lowest main plot mean (4.03 cm) was shown by 1.0 per cent EMS under $V_1$ the highest value (4.7 cm) was shown by the same dose under $V_3$ but major treatments were not found to be significantly different. Sub plot treatments exhibited significant differences in mean fruit length ranging from 3.77 cm in the third branch category which was significantly inferior to all others to 4.57 in the second branch category.

Significant differences in mean values were noted in $V_1$ only under 20 kR gamma rays where the mean fruit length in the second branch category (5.07 cm) was significantly superior to the mean fruit lengths of 3.21 cm and 3.77 cm in the third and later branch categories respectively. The same treatment gave significantly different mean fruit length in $V_2$ also, with the first branch category mean of 5.49 cm being significantly superior to the mean values shown by the later formed branches as well as the bulk seed collection. In the third variety, the second branch category mean of 5.92 cm under 1.0 per cent EMS was found to be significantly superior to the bulk seed collection.

3.3. Phenotypic frequency of fruit length variants:

The frequency distribution of fruit length variants ( in percentage) as affected by the two mutagens under five $M_1$ branch categories in three varieties is presented in Table 3-3. The results of statistical analysis is represented in Table 3.3-A. Significant variations were noted in mean frequency distribution among varieties, dosesof mutagen, varieties into doses interaction, $M_1$ branch categories, varieties into $M_1$ branch categories, treatments into modes of seed collection, varieties into treatments into modes interaction and the three phenotypic categories. No significant variation was available with respect to varieties into phenotypic classes, treatments into phenotypic classes and modes of seed collection into phenotypic classes interactions.

The different doses of mutagens gave positive and negative variants in all the three varieties but the frequency distribution varied depending on varieties, exposures and the $M_1$ branch categories. The mean frequency for negative variants in fruit length ranged from 4.86 per cent under fifth branch-category in 1.0 per cent EMS in $V_2$ to 43.72 per cent under the third branch category in 20 kR in $V_1$. Positive variation was found to be minimum under the 4th branch category in 1.0 per cent EMS in $V_1$

(7.49%) and maximum under the fifth branch category in 30 kR in $V_2$(37.50%). The frequency of variants coming under the negative and positive phenotypic classes were found to be almost equal under the first branch category in 1.0 per cent (23.5% and 23.89% respectively), third category in 20 kR (15.57% and 15.16% respectively) and third category in 30 kR (18.84% and 17.63% respectively) in $V_2$. The maximum variation in the mean frequency of positive and negative variants was also found in the same variety under fifth branch category in 30 kR being 6.5 per cent for negative group and 37.5 per cent for the positive group. The effect produced by 20 kR gamma rays under the first and fifth categories in $V_1$ and 0.5 per cent EMS under the first branch category in $V_3$ were comparable, the frequencies being approximately equal to 25:50:25 in the negative, control and positive categories respectively.

In the case of the number of plants coming under the three phenotypic classes, between $V_1$ and $V_2$ an insignificant difference was noted whereas $V_3$ showed a significant reduction due to the lack of branch-wise collections in the physical mutagen treatments. Significance was noted for the number of plants coming under the three phenotypic categories but negative (23.20%) and positive (24.24%) variants were produced in approximately equal proportion. Positive variation was found to be maximum in

$V_2$ and negative variation in $V_1$ but the difference was not significant.

An insignificant maximum frequency of positive and negative variants were produced by plants treated with 1.0 per cent EMS. In general, 20 kR gamma rays produced minimum positive variants in the different varieties and the higher dose of gamma rays produced minimum negative variants. The mean frequencies of both positive and negative variants were found to be maximum in the bulk progeny and the corresponding minimum frequencies in the fourth category.

4. Weight of fruits:

4.1. Mean fruit weight as influenced by genotypes and mutagens

Details regarding the effect of varieties, mutagens and their doses on fruit weight is shown in Table 4-1. Significant variation was noted between mutagens, between the levels of gamma rays and the treatments compared to control. The differences in mean value between varieties, between levels of EMS and variety into dose effect interactions were not significant.

The mean fruit weight in $V_1$ ranged from 1.02 g in 20 kR to 1.67 g in control. The mean fruit weight in $V_2$ also showed only a negative shift, ranging from 1.17 g in

Table 4-1 Mean fruit weight(g) as influenced by genotypes and mutagens

| Varieties | Control | EMS | | Gamma rays | | General mean |
|---|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20kR | 30kR | |
| $V_1$ | 1.67 | 1.19 | 1.12 | 1.02 | 1.49 | 1.29 |
| $V_2$ | 1.36 | 1.21 | 1.32 | 1.17 | 1.30 | 1.27 |
| $V_3$ | 1.59 | 1.18 | 1.06 | 1.17 | 1.58 | 1.31 |
| General mean | 1.54 | 1.19 | 1.16 | 1.12 | 1.46 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Between varieties (V) | 0.16 | - |
| Between mutagens | 4.42* | 0.37 |
| Between levels of EMS | 0.10 | - |
| Between levels of gamma rays | 11.61* | 0.37 |
| Treated Vs Control | 16.95* | 0.37 |
| Varieties X Treatments | 1.19 | - |

* Significant at 5% level

20 kR to 1.36 g in control. In the case of $V_3$, 1.0 per cent EMS showed the maximum reduction in mean fruit weight (1.06 g) with a maximum of 1.60 g in control. The varietal means showed no significant differences whereas a significant difference between the doses and control population was observed in $V_1$ and $V_3$. In $V_1$, mean fruit weight as influenced by 0.5 per cent EMS (1.19 g) 1.0 per cent EMS (1.12 g) and 20 kR gamma rays (1.02 g) were significantly lower as compared to control. In $V_3$ also mean fruit weights for the above three doses were significantly inferior when compared to control. In $V_1$ and $V_3$ significant differences in mean fruit weight were observed between the levels of gamma rays.

Significant difference in mean values between the mutagens tested was also observed in $V_1$ and $V_3$. There was a significant increase in mean fruit weight in 30 kR (1.49 g) as compared to 1.0 per cent EMS (1.15 g) in $V_1$ whereas in $V_3$ the mean fruit weight in both 0.5 per cent (1.18 g) and 1.0 per cent EMS (1.05 g) was significantly lesser than that in 30 kR gamma rays (1.58 g).

It was noted that in the case of the varieties under study all the treatments in both the mutagens led to a significant reduction in mean value compared to control. Drastic reduction in mean fruit weight was observed in EMS treatments compared to gamma ray exposures.

## 4.2. Mean fruit weight under different $M_1$ branch categories

The influence of doses and $M_1$ branch categories on the mean fruit weight in different varieties is given in Table 4-2. The mean values among varieties, treatments, varieties into treatments interaction, varieties into branch categories interaction, treatments into branch categories interaction and varieties into treatments ~~into treatments~~ into branch categories interaction showed significant differences. No significant variation in mean values was observed among the major treatments (varieties and doses of mutagen) and $M_1$ branch categories.

A range in mean fruit weight from 0.89 g in the fourth branch category under 20 kR gamma rays to 1.77 g in the first branch category under 0.5 per cent EMS was noticed in $V_1$. In $V_2$ the values ranged from 1.07 g in the fourth branch category under 30 kR gamma rays to 1.87 g in the first branch category under 20 kR gamma ray exposures. Mean fruit weights in $V_3$ varied from 1.06 g to 1.70 g under 1 per cent EMS in the fifth and second branch categories respectively.

In $V_1$ the lowest and the highest mean fruit weights under the different doses were distributed between the first and the fourth branch categories only. When the earlier formed branch categories registered the maximum

Table 4-2 Mean fruit weight(g) as influenced by varieties, $M_1$ branch categories and mutagens & their doses

| Varieties | Mutagens | Doses | $M_1$ branch categories | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| $V_1$ | EMS | 0.5% | 1.77 | 1.23 | 1.19 | 1.09 | 1.19 | 1.29 |
| | | 1.0% | 0.96 | 1.28 | 1.28 | 1.31 | 1.12 | 1.19 |
| | Gamma rays | 20kR | 1.47 | 1.40 | 1.08 | 0.89 | 1.02 | 1.17 |
| | | 30kR | 1.47 | 1.41 | 1.27 | 1.14 | 1.49 | 1.35 |
| $V_2$ | EMS | 0.5% | 1.74 | 1.19 | 1.11 | 1.31 | 1.21 | 1.31 |
| | | 1.0% | 1.35 | 1.30 | 1.31 | 1.39 | 1.32 | 1.33 |
| | Gamma rays | 20kR | 1.87 | 1.36 | 1.23 | 1.19 | 1.17 | 1.36 |
| | | 30kR | 1.10 | 1.34 | 1.19 | 1.07 | 1.30 | 1.19 |
| $V_3$ | EMS | 0.5% | 1.30 | 1.39 | 1.69 | 1.26 | 1.38 | 1.40 |
| | | 1.0% | 1.07 | 1.70 | 1.39 | 1.29 | 1.06 | 1.29 |
| | Gamma rays | 20kR | 0 | 0 | 0 | 0 | 1.17 | 1.17 |
| | | 30kR | 0 | 0 | 0 | 0 | 1.58 | 1.58 |
| | | Mean | 1.41 | 1.36 | 1.27 | 1.20 | 1.25 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Major treatments | 0.19 | |
| Varieties (V) | 286.67* | 0.52 |
| Doses (T) | 151.44* | " |
| V x T | 149.77* | " |
| Minor treatments (M) | 2.22 | 0.24 |
| V x M | 32.30* | 0.52 |
| T x M | 30.10* | " |
| V x T x M | 11.00* | " |

* Significant at 5% level

mean value for 0.5 per cent EMS and the different doses of gamma rays, the later formed branches recorded the minimum means for the same treatments. Opposite was the case with 1 per cent EMS. In general, plants raised from the seeds collected from earlier formed $M_1$ branches gave higher mean values for fruit weight as compared to later formed branches. The same trend was followed in $V_2$ with the maximum values for the lower doses of the two mutagens falling in the first branch category and the corresponding lower values in the third branch category under EMS and by the bulk plant seed collection in gamma rays. The maximum mean fruit weight under 30 kR (1.34 g) was in the second branch category and the minimum (1.07 g) in the fourth branch category. A difference in the distribution under 1 per cent EMS was noted by having the maximum mean fruit weight under the fourth category and the minimum under the third branch category. In $V_3$ under 0.5 per cent EMS mean fruit weight ranged from 1.26 g in the fourth branch category to 1.70 in the 3rd branch category whereas in 1.0 per cent it ranged from 1.06 g to 1.70 g in the fifth and second branch categories respectively.

Main plot means ranged insignificantly in $V_3$ from 1.17 g under 20 kR to 1.40 g under 0.5 per cent EMS. In all the three varieties 0.5 per cent EMS registered higher

mean values. Sub-plot means ranged from 1.2 g in the fourth branch category to 1.41 g in the first branch category but were not significantly different.

In the case of $V_1$, significantly superior fruit weight was shown by 0.5 per cent EMS under the first branch category as compared to later formed ones. The lower dose of gamma rays also registered significant superiority in the first branch category. In $V_2$ also, significant superiority was shown by the lower doses of both the mutagens under the first branch category. In $V_3$, 1.0 per cent EMS recorded a significantly superior fruit weight of 1.70 g under the 2nd branch category as compared to the first and fifth branch categories.

4.3. Phenotypic frequency of fruit weight variants:

In Table 4-3 the frequency distribution of fruit weight variants ( in percentage) in three varieties of chillies as influenced by the different doses of EMS and gamma rays, under five $M_1$ branch categories is presented. The results of statistical analysis are presented in Table 4-3-A. Statistical analysis of the data showed significant variation in mean frequency distribution among varieties, doses of mutagen, varieties into doses interaction, modes of seed collection, varieties into $M_1$ branch-categories, treatments into branch categories

Table 4-3-A. Statistical analysis on the frequency distribution of fruit weight variants (transformed values)

| | | Mutagens & doses | | | | $M_1$ branch categories | | | | | Phenotypic classes | | | Mean (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EMS | | Gamma rays | | | | | | | | | | |
| | | 0.5% | 1.0% | 20kR | 30kR | 1 | 2 | 3 | 4 | 5 | -ve variants | control group | +ve variants | |
| Varieties | $V_1$ | 34.53 | 34.39 | 34.79 | 34.79 | 34.63 | 35.01 | 34.27 | 34.27 | 34.91 | 30.74 | 43.41 | 30.49 | 34.62 |
| | $V_2$ | 34.92 | 34.90 | 34.86 | 34.67 | 34.62 | 34.67 | 35.10 | 34.87 | 34.92 | 29.28 | 41.54 | 34.32 | 34.84 |
| | $V_3$ | 34.92 | 34.96 | 6.99 | 6.91 | 17.54 | 17.37 | 17.45 | 17.47 | 34.91 | 22.44 | 26.63 | 25.77 | 20.95 |
| Mean | | 34.79 | 34.75 | 25.55 | 25.46 | 28.95 | 29.01 | 29.94 | 28.87 | 34.91 | 27.49 | 37.19 | 30.19 | |
| Phenotypic classes | -ve variants | 30.19 | 30.26 | 28.22 | 23.28 | 24.67 | 23.57 | 25.42 | 23.35 | 28.81 | | | | |
| | Control group | 43.01 | 39.73 | 32.11 | 33.92 | 32.13 | 33.05 | 34.21 | 33.28 | 40.43 | | | | |
| | +ve variants | 31.75 | 34.91 | 26.72 | 27.4 | 31.24 | 29.59 | 21.44 | 24.98 | 31.56 | | | | |
| $M_1$ branch categories | 1 | 34.82 | 34.81 | 23.96 | 23.19 | | | | | | | | | |
| | 2 | 34.91 | 34.93 | 23.33 | 22.88 | | | | | | | | | |
| | 3 | 34.79 | 34.48 | 23.21 | 23.29 | | | | | | | | | |
| | 4 | 34.52 | 34.52 | 23.25 | 23.17 | | | | | | | | | |
| | 5 | 34.91 | 35.02 | 34.96 | 34.75 | | | | | | | | | |

Analysis of variance

| Source | F. value | C.D.value |
|---|---|---|
| Varieties (V) | 9427.69* | 0.26 |
| Treatments (T) | 3198.81* | 0.29 |
| Branch categories (M) | 675.03* | 0.29 |
| Phenotypic classes (S) | 20.83* | 3.07 |
| V x T combinations | 3261.65* | 0.51 |
| V x M " | 676.44* | 0.51 |
| T x M " | 207.75* | 0.58 |
| T x S " | 0.72 | - |
| V x S " | 3.07* | 1.25 |
| M x S " | 1.22 | - |

* Significant at 5% level

and varieties into treatments into modes interactions, the three phenotypic categories and varieties into phenotypic categories interaction, treatments into phenotypic classes and modes into phenotypic classes interactions were found to be insignificant.

Both positive and negative variants were produced by the different concentrations of EMS and gamma rays, in the different varieties. A dose and $M_1$ branch-category dependent variation in mean frequency distribution for the variants was observed in the three varieties. The minimum mean frequency of 5.41 per cent for negative variants in fruit weight was observed under the fourth branch-category in 1.0 per cent in $V_1$, the maximum value of 46.64 per cent being under the fifth branch category of $V_3$ in the same dose. Positive variation was found to be minimum under the fourth category in 0.5 per cent EMS in $V_1$ and it was maximum (64.92%) under the first category in 20 kR in $V_2$. The frequency of variants from the control group was found to be maximum under the first category in 20 kR in $V_1$ and under the 3rd category in 0.5 per cent in $V_3$ being 64.92 per cent and 50.18 per cent respectively.

A significant reduction in percentage frequency under the three phenotypic classes was noted in $V_3$, as there was no branch-wise collection from $M_1$ owing to lack

of branching under gamma ray exposures. Frequency of positive variants (30.19%) in the different varieties was found to be significantly greater as compared to the negative variants (27.49%). In $V_1$, frequency of plants were not significantly different among positive and negative variants but in the other two varieties significant difference was noted. Variety $V_2$ showed maximum positive variation (34.32%) where as $V_1$ registered the maximum negative variation (30.74%).

Plants treated with 1.0% EMS gave maximum frequency of positive (34.91%) and negative variants (30.26%). Minimum mean frequency of positive variants was observed under 20 kR and of negative variants under 30 kR gamma rays. The fifth branch category recorded the maximum mean frequency of 28.81 per cent under negative variants and 31.56 per cent under positive variants but the values registered no significant increase as compared to the other mean frequencies.

5. Number of seeds per fruit:

5.1. Mean number of seeds per fruit as influenced by genotypes and mutagens.

Table 5-1 represents the mean number of seeds per fruit in the varieties tested, as influenced by the doses of mutagen. There was no significant difference among

Table 5-1 Mean number of seeds/fruit as influenced by genotypes and mutagens

| Varieties | Control | EMS | | Gamma rays | | General mean |
|---|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20kR | 30kR | |
| $V_1$ | 55.07 | 39.91 | 36.73 | 36.01 | 37.82 | 40.91 |
| $V_2$ | 49.78 | 45.19 | 44.95 | 37.25 | 47.30 | 44.89 |
| $V_3$ | 56.54 | 39.65 | 36.99 | 44.62 | 42.95 | 39.57 |
| General mean | 43.79 | 41.58 | 38.59 | 38.96 | 46.02 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Between varieties (V) | 0.90 | - |
| Between mutagens | 0.41 | - |
| Between levels of EMS | 0.32 | - |
| Between levels of gamma rays ) | 2.15 | - |
| Treated Vs Control | 0.03 | - |
| Varieties x Treatments | 1.87 | - |

varieties, between mutagens or their doses, treatments vs control and the variety into dose effect interactions.

The mean number of seeds per fruit in $V_1$ showed a reduction in number of seeds which ranged from 36.01 in 20 kR to 55.07 in control. In $V_2$ also, there was a general reduction in number of seeds per fruit on treatment, ranging from 37.25 in 20 kR to 49.78 in control. In $V_3$ the mean values ranged from 36.99 seeds per fruit in 1.0 per cent to 56.54 in control. A variety dependent insignificant variation in number of seeds per fruit was noticed. The maximum value of 44.89 seeds per fruit was noted in $V_2$ followed by $V_1$ (40.91) and $V_3$ (39.57). The order is exactly opposite to what is observed in the control where $V_3$ records the highest mean of 56.54 followed by $V_1$ with 55.07 and $V_2$ with 49.78. Hence it could be noted that the reduction in number of seeds per fruit on treatment was greater in varieties with a higher mean value for the same, under normal conditions. Variety $V_2$ was found to be comparatively resistant to mutagen treatment where the range in mean value was only of the order of 10 units, as compared to an approximate value of 20 units in the other two varieties. The minimum number of seeds per fruit is comparable in all the three varieties. In the case of chemical mutagen, higher the dose greater was the reduction in seed number. But higher dose of physical mutagen led to a proportionate increase in mean

value in all the three varieties tested.

In general mutagenic treatment showed a complete but insignificant negative shift in all the three varieties.

5.2. Mean number of seeds per fruit under different $M_1$ branch categories

Data regarding the mean number of seeds per fruit as influenced by varieties, doses and $M_1$ branch categories is given in Table 5-2. Statistical analysis of the data showed significant variation in mean values among the major treatments, varieties, treatments, varieties into treatments interaction, minor treatments, varieties into branch categories and treatments into branch categories interaction and also varieties into treatments into branch categories interaction.

Average number of seeds per fruit ranged from 31.85 in 20 kR under the fourth branch category to 64.8 in 0.5 per cent EMS under the first branch catagory in the first variety. Variety $V_2$ showed a wide range from 34.88 in the fourth branch category under the higher dose of gamma rays to 67.95 in the first branch category under the lower dose of gamma rays. In $V_3$ it ranged from 34.01 in 1.0 per cent EMS under the fifth branch category to 57.59 in 0.5 per cent EMS under the third branch category.

Table 5-2 Mean number of seeds/fruit as influenced by varieties, $M_1$ branch categories and mutagens & their doses

| Varieties | Mutagens | Doses | $M_1$ branch categories | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| $V_1$ | EMS | 0.5% | 64.79 | 43.38 | 46.53 | 39.92 | 39.91 | 46.91 |
| | | 1.0% | 35.39 | 42.30 | 50.21 | 52.19 | 36.73 | 43.39 |
| | Gamma rays | 20kR | 48.90 | 44.81 | 35.39 | 31.85 | 35.01 | 39.19 |
| | | 30kR | 51.76 | 50.17 | 45.21 | 44.81 | 37.82 | 45.95 |
| $V_2$ | EMS | 0.5% | 67.72 | 41.51 | 34.88 | 53.46 | 45.19 | 48.55 |
| | | 1.0% | 45.29 | 40.37 | 48.47 | 53.96 | 44.95 | 46.61 |
| | Gamma rays | 20kR | 67.95 | 55.43 | 52.12 | 45.25 | 37.25 | 51.59 |
| | | 30kR | 35.62 | 54.41 | 42.50 | 34.88 | 47.30 | 42.94 |
| $V_3$ | EMS | 0.5% | 41.81 | 47.99 | 57.59 | 46.23 | 39.65 | 46.65 |
| | | 1.0% | 37.17 | 56.57 | 47.12 | 45.24 | 34.01 | 44.02 |
| | Gamma rays | 20kR | 0 | 0 | 0 | 0 | 44.62 | 44.62 |
| | | 30kR | 0 | 0 | 0 | 0 | 52.95 | 52.95 |
| | | Mean | 49.64 | 47.69 | 46.00 | 44.78 | 41.28 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Major treatments | 486.74* | 12.01 |
| Varieties (V) | 1071.48* | 17.73 |
| Doses (T) | 400.65* | " |
| V x T | 334.79* | " |
| Minor treatments (M) | 41.59* | 7.88 |
| V x M | 236.83* | 17.73 |
| T x M | 165.29* | " |
| V x T x M | 142.31* | " |

* Significant at 5% level

Lowest mean number of seeds under 0.5 per cent EMS and 30 kR gamma rays in $V_1$ were observed in the fifth branch category and the corresponding highest values in the first branch category. In the other two doses, the same values were distributed among the first and the fourth branch categories, the maximum value falling in the later-formed branch category for the chemical mutagen and in the first branch category for the physical mutagen. In $V_2$ the maximum average number of seeds under the lower doses of EMS and gamma rays were comparable, being 67.72 for EMS and 67.95 for gamma rays both falling under the first branch category. The corresponding minimum values fell under the third branch category and the fifth branch category for EMS and gamma rays respectively. For the higher doses of the two mutagens, the extreme values were recorded under the 2nd and the 4th branch categories. Here also as in $V_1$ the maximum value for EMS was registered in the later formed branches and for gamma rays in the earlier formed branch category. The range was comparatively low in $V_3$ extending from 39.65 under the fifth branch category to 57.59 in the third branch category for 0.5 per cent EMS and from 34.01 in the bulk seed collection to 56.57 in the second branch category for 1.0 per cent EMS.

The lowest main plot mean (39.19) was recorded by 20 kR gamma rays in $V_1$ which was significantly inferior to the highest value (52.95) under 30 kR in $V_3$ and also to the average value obtained under 20 kR gamma rays in $V_2$ (51.59). The sub plot means ranged from 41.28 under the fifth branch category to the significantly superior value of 49.64 under the first branch category.

Variety $V_1$ showed significantly higher number of seeds per fruit in the first branch category (64.79) as compared to all other branch categories under 0.5 per cent EMS. In $V_2$ also, the same branch category under the same dose registered significantly superior values as compared to all the other branch categories except the fourth branch category which was significantly superior to the third branch category. In the same variety, under 20 kR exposures, the first branch category mean of 67.95 was found to be significantly superior to the fourth and fifth branch category means where as in the higher dose exposure, the second branch category mean (54.41) had significant superiority as compared to the first and third branch category means. In $V_3$, 0.5 per cent EMS showed significantly higher mean number of seeds per fruit in the third branch category as compared to the fifth and in 1.0 per cent EMS, the 2nd branch category showed significant superiority over the 1st and fifth branch categories.

5.3. Phenotypic frequency of seed number variants:

Data regarding the frequency distribution of seed number variants (in percentage) as influenced by the different doses of the two mutagens, three varieties of chillies under five $M_1$ branch categories is depicted in Table 5-3. The results of statistical analysis is shown in Table 5-3-A. On statistical analysis, the data showed significant variation in mean frequency distribution among varieties, doses of mutagen, varieties into doses interaction, modes of seed collection, varieties into branch categories, treatments into branch categories and varieties into treatments into branch-categories interactions and the three phenotypic categories. Varieties into phenotypic classes, treatments into phenotypic classes and modes into phenotypic classes interactions registered no significant differences in mean frequencies.

Mean frequency of negative variants ranged from 10.7 per cent in the bulk progeny under 0.5 per cent EMS in $V_1$ to 39.19 per cent in the same category of the same variety under the lower dose of the physical mutagen. The range was from 12.28 per cent in the first category under 0.5 per cent EMS in $V_2$ to 62.22 per cent in the same category under 20 kR gamma rays in $V_2$ in the case of frequency distribution of positive variants. An almost equal frequency distribution under the three phenotypic

Table 5-3-A. Statistical analysis on the frequency distribution of seed number variants (transformed values)

| | Mutagens & doses | | | | $M_1$ branch categories | | | | | Phenotypic classes | | | Mean (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EMS | | Gamma rays | | | | | | | | | | |
| | 0.5% | 1.0% | 20kR | 30kR | 1 | 2 | 3 | 4 | 5 | -ve variants | control group | +ve variants | |
| Varieties | | | | | | | | | | | | | |
| $V_1$ | 34.54 | 34.95 | 34.75 | 34.88 | 34.62 | 35.08 | 34.89 | 34.58 | 34.71 | 27.13 | 44.71 | 31.38 | 34.78 |
| $V_2$ | 34.91 | 34.97 | 34.90 | 34.68 | 34.89 | 34.88 | 34.99 | 34.79 | 34.62 | 28.31 | 42.55 | 34.25 | 34.87 |
| $V_3$ | 34.72 | 35.01 | 7.01 | 6.93 | 17.25 | 17.48 | 17.54 | 17.36 | 34.96 | 21.51 | 28.23 | 31.23 | 20.92 |
| Mean | 34.72 | 34.98 | 25.55 | 25.49 | 28.92 | 29.15 | 29.14 | 28.91 | 34.81 | 25.65 | 38.49 | 32.28 | |
| Phenotypic classes | | | | | | | | | | | | | |
| -ve variants | 29.05 | 28.91 | 22.58 | 22.06 | 18.71 | 25.04 | 24.77 | 22.29 | 29.54 | | | | |
| Control group | 44.02 | 40.89 | 33.21 | 35.87 | 33.65 | 33.19 | 35.02 | 38.67 | 43.47 | | | | |
| +ve variants | 31.61 | 35.64 | 26.93 | 34.96 | 29.43 | 29.33 | 27.72 | 25.37 | 30.48 | | | | |
| $M_1$ branch categories | | | | | | | | | | | | | |
| 1 | 34.46 | 35.03 | 22.89 | 23.31 | | | | | | | | | |
| 2 | 35.01 | 35.04 | 23.35 | 23.19 | | | | | | | | | |
| 3 | 34.99 | 35.06 | 23.24 | 23.28 | | | | | | | | | |
| 4 | 34.47 | 34.78 | 23.27 | 23.13 | | | | | | | | | |
| 5 | 34.68 | 34.97 | 35.01 | 34.59 | | | | | | | | | |

Analysis of variance

| Source | F value | C.D.value |
|---|---|---|
| Varieties (V) | 6225.24* | 0.26 |
| Treatments (T) | 2100.27* | 0.29 |
| Branch categories (M) | 116.81* | 0.29 |
| Phenotypic classes (S) | 23.32* | 3.07 |
| V x T combinations | 2082.87* | 0.51 |
| V x M " | 120.93* | 0.51 |
| T x M " | 39.34* | 0.58 |
| T x S " | 1.61 | - |
| V x S " | 2.33* | 1.25 |
| M x S " | 0.98 | - |

* Significant at 5% level

classes was noted in the second branch category under 1.0 per cent EMS and 20 kR gamma rays.

Here also, $V_3$ showed a significant reduction in the number of plants coming under the three phenotypic classes due to the absence of branch-wise seed collection. The frequency of plants coming under the positive group was found to be significantly greater than the negative variants, in the different varieties. Maximum frequency for positive variants (34.25%) was registered under $V_2$ and minimum frequency under $V_3$ (31.23%). Negative variants also followed the same trend but variations were not significant. Treatment with 0.5 per cent EMS produced maximum negative variants whereas the higher dose of EMS produced maximum negative variants whereas the higher dose of EMS gave maximum positive variants. Negative variants were minimum under 30 kR gamma rays and positive variants under 20 kR but the variations were insignificant. The frequency of negative and positive variants were maximum in the fifth branch-category but no significant superiority was exhibited.

## 6. Number of fruits per plant

### 6.1. Mean number of fruits per plant as influenced by genotypes and mutagens

Data regarding the effects of varieties, mutagens and their doses on the total number of fruits per plant is presented in Table 6-1. Statistical analysis of the data showed significant variation in mean value among varieties as well as between mutagens. An insignificant variation was noted between levels of mutagen, treated vs control and variety into dose effect interactions.

Mean number of fruits in $V_1$ ranged from 20.27 in 30 kR to 27.53 in 1.0 per cent EMS with a control value of 22.18. Hence the lowest and highest values were distributed in the highest doses of physical and chemical mutagens respectively. In $V_2$ the range was from 22.98 in 20 kR to 34.79 in 1.0 per cent, the control being 32.93 and in $V_3$ from 21.99 in 30 kR to 28.66 in 1.0 per cent EMS with a control value of 23.89. It was observed that the highest mean yield in all three varieties were noted under 1.0 per cent EMS.

The variation in mean value depending on the variety was insignificant and the general mean was 22.98, 28.42 and 24.69 in $V_1$, $V_2$ and $V_3$ respectively. Varietal means are comparable to the control values denoting an almost equal shift in both positive and negative directions due to mutagen treatment.

Table 6-1 Mean number of fruits as influenced by genotypes and doses of mutagens

| Varieties | Control | EMS | | Gamma rays | | General mean |
|---|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20kR | 30kR | |
| $V_1$ | 22.18 | 23.03 | 27.53 | 21.87 | 20.27 | 22.98 |
| $V_2$ | 32.93 | 27.12 | 34.79 | 22.98 | 24.32 | 28.42 |
| $V_3$ | 23.89 | 26.14 | 28.66 | 22.80 | 21.99 | 24.69 |
| General mean | 25.33 | 25.63 | 30.32 | 22.35 | 22.19 | |

Analysis of variance

| Source | F value | C.D value |
|---|---|---|
| Between Varieties (V) | 4.29* | 4.73 |
| Between mutagens | 8.04* | 4.73 |
| Between levels of EMS | 2.73 | -- |
| Between levels of gamma rays | 0.003 | -- |
| Treated Vs Control | 0.89 | -- |
| Varieties x Treatments | 1.32 | -- |

* Significant at 5% level

In almost all cases chemical mutagen treatment led to an increase in total number of fruits per plant which was significant in $V_2$ under 1.0 per cent being 34.79 with a control value of 32.93. On the other hand physical mutagen treatment always led to a reduction in the number of fruits per plant and significant differences were available between 20 kR gamma rays (22.98) and 1.0 per cent EMS (34.79) treatments in $V_2$.

## 6.2. Mean number of fruits per plant under different $M_1$ branch categories

Data regarding the mean number of fruits per plant as influenced by varieties, doses of mutagens as well as branch categories is presented in Table 6-2. Significant variation in mean values was noted among the major treatments ( the four different doses under the three varieties), varieties, treatments, varieties into treatments, varieties into modes and varieties into treatments into branch-categories interactions. Minor treatments ( five $M_1$ branch categories) and treatments into modes interaction showed no significant variation in mean values.

The mean values under 1.0 per cent EMS ranged from 20.27 under 30 kR gamma rays in $V_1$ in the fifth branch category to 28.68 in the fourth branch category. In $V_2$ the range was from 23.96 in the fourth branch category under

Table 6-2 Mean number of fruits per plant as influenced by varieties, $M_1$ branch categories and mutagens & their doses

| Varieties | Mutagens | Doses | $M_1$ branch categories | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| $V_1$ | EMS | 0.5% | 23.04 | 20.73 | 23.21 | 26.65 | 23.03 | 23.33 |
| | | 1.0% | 23.45 | 25.69 | 25.00 | 28.68 | 27.53 | 26.07 |
| | Gamma rays | 20kR | 22.81 | 27.87 | 24.36 | 27.46 | 21.87 | 24.87 |
| | | 30kR | 21.08 | 24.69 | 21.49 | 23.88 | 20.27 | 22.28 |
| $V_2$ | EMS | 0.5% | 27.74 | 26.68 | 35.09 | 29.23 | 27.72 | 29.29 |
| | | 1.0% | 24.47 | 24.44 | 28.46 | 28.87 | 34.79 | 28.20 |
| | Gamma rays | 20kR | 28.76 | 33.97 | 35.21 | 28.55 | 25.88 | 30.47 |
| | | 30kR | 35.13 | 31.53 | 32.66 | 23.96 | 24.32 | 29.52 |
| $V_3$ | EMS | 0.5% | 31.30 | 40.66 | 33.52 | 31.18 | 26.12 | 32.56 |
| | | 1.0% | 30.62 | 33.99 | 24.01 | 29.09 | 28.66 | 29.27 |
| | Gamma rays | 20kR | 0 | 0 | 0 | 0 | 22.80 | 22.80 |
| | | 30kR | 0 | 0 | 0 | 0 | 21.99 | 21.99 |
| | | Mean | 26.84 | 30.11 | 28.29 | 27.75 | 26.41 | |

Analysis of variance

| Source | F value | C.D. value |
|---|---|---|
| Major treatments | 23.85* | 6.14 |
| Varieties (V) | 35.10* | 8.28 |
| Doses (T) | 19.98* | - |
| V x T | 22.04* | - |
| Minor treatments (M) | 2.39 | 4.39 |
| V x M | 5.11* | 8.28 |
| T x M | 1.49 | - |
| V x T x M | 4.51* | - |

* Significant at 5% level

30 kR gamma rays to 35.21 in the third branch category under 20 kR gamma rays. In the third variety, the average fruit number varied from 21.99 in the fifth branch category under 30 kR to 40.66 in the second branch category under 0.5 per cent EMS.

In $V_1$, the maximum mean number of fruits under the different doses of EMS was registered in the fourth branch category whereas for the two gamma ray exposures, the same was observed in the second branch category. The minimum values for the different doses of chemical mutagens were registered in the earlier formed branches where as in physical mutagen it was observed in the bulk plant seed collection. In $V_2$ both the doses of EMS showed the minimum values in the second branch category and the maximum values in the third under 0.5 per cent and in the bulk seed collection for 1.0 per cent concentration. The minimum mean number of fruits per plant under 20 kR was in the bulk plant seed collection with the corresponding maximum value in the third branch category. In the case of 30 kR gamma rays the corresponding values were shown by the fourth and first branch categories respectively. The maximum mean number of fruits per plant in the different doses were comparable. In $V_3$ the maximum mean number of fruits were shown by the second branch category for the different

doses of EMS, with the corresponding minimum means in the fifth (0.5%) and the third (1.0%) branch categories.

Main plot means ranged from 21.99 under 30 kR gamma rays to 32.56 under 0.5 per cent EMS in $V_3$. The minimum value was significantly inferior to the means registered under the different doses of the mutagens in $V_2$ and under the different doses of EMS in $V_3$. In $V_3$ 20 kR gamma rays also showed a significantly inferior mean fruit number. The same was the case with 0.5 per cent EMS and 30 kR gamma rays in $V_1$. The maximum value was found to be significantly superior to the mean values registered under the different doses in $V_1$ and the different gamma ray exposures in $V_3$. The sub-plot means ranged insignificantly from 26.41 in the bulk plant seed collection to 30.11 in the second branch category.

No significant main x sub plot interaction was observed in $V_1$. In $V_2$ the value under third branch category (35.09) in 0.5 per cent EMS was found to be significantly superior to the second branch category (26.68) whereas in 1.0 per cent EMS, the fifth branch category registered significant superiority over the first and second branch categories. In the case of the different gamma ray exposures also the maximum mean number of fruits observed was significantly superior to the bulk plant seed collec-

tion and also the minimum mean value of the fourth branch category mean in 30 kR gamma rays. In $V_3$, both the doses of chemical mutagen showed significantly high mean values in the second branch category the superiority being over the first, fourth and fifth branch category means in 0.5 per cent over the third branch category mean in 1.0 per cent EMS.

6.3. Phenotypic frequency of fruit number variants:

Table 6-3 gives the frequency distribution of variants in the number of fruits per plant as affected by physical and chemical mutagens under five $M_1$ branch categories in three varieties of chillies. The results of statistical analysis is represented in Table 6-3-A. Significant variation in mean frequency distribution among varieties, doses of mutagen, varieties into doses interaction, $M_1$ branch categories treatments into modes of seed collection, varieties into treatments into modes interaction, the three phenotypic categories, varieties into phenotypic classes, treatments into phenotypic classes and modes of seed collection into phenotypic classes interactions.

Both positive and negative variants were produced in all the three varieties under the different doses of EMS and gamma rays. The frequency of those variants differed depending on varieties, exposures and the $M_1$ branch cate-

Table 6-3-A. Statistical analysis on the frequency distribution of fruit number variants ( transformed values)

| Varieties | Mutagens & doses: EMS 0.5% | EMS 1.0% | Gamma rays 20kR | Gamma rays 30kR | $M_1$ branch categories: 1 | 2 | 3 | 4 | 5 | Phenotypic clases: -ve variants | control group | +ve variants | Mean (V) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_1$ | 34.78 | 34.91 | 34.66 | 34.87 | 34.80 | 35.00 | 34.51 | 34.96 | 34.75 | 31.02 | 44.28 | 29.65 | 34.81 |
| $V_2$ | 34.38 | 33.97 | 34.65 | 34.57 | 34.42 | 34.00 | 34.49 | 34.33 | 34.71 | 26.63 | 48.52 | 29.33 | 34.39 |
| $V_3$ | 34.39 | 34.13 | 6.89 | 6.84 | 17.10 | 17.16 | 17.05 | 17.23 | 34.53 | 19.54 | 34.93 | 19.19 | 20.62 |
| Mean | 34.59 | 34.35 | 25.40 | 25.43 | 28.77 | 28.72 | 28.69 | 28.84 | 34.67 | 25.73 | 42.58 | 26.06 | |

| Phenotypic classes | Mutagens & doses: EMS 0.5% | EMS 1.0% | Gamma rays 20kR | Gamma rays 30kR | $M_1$ branch categories: 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|
| -ve variants | 31.71 | 25.64 | 22.09 | 23.48 | 20.62 | 21.44 | 23.19 | 24.48 | 27.28 |
| control group | 45.28 | 50.09 | 38.17 | 36.77 | 34.47 | 38.03 | 41.21 | 38.56 | 48.54 |
| +ve variants | 27.82 | 28.56 | 24.1 | 23.75 | 21.72 | 26.18 | 22.86 | 23.48 | 26.94 |

| $M_1$ branch categories | Mutagens & doses: EMS 0.5% | EMS 1.0% | Gamma rays 20kR | Gamma rays 30kR |
|---|---|---|---|---|
| 1 | 34.78 | 33.70 | 23.73 | 22.88 |
| 2 | 34.51 | 34.30 | 22.84 | 23.23 |
| 3 | 34.49 | 34.08 | 23.00 | 23.18 |
| 4 | 34.40 | 34.55 | 22.93 | 23.46 |
| 5 | 34.75 | 35.04 | 34.49 | 34.38 |

Analysis of variance

| Source | F Value | C.D value |
|---|---|---|
| Variaties (V) | 4035.58* | 0.39 |
| Treatments (T) | 1266.99* | 0.46 |
| Branch categories (M) | 142.58* | 0.63 |
| Phenotypic classes (S) | 200.12* | 1.90 |
| V x T combinations | 1317.10* | 0.79 |
| V x M " | 134.92* | 1.09 |
| T x M " | 39.70* | 1.26 |
| T x S " | 4.59* | 3.81 |
| V x S " | 5.31* | 3.30 |
| M x S " | 15.53* | 4.26 |

* Significant at 5% level

gories. The mean frequency for negative variants in number of fruits per plant ranged from 7.35 per cent under the second branch category in 20 kR in $V_2$ to 50.42 per cent under the fourth category in 0.5 per cent EMS in $V_3$. Positive variation was found to be minimum under the second branch category in 1.0 per cent EMS in $V_2$ (8.19%) and maximum under 30 kR gamma rays in the same variety and branch-category (56.32%). Both positive and negative variants were produced in approximately equal proportions under the first branch category in 30 kR gamma rays in $V_3$, the third branch category in the same dose of the same variety, the first branch category in 30 kR in $V_1$ and in 20 kR in $V_2$ under the same branch category. The effects produced by 0.5 per cent EMS under the first branch category of $V_1$, under the second branch category in 20 kR and the fifth branch category in 1.0 per cent of the same variety were comparable, the frequencies being approximately equal to 25:50:25 in the negative, control and positive categories respectively.

The frequencies of plants falling in the three phenotypic classes showed no significant differences between $V_1$ and $V_2$ but $V_3$ showed a significant reduction as there was no branch-wise fruit collection from the two doses of physical mutagen. Significance was noted for the number of plants coming under the three phenotypic categories,

but negative (25.73%) and positive (26.06%) variants were produced in approximately equal proportions. The maximum frequency of negative variants (31.02%) and positive variants (29.65%) were recorded under $V_1$. The mean frequencies registered under the negative and positive groups in $V_1$ and $V_2$ were found to be significantly superior to the corresponding values under $V_3$. Maximum frequency of negative variants was noted under 0.5 per cent EMS and positive variants under 1.0 per cent EMS. A significantly higher frequency of negative variants as compared to other treatments was noted under 1.0 per cent EMS. Positive and negative variants were maximum in the fifth branch category. Under negative variants, the first and second branch categories were found to be significantly inferior to the maximum value and under positive variants, the second and the fifth branch category means were found to be significantly superior to all the other mean frequencies.

## 7. Yield per plant:

### 7.1. Mean yield per plant as influenced by genotypes and mutagens

Yield per plant in the different varieties as influenced by the mutagens and their doses is presented in Table 7-1. On statistical analysis, no significant variation in the mean value was noted among varieties, between mutagens and their levels, treated vs control populations and variety into dose effect interactions.

Mean yield per plant in $V_1$ ranged from 21.45g in 30 kR to 39.59g in the control which recorded the maximum yield. In $V_2$ control population showed the lowest mean yield of 28.44g with 1.0 per cent EMS recording the highest value of 45.71g. In $V_3$ also, mutagen treatment led to an increase in mean yield above the control from 23.29g in control to 35.33g in 30 kR gamma rays. The varietal means showed an insignificant variation, ranging from 28.31g in $V_1$ to 34.01g in $V_2$. $V_3$ recorded a mean value of 29.22g. It was noted that the shift in mean yield on mutagenic treatment was unidirectional in all the varieties tested. In $V_1$ where the control population recorded the maximum mean yield as compared to the other two varieties, this shift was in negative direction alone whereas in $V_2$ and $V_3$ this shift was in the positive direction alone. Hence in the last two varieties, mutagenic treatment resulted in a general, but insignificant increase in mean yield.

Table 7-1 Mean yield/plant(g) as influenced by genotypes and mutagens

| Varieties | Control | EMS | | Gamma rays | | General mean |
|---|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20kR | 30kR | |
| $V_1$ | 39.59 | 25.79 | 30.91 | 23.81 | 21.45 | 28.31 |
| $V_2$ | 28.44 | 33.93 | 45.71 | 29.55 | 32.87 | 34.01 |
| $V_3$ | 23.29 | 31.24 | 29.97 | 26.27 | 35.33 | 29.22 |
| General mean | 30.44 | 30.32 | 35.53 | 26.54 | 29.88 | |

Analysis of variance

| Source | F value | C.D.value |
|---|---|---|
| Between varieties (V) | 1.08 | - |
| Between mutagens | 1.49 | - |
| Between levels of EMS | 0.91 | - |
| Between levels of gamma rays | 0.37 | - |
| Treated Vs Control | 0.001 | - |
| Varieties X Treatments | 1.002 | - |

## 7.2. Mean yield per plant under different $M_1$ branch categories

Mean yield per plant due to varieties, mutagens and their doses and the five $M_1$ branch categories is depicted in Table 7-2. Statistical analysis of the data showed significant variation in mean values among the major treatments (four different doses under the three varieties), varieties, treatments, varieties into treatments, varieties into modes, treatments into branch categories and varieties into treatments into branch categories interactions. The influence of $M_1$ branch categories was not found to be significantly different.

A range in mean yield per plant from 21.45g in the fifth branch category under 30 kR to 39.59g in the second branch category under 20 kR was noted in $V_1$. In $V_2$ a wide range in value from 26.29g in the fourth category under 30 kR to 59.85g in the second category under 20 kR gamma rays was noticed. The values ranged from 26.28 in the fifth branch category under 20 kR to 57.46g in the second category under 1.0 per cent EMS in the variety $V_3$. It was notable that the second branch category always registered the maximum mean yield in all the varieties tried and that too under 20 kR exposures. Only in the non-availability of branch-wise collection under gamma ray exposures in $V_3$ the maximum value shifted to 1.0 per cent EMS.

Table 7-2 Mean yield/plant(g) as influenced by varieties, $M_1$ branch categories and mutagens & their doses

| Varieties | Mutagens | Doses | $M_1$ branch categories | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| $V_1$ | EMS | 0.5% | 35.70 | 26.55 | 28.82 | 31.00 | 25.79 | 29.57 |
| | | 1.0% | 27.35 | 34.36 | 33.37 | 33.96 | 30.91 | 31.99 |
| | Gamma rays | 20kR | 33.34 | 39.59 | 28.47 | 25.99 | 23.81 | 30.24 |
| | | 30kR | 31.14 | 35.17 | 28.17 | 38.14 | 21.45 | 30.81 |
| $V_2$ | EMS | 0.5% | 41.28 | 33.13 | 29.94 | 38.34 | 33.93 | 35.12 |
| | | 1.0% | 33.78 | 32.45 | 37.26 | 39.59 | 45.71 | 37.76 |
| | Gamma rays | 20kR | 51.96 | 59.85 | 44.34 | 31.91 | 29.55 | 43.51 |
| | | 30kR | 39.29 | 40.28 | 39.94 | 26.29 | 32.87 | 35.73 |
| $V_3$ | EMS | 0.5% | 38.99 | 48.81 | 56.18 | 37.83 | 31.24 | 42.61 |
| | | 1.0% | 30.14 | 57.46 | 33.07 | 40.20 | 29.97 | 38.17 |
| | Gamma rays | 20kR | 0 | 0 | 0 | 0 | 26.27 | 26.27 |
| | | 30kR | 0 | 0 | 0 | 0 | 35.33 | 35.33 |
| | | Mean | 36.29 | 40.76 | 35.85 | 34.33 | 33.58 | |

Analysis of variance

| Source | F value | C.D. value |
|---|---|---|
| Major treatments | 11.94* | 11.08 |
| Varieties (V) | 17.17* | 12.58 |
| Doses (T) | 8.71* | - |
| V x T | 11.81* | - |
| Minor treatments (M) | 2.44 | 7.63 |
| V x M | 4.00* | 12.58 |
| T x M | 2.46* | " |
| V x T x M | 5.35* | " |

* Significant at 5% level

Lowest mean yield in $V_1$ was observed under the bulk seed collection category as compared to branch-wise collections in the different gamma ray exposures and 0.5 per cent EMS but under 1.0 per cent a shift to the first branch category was noticed. The maximum mean yield of 35.70g was registered by 0.5 per cent EMS concentration in the first branch category and the higher concentration of EMS in the second branch category, the value being comparable to that of the lower concentration. The corresponding values in the lower and higher doses of gamma rays were recorded in the second and fourth categories respectively, which were comparatively higher than those for EMS.

The mean yields in $V_2$ under 0.5 per cent EMS ranged from 28.94g per plant in the third branch category to 41.28g per plant in the first branch category. The maximum mean yield in the bulk progeny (45.71g) and the minimum value in the second branch category (32.45g) were recorded by 1.0 per cent EMS. Highest mean yield under the different gamma ray exposures was observed in the second branch category with the corresponding lowest values in the bulk progeny and the fourth category. A maximum mean yield of 59.85g was recorded by 20 kR exposure which was comparatively superior to all other doses. In $V_3$, the values ranged from 31.24g (0.5% EMS) and 29.97g (1.0% EMS) in the bulk progeny to 56.18g (0.5% EMS) in the third branch

category and 57.46g(1.0% EMS) in the second branch category.

Main plot means ranged from 26.27g under 20 kR in $V_3$ to 43.51g in $V_2$ under the same dose. The main plot means under 1.0 per cent EMS and 20 kR gamma rays in $V_2$ and the different concentrations of EMS in $V_3$ were significantly superior to the lowest main plot means and the highest mean value of 43.51g was significantly superior to the means registered under the different doses in $V_1$ and the lowest mean value in $V_3$. The $V_3$ mean yield of 42.61g under 0.5 per cent was also significantly superior to several other main plot means.

The sub-plot means ranged from 33.58g in the fifth branch category to 40.76g in the second branch category but no significance was observed. In five out of ten cases, maximum mean yield was recorded in the second branch category.

The maximum mean yields of 39.59g under 20 kR in $V_1$ and 35.17g in 30 kR gamma rays under the second branch category were found to be significantly superior to the means recorded under the later formed branches and the bulk progeny. In $V_2$ the maximum mean yields under 1.0 per cent EMS and 30 kR gamma rays were found to be significantly superior to the minimum values under the same doses.

The second branch category mean of 59.85g under 20 kR was significantly superior to all other branch category means. The minimum value under the same dose was significantly inferior to the average values under the first and third branch categories also. The maximum mean yield recorded under 0.5 per cent in $V_1$ was significantly superior to the values under the first, fourth and fifth categories. The minimum value under the same dose was significantly inferior to the second branch category mean also. Under 1.0 per cent EMS also the second branch category mean of 57.46g was significantly superiorto all the other means.

7.3. Phenotypic frequency of yield variants

The frequency distribution of yield variants in percentage as affected by the different doses of EMS and gamma rays under five $M_1$ branch categories in the varieties $V_1$, $V_2$ and $V_3$ is depicted in Table 7-3. The results of statistical analysis are in Table 7-3-A. Mean number of plants coming under the different categories was found to vary significantly among varieties, doses of mutagen, varieties into doses interaction, $M_1$ branch categories, treatments into modes of seed collection, varieties into treatments into modes interaction, the three phenotypic categories, varieties into phenotypic classes, treatments into pheno-

typic classes and modes of seed collection into phenotypic classes interaction.

The different doses of EMS and gamma rays gave both positive and negative variants in all the three varieties but the frequency of these variants differed depending on varieties, exposures and the $M_1$ branch categories. The second branch category under 20 kR gamma rays in $V_2$ registered the minimum frequency of negative variants (8.1%) and the maximum of positive variants (63.5%). The corresponding maximum and minimum values were observed under the 2nd branch category in 20 kR gamma rays in $V_1$ (54.43%) and the third branch category in 0.5 per cent EMS of the same variety (10.21%). Frequency of variants from the control was found to be maximum under the fourth branch category in 30 kR gamma rays in $V_1$ and the first branch category in 0.5 per cent EMS in $V_2$, the mean frequencies in the control group being about 10 per cent and 14 per cent respectively.

In the case of yield variants also a significant reduction in frequency under the three phenotypic classes was noted in $V_3$, owing to the lack of branch-wise seed collection from the two exposures of gamma rays. The frequency of variants coming under the negative group in the different varieties (31.43%) was found to be significantly superior to the positive variants (28.53%).

In $V_1$ and $V_2$ frequency of plants were found to be significantly different among positive and negative variants. Number of plants coming under both negative and positive phenotypic categories were found to be maximum in $V_1$. The maximum frequency of both negative and positive variants were recorded by 0.5 per cent EMS. Negative variants created by the different concentrations of EMS was significantly superior to the different gamma ray exposures. Positive variants produced by 0.5 per cent EMS were significantly superior to all other treatments whereas the value registered under 1.0 per cent EMS was significantly inferior to all other treatments. The mean frequencies of both positive and negative variants were found to be maximum in the fifth branch category. Mean frequency of negative variants in the bulk progeny was found to be significantly superior to the frequencies registered under all other categories. The second branch category registered a mean negative frequency of 25.99 per cent which was significantly inferior to all other mean frequencies in the negative group. In the positive group, mean frequencies registered under the second and bulk progeny were found to be significantly superior to all other values.

Fig. I. Chlorophyll deficient mutants in $M_2$-control plants (top) and chlorina types (below)

Fig. II. Association of different modes of fruit bearing in a single plant (CA-30 under 30 kR gamma rays in the first $M_1$ branch category)

Fig. III. Fruit size variation induced by the Mutagens in CA-30 (control on top).

Fig. IV. Twin fruits due to mutagen treatment in the three varieties tested. (control type on top).

# DISCUSSION

# DISCUSSION

Quantitative characters, majority of the productive traits and their contributes are controlled by the co-ordinated action of genes at many loci. East (1935) has pointed out that mutations affecting quantitative characters occur spontaneously in nature as was observed in doubled haploids of Nicotiana tabaccum and that such mutations occur both in the positive and negative directions. Many mutation breeders including Oka et al. (1958) in rice, Gregory (1955) in groundnut, Rawlings et al. (1958) in soybean, Martens and Burdick (1957) in tomato, Scossiroli et al. (1960) in what and Gaul (1965), Brock (1965) and Goul and Mittenstenchelld (1961) in barley have analysed the effect of different mutagens on polygenic systems and proved beyond doubt that induced genetic variability is a useful tool for the improvement of quantitative traits.

During the present investigation, the effects of two doses each of EMS and gamma rays on three varieties of chillies were studied with respect to seven quantitative characters and the results of analysis of mean values and frequency distribution of different phenotypic classes are presented below.

Table 8-1 Direction of shift in mean value for various quantitative characters

| Characters | | EMS | | Gamma rays | |
|---|---|---|---|---|---|
| | | 0.5% | 1.0% | 20 kR | 30 kR |
| 1) Plant height | $V_1$ | + | + | + | + |
| | $V_2$ | - | - | + | + |
| | $V_3$ | + | + | - | - |
| 2) Number of branches | $V_1$ | + | + | + | + |
| | $V_2$ | + | - | + | + |
| | $V_3$ | + | + | - | - |
| 3) Fruit length | $V_1$ | - | - | - | - |
| | $V_2$ | - | + | + | + |
| | $V_3$ | - | - | - | + |
| 4) Fruit weight | $V_1$ | -* | -* | -* | - |
| | $V_2$ | - | - | + | - |
| | $V_3$ | - | - | - | - |
| 5) Number of seeds per fruit | $V_1$ | - | - | - | - |
| | $V_2$ | - | - | + | - |
| | $V_3$ | - | - | - | - |
| 6) Number of fruits per plant | $V_1$ | + | + | + | - |
| | $V_2$ | + | + | - | + |
| | $V_3$ | + | + | + | + |
| 7) Yield/plant | $V_1$ | - | - | - | - |
| | $V_2$ | + | + | + | + |
| | $V_3$ | + | + | + | + |

* Significant at 5% level.

An increase in mean value for plant height over control was noted in majority of the treatments. In the case of $V_1$, the two different concentrations of EMS and the two exposures of gamma rays led to a general enhancement in mean plant height whereas varieties $V_2$ and $V_3$ showed both negative and positive shifts in mean value. Chemical mutagen treatment led to a decrease in mean value only in $V_2$ and physical mutagen treatment produced a corresponding decrease in $V_3$ for the character concerned. Both EMS and gamma rays thus showed characteristic effects depending on varieties. Most of the $M_1$ branches showed a positive shift in mean plant height in $V_1$ and $V_3$ but in $V_2$, negative shift was more prominent. In $V_1$ for chemical mutagen treatment, only the second branch-category under 0.5 per cent recorded a negative value, all other branch-categories showed positive shift. In gamma ray treatment however, the fifth branch-category under 20 kR as well as the first and fifth category under 30 kR recorded negative values. Positive shift was shown by the second category under 0.5 per cent and the fourth and fifth categories under 1.0 per cent in $V_2$. On the other hand, the middle three categories under 20 kR and the early emerged branches under 30 kR recorded positive shifts. In $V_3$, positive shift was more prominent in the different branch-categories on EMS treatment. In the absence of branch-wise collection in physical

mutagen treatment, the bulk progeny recorded a negative shift in mean value.

A positive shift in mean values was more prominent in the case of plant height, although the frequency of both positive and negative variants in the polygenic system was nearly equal. This is because it is the magnitude of the phenotypic effect of a mutation which gives the positive shift in mean.

A reduction in mean plant height as a result of mutagen treatment as was noted in certain cases in the present investigation has been reported by several workers. Sakai and Susuki (1964) after X-irradiation in rice reported that mutation of polygenes responsible for quantitative characters like plant height occur in most cases unidirectionally in minus direction. Nayar (1976) found significant reduction in mean values in $M_2$ and $M_3$ generations for six polygenic characters including plant height in rice following EMS and gamma ray treatments.

Increase in mean values for plant height as a result of mutagen treatment, as has been noted in some cases in the present study, has also been reported by several workers. Kumar and Das (1977) studied induced polygenic variations in Brassica for plant height following treatments with

gamma rays and thermal neutrons. The mean values were increased in $M_2$ and later generations in comparison to the unirradiated. They suggested that this may be related to the effect of selection applied in $M_2$ and later generations. Goud et al. (1971) studied induced polygenic mutations in two varieties of ragi after treating the seeds with EMS and reported that mean plant height in both the varieties shifted in the positive direction.

In variety $V_1$, mutagen treatment led to a general increase in mean number of branches in all treatments tried whereas in $V_2$ and $V_3$, both positive and negative shifts were observed. A negative shift in mean number of branches was noted under 1.0 per cent EMS in $V_2$. In $V_3$, both the exposures of gamma rays drastically reduced the branching ability. Under the higher concentration of EMS in $V_1$ all the branch categories showed a positive shift in mean value and three out of the five categories in the lower concentration also registered the same trend. In physical mutagen treatment also, positive shift was more prominent in the branch-wise collections, with the bulk progeny recording a negative shift. In the lower concentration of EMS, 80 per cent of the branch categories showed a positive shift whereas in the higher concentration,

the same proportion showed a negative shift in $V_2$. The higher concentration of gamma rays registered a complete positive shift but only the second and third branch categories recorded a positive shift under the lower concentration, in the same variety. In $V_3$ 0.5 per cent EMS showed a total positive shift whereas under 1.0 per cent EMS, only 60 per cent of the branches showed an increase in mean value. The bulk progeny registered a negative shift in mean value in both the exposures of gamma rays. In the case of number of branches/ plant the mean values in general registered a positive shift in the different varieties and treatments which is quite reasonable, as there was a complete absence of negative variants in $V_2$ and $V_3$. Positive variation was also not very high but the larger control group, along with the absence of negative variants, contributed to the positive shift in mean.

Reduction in mean value for number of tillers following X- irradiation has been reported by Sakai and Susuki (1964) in rice. Gamma ray and EMS treatments in rice has led to a significant reduction in mean number of tillers in $M_2$ and $M_3$ generations (Nayar, 1976). Goud (1967a) in hexaploid wheat observed a shift in mean towards the

negative direction for tiller number. On the other hand, Bateman (1959) observed that the means for tillers per plant in rice increased after irradiation and suggested that the overall effect of polygenic mutation in rice was unidirectional. The mean number of branches in $M_2$ and later generations were found to be increased due to treatment with gamma rays and thermal neutrons, as was reported by Kumar and Das (1977) in Brassica. Shift in mean values under $M_1$ branch categories suggest that the frequency of mutated sectors vary depending on the genotypes and mutagen and their doses.

A complete negative shift in mean fruit length on mutagen treatment was observed in $V_1$. In $V_2$, positive shift was more prominent and in $V_3$, three out of the four treatments registered negative shift. All the different branch categories under 0.5 per cent and all except the third branch category under 1.0 per cent EMS recorded negative shift in mean value in $V_1$. In the case of gamma ray exposure, all except the second branch category in 20 kR and the later formed branches in 30 kR recorded negative shift. In $V_2$, the lower and higher concentrations of EMS showed characteristic effect, all except the later formed branches showing a negative shift under 0.5 per cent and all the different branch categories recording positive

shift under 1.0 per cent. All except the earlier formed branches showed a negative shift in mean value under 20 kR and all except the second category and bulk progeny showed negative under 30 kR. The third branch category alone under 0.5 per cent and the second branch category alone under 1.0 per cent registered positive shifts in mean value in $V_3$.

A negative shift in mean panicle length parallel to fruit length following X- irradiation has been reported in rice by Sakai and Susuki (1964). These authors based on the results from various sources and their own work, arrived at the general conclusion that induced mutations in plants occur in minus directions so far as yield components are concerned. Nayar (1976) has also reported similar reductions in mean panicle length in rice. For fruit length, mean values were mostly shifted in the negative direction in all the three varieties, because the frequency distribution of negative variants was found to be greater than the positive variants although the magnitude of negative phenotypic effects as compared to the positive was not commendable.

In variety $V_1$, mutagen treatment led to a general decrease in mean fruit weight which was significant under the two concentrations of EMS and 20 kR gamma rays.

Table 8-2. The mode of distribution of mean values for quantitative characters among the five $M_1$ branch categories, represented as 1-5 (EMS)

| Characters | | $M_1$ branch number showing mean value shift | | | |
|---|---|---|---|---|---|
| | | Negative shift | | Positive shift | |
| | | 0.5% EMS | 1.0% EMS | 0.5% EMS | 1.0% EMS |
| 1. Plant height | $V_1$ | 2 | - | 1,3,4,5 | 1,2,3,4,5 |
| | $V_2$ | 1,3,4,5 | 1,2,3 | 2 | 4,5 |
| | $V_3$ | - | 4,5 | 1,2,3,4,5 | 1,2,3 |
| 2. Number of branches | $V_1$ | 3,5 | - | 1,2,4 | 1,2,3,4,5 |
| | $V_2$ | 3 | 1,2,3,4 | 1,2,4,5 | 5 |
| | $V_3$ | - | 1,3 | 1,2,3,4,5 | 2,4,5 |
| 3. Fruit length | $V_1$ | 1,2,3,4,5 | 1,2,4,5 | - | 3 |
| | $V_2$ | 1,2,3,5 | - | 4 | 1,2,3,4,5 |
| | $V_3$ | 1,2,4,5 | 1,3,4,5 | 3 | 2 |
| 4. Fruit weight | $V_1$ | 2,3,4,5 | 1,2,3,4,5 | 1 | - |
| | $V_2$ | 2,3,4,5 | 1,2,3,5 | 1 | 4 |
| | $V_3$ | 1,2,4,5 | 1,3,4,5 | 3 | 2 |
| 5. Number of seeds per fruit | $V_1$ | 2,3,4,5 | 1,2,3,4,5 | 1 | - |
| | $V_2$ | 2,3,5 | 1,2,3,5 | 1,4 | 4 |
| | $V_3$ | 1,2,4,5 | 1,3,4,5 | 3 | 2 |
| 6. Number of fruits per plant | $V_1$ | 2 | - | 1,3,4,5 | 1,2,3,4,5 |
| | $V_2$ | 3 | 5 | 1,2,4,5 | 1,2,3,4 |
| | $V_3$ | - | - | 1,2,3,4,5 | 1,2,3,4,5 |
| 7. Yield/plant | $V_1$ | 1,2,3,4,5 | 1,2,3,4,5 | - | - |
| | $V_2$ | - | - | 1,2,3,4,5 | 1,2,3,4,5 |
| | $V_3$ | - | - | 1,2,3,4,5 | 1,2,3,4,5 |

(contd...)

Table 8-2(contd.) The mode of distribution of mean values for quantitative characters among the five $M_1$ branch categories, represented as 1-5 (Gamma rays)

| Characters | | $M_1$ branch number showing mean value shift | | | |
|---|---|---|---|---|---|
| | | Negative shift | | Positive shift | |
| | | 20 kR | 30 kR | 20 kR | 30 kR |
| 1. Plant height | $V_1$ | 5 | 1,5 | 1,2,3,4 | 2,3,4 |
| | $V_2$ | 1,5 | 4,5 | 2,3,4 | 1,2,3 |
| | $V_3$ | 5 | 5 | - | - |
| 2. Number of branches | $V_1$ | 5 | 1,5 | 1,2,3,4 | 2,3,4 |
| | $V_2$ | 1,4,5 | - | 2,3 | 1,2,3,4,5 |
| | $V_3$ | 5 | 5 | - | - |
| 3. Fruit length | $V_1$ | 1,3,4,5 | 1,2,3,5 | 2 | 4 |
| | $V_2$ | 3,4,5 | 1,3,4 | 1,2 | 2,5 |
| | $V_3$ | 5 | - | - | 5 |
| 4. Fruit weight | $V_1$ | 1,2,3,4,5 | 1,2,3,4,5 | - | - |
| | $V_2$ | 3,4,5 | 1,2,3,4,5 | 1,2 | - |
| | $V_3$ | 5 | 5 | - | - |
| 5. Number of seeds per fruit | $V_1$ | 1,2,3,4,5 | 1,2,3,4,5 | - | - |
| | $V_2$ | 4,5 | 1,3,4,5 | 1,2,3 | 2 |
| | $V_3$ | 5 | 5 | - | - |
| 6. Number of fruits per plant | $V_1$ | 5 | 1,3,5 | 1,2,3,4 | 2,4 |
| | $V_2$ | 1,4,5 | 2,3,4 | 2,3 | 1,5 |
| | $V_3$ | - | - | 5 | 5 |
| 7. Yield/plant | $V_1$ | 1,2,3,4,5 | 1,2,3,4,5 | - | - |
| | $V_2$ | - | - | 1,2,3,4,5 | 1,2,3,4,5 |
| | $V_3$ | - | - | 5 | 5 |

In $V_2$ also mean fruit weight was found to be decreased in most of the cases and In $V_3$, a total reduction was noted which was significant under 20 kR gamma rays. In all the varieties EMS led to a reduction in mean fruit weight. Gamma rays under 20 kR led to significant reduction in mean values in $V_1$ and $V_3$ where as in $V_2$ an increase was noted. The higher dose of gamma rays also reduced mean fruit weight. In $V_1$ among EMS and gamma ray treatments, only the first branch category under 0.5 per cent registered a positive shift in mean fruit weight. In $V_2$ the early formed branch category under 0.5 per cent and the later formed branches under 1.0 per cent registered positive shift. Under 20 kR gamma rays both the first and second branch categories registered positive shift leading to a general shift in positive direction for the treatment mean. Under 30 kR, all the branch categories showed a negative shift. In $V_3$ the third branch category under 0.5 per cent EMS and the second branch category under 1.0 per cent EMS registered positive shift. Under physical mutagen treatment, both the bulk progenies showed negative shifts in mean value. In general, a significant negative shift in mean value was noted for fruit weight although the frequency of positive variants was comparatively greater than the negative variants. This is attributed to the greater magnitude of the

negative phenotypic effects created, leading to a fall in mean fruit weight.

In parallel to what has been observed in majority of the treatments in the present study, Nayar and Ninan (1978) observed that gamma ray exposures resulted in a significant reduction in mean weight of ear in $M_2$ and $M_3$ compared to control. Rawlings et al. (1958) reported that seed weight in soya beans increased after irradiation. Rao and Siddiq (1977) analysed induced variations for yield and its components in two varieties of rice and suggested that the changes in the mean value and skewness of the frequency distribution in the mutagen treated population varied with the variety, character, mutagen and the generations as was noted in the present investigation.

Number of seeds per fruit showed a negative shift in mean value in almost all the treatments. The different concentrations of EMS in all the three varieties showed a negative shift. As in fruit weight, 20 kR gamma rays exposure in $V_2$ alone showed a positive shift in mean seed number. In $V_1$ the early formed branch category under 0.5 per cent alone showed a positive shift among the different treatments. For chemical mutagen treatment in

$V_2$, the earlier and the later formed branches recorded a positive shift where as the case was reversed in $V_3$. For physical mutagen treatment in $V_2$, the later formed branches were found to be more adversely affected for the character concerned in 20 kR but in the higher exposure, a complete negative shift was observed. In $V_3$ the bulk progeny recorded a negative shift for both the exposures. In parallel with the present results, Sakai and Suzuki (1964) and Tanaka (1968) found that the distribution of variance for certain quantitative characters was skewed and therefore stated that mutations for polygenes occurred mostly in a negative direction. Gregory (1965, 1966) postulated that the number of both positive and negative mutants in the polygenic system is nearly equal and that it is the magnitude of the phenotypic effect of a mutation which gives the negative effect and not its unidirectional character. In seed number per fruit, an insignificant negative shift in mean value was noted in all 3 varieties tested under the different treatments tried. This is because although the frequency of negative variants was in no way superior to the positive variants, the magnitude of decrease in seed number was commendable.

In the first and second varieties, a positive shift in the number of fruits per plant was noted for three out of

four treatments and in $V_3$ all the four treatments registered a positive shift. Chemical mutagen treatment in the three varieties tested always resulted in a higher mean number of fruits per plant. In physical mutagen treatment, 30 kR in $V_2$ and 20 kR in $V_3$ registered negative shifts. In $V_1$ for EMS treatment, all branch categories except the second under 0.5 per cent registered a positive shift in mean value. For gamma ray treatment, the fifth category under 20 kR and the first, third and fifth categories under 30 kR recorded negative shifts. The third branch-category under 0.5 per cent and the fifth branch-category under 1.0 per cent recorded negative shifts in $V_2$. For gamma ray treatment, the second and third branch categories under 20 kR and the first and fifth categories under 30 kR showed positive shifts. Both the mutagens in $V_3$ recorded positive shift in mean number of fruits in all the $M_1$ branch categories. In the case of number of fruits per plant, the mean values in general showed a positive shift which is due to the combined effect of the greater magnitude and the larger frequency of positive variants. Several workers including Miah and Yamaguchi (1965) are of opinion that mutations for majority of the polygenic traits occured symmetrically in positive and negative directions following gamma irradiation. Swaminathan (1966 b) was of opinion that the direction of incidence of micro mutations was

strongly influenced by the previous selection history of the variety.

Yield per plant showed a complete negative shift in $V_1$ and positive shifts in $V_2$ and $V_3$ under the various treatments. The response of the different varieties was characteristic in that all the five different branch categories in $V_1$ recorded negative shifts and in $V_2$ and $V_3$ all the branch categories recorded positive shifts in mean yield under both physical and chemical mutagen treatments. For yield per plant, the complete negative shift in $V_1$ means is attributed to a greater frequency of negative variants. The positive shifts in mean noted in $V_2$ and $V_3$ is due to a higher frequency of positive variants, supported by the greater magnitude of positive variants in fruit number which was able to compensate the effects of low mean fruit weights. A reduction in mean yield as a result of mutagen treatment has been reported by Papa et al.(1961) in soya bean, using physical mutagens. Vasudevan et al. (1969) observed increase in mean yield in barley at the highest exposure of X-rays. Matsuo and Onozawa (1961) concluded from irradiation experiments on rice that mutations of polygens could occur in plus as well as minus directions in the case of grain yield in rice. Griffiths and Johnston (1962) showed that in oats seed irradiation

caused mutations with regard to yield only in the minus direction. Rao and Siddiq (1977) induced variations for yield and its components in two varieties of rice and suggested that the changes in the mean value varied with the variety, character, mutagen and the generations. They opined that the negative shift in the mean for yield need not make breeders sceptical about the usefulness of mutation breeding for yield improvement. Mutants which transgress the upper range of the parents, though they occur at very low frequency, can still provide the necessary base for the desired direction of selection.

In general, a reduction in mean values for quantitative characters were noted in the present investigation as has been reported in wheat (Bhatia and Swaminathan, 1962; Scossiroli, 1966; Borojevic, 1969; Borojevic and Borojevic, 1968); Arabidopsis thaliana (Brock, 1967). Brassica campestris (Gupta and Swaminathan, 1967; Kumar and Das, 1969; 1974) and barley (Gaul, 1964a; 1967). In extensive studies performed by Scossiroli (1966a,b) and Scossiroli et al. (1966) on wheat, this effect was shown in the same population for a large number of characters. Miah and Yamaguchi (1965) assumed that following gamma ray treatments in rice, mutations for most of the quantitative

characters occurred symmetrically in plus as well as minus directions. Gaul (1965) after reviewing the concept of induced micro and macro mutations in barley suggested that the induced polygenic mutations in barley do not follow any particular direction and that they are at random. Aastveit (1967) also opined the same for rye following irradiation.

Phenotypic frequency distribution under the five $M_1$ branch-categories:

The frequency distribution of positive and negative variants created by the different doses of gamma rays and EMS was found to be dependent upon varieties, exposures and modes of $M_1$ seed collection.

In $V_1$ for plant height, the maximum and minimum phenotypic distribution of negative variants under 0.5 per cent and 1.0 per cent EMS was found to be in the bulk progeny and third branch-category respectively. Positive variants were found to be more in the earlier formed branches. For gamma-ray treatment, under 20 kR the fourth branch category showed maximum negative variants with a corresponding minimum value for positive variants. The earlier formed branches showed maximum positive variants with fewer negative variants. But in 30 kR, negative variants were maximum

Table 8-3. The maximum and minimum phenotypic distributions of negative and positive mutants induced by EMS among the five $M_1$ branch categories

| Character | | Branch category showing maximum & minimum distribution of | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Negative variants | | | | Positive variants | | | |
| | | 0.5% EMS | | 1.0% EMS | | 0.5% EMS | | 1.0% EMS | |
| | | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum |
| 1. Plant height | $V_1$ | 5 | 3 | 5 | 3 | 1 | 3 | 2 | 1 |
| | $V_2$ | 3 | 4 | 5 | 3 | 3 | 2 | 3 | 1 |
| | $V_3$ | 1 | 4 | 4 | 2 | 2 | 1 | 2 | 4 |
| 2. Number of branches | $V_1$ | 1 | 2 | 5 | 2 | 1 | 5 | 4 | 1 |
| | $V_2$ | - | - | - | - | 2 | 5 | 5 | 4 |
| | $V_3$ | - | - | - | - | 3 | 5 | 2 | 1 |
| 3. Fruit length | $V_1$ | 3 | 4 | 4 | 3 | 2 | 5 | 3 | 1 |
| | $V_2$ | 3 | 4 | 2 | 5 | 1 | 3 | 3 | 4 |
| | $V_3$ | 1 | 4 | 5 | 3 | 3 | 5 | 4 | 5 |
| 4. Fruit weight | $V_1$ | 1 | 2 | 5 | 4 | 3 | 4 | 4 | 2 |
| | $V_2$ | 3 | 4 | 2 | 5 | 1 | 3 | 4 | 5 |
| | $V_3$ | 3 | 5 | 5 | 2 | 5 | 2 | 2 | 5 |
| 5. Number of seeds/ fruit | $V_1$ | 1 | 5 | 5 | 4 | 2 | 1 | 4 | 2 |
| | $V_2$ | 3 | 4 | 2 | 5 | 1 | 4 | 1 | 2 |
| | $V_3$ | 3 | 4 | 5 | 4 | 2 | 5 | 3 | 5 |
| 6. Number of fruits/ plant | $V_1$ | 5 | 1 | 5 | 3 | 4 | 3 | 4 | 3 |
| | $V_2$ | 3 | 4 | 1 | 5 | 1 | 4 | 5 | 2 |
| | $V_3$ | 4 | 2 | 5 | 3 | 2 | 1 | 5 | 3 |
| 7. Yield/ plant | $V_1$ | 3 | 4 | 5 | 2 | 1 | 3 | 2 | 5 |
| | $V_2$ | 3 | 4 | 1 | 5 | 1 | 3 | 5 | 1 |
| | $V_3$ | 5 | 2 | 5 | 3 | 2 | 1 | 2 | 1 |

(contd..)

- Table 8-3 (contd.) The maximum and minimum phenotypic distribution of negative and positive mutants induced by gamma rays among the five $M_1$ branch categories.

| Character | | Branch category showing maximum & minimum distribution of | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Negative variants | | | | Positive variants | | | |
| | | 20 kR | | 30 kR | | 20 kR | | 30 kR | |
| | | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum |
| 1. Plant height | $V_1$ | 4 | 1 | 1 | 5 | 2 | 4 | 4 | 1 |
| | $V_2$ | 5 | 2 | 5 | 1 | 3 | 5 | 2 | 5 |
| | $V_3$ | - | - | - | - | - | - | - | - |
| 2. Number of branches | $V_1$ | 2 | 3 | 4 | 5 | 2 | 3 | 5 | 3 |
| | $V_2$ | - | - | - | - | 2 | 4 | 1 | 4 |
| | $V_3$ | - | - | - | - | - | - | - | - |
| 3. Fruit length | $V_1$ | 3 | 4 | 2 | 4 | 5 | 3 | 5 | 3 |
| | $V_2$ | 5 | 2 | 1 | 5 | 1 | 3 | 5 | 4 |
| | $V_3$ | - | - | - | - | - | - | - | - |
| 4. Fruit weight | $V_1$ | 5 | 1 | 5 | 1 | 1 | 3 | 1 | 5 |
| | $V_2$ | 4 | 2 | 1 | 2 | 1 | 4 | 5 | 4 |
| | $V_3$ | - | - | - | - | - | - | - | - |
| 5. Number of seeds per fruit | $V_1$ | 5 | 1 | 3 | 2 | 1 | 5 | 1 | 4 |
| | $V_2$ | 2 | 1 | 1 | 2 | 1 | 4 | 1 | 4 |
| | $V_3$ | - | - | - | - | - | - | - | - |
| 6. Number of fruits/ plant | $V_1$ | 1 | 4 | 1 | 3 | 1 | 4 | 4 | 1 |
| | $V_2$ | 1 | 2 | 4 | 1 | 3 | 5 | 2 | 4 |
| | $V_3$ | - | - | - | - | - | - | - | - |
| 7. Yield/ plant | $V_1$ | 2 | 1 | 5 | 2 | 1 | 5 | 4 | 5 |
| | $V_2$ | 5 | 2 | 4 | 2 | 2 | 4 | 2 | 4 |
| | $V_3$ | - | - | - | - | - | - | - | - |

and positive variants minimum in the earlier formed branches with more positive variants in the later branch-categories. In $V_2$, positive variants for both the concentrations of EMS were maximum in the third branch category which in general registered fewer negative variants. Negative variation was also found to be maximum in later branch-categories. For physical mutagen treatment, the bulk progeny always registered minimum positive and maximum negative variants for the character concerned. Positive variants were found to be greater in the earlier branch categories. In $V_3$, the second branch-category registered maximum positive and minimum negative variants under EMS treatment, for the character concerned. Wherever negative variation was found to be maximum, positive variation registered a correspondingly low value. In $V_3$ branch-wise seed collection was absent from gamma ray treated $M_1$ population.

In the case of number of branches, the treatments differed significantly. In general, positive variants were maximum and negative variants minimum in the earlier formed branches for $V_1$ under EMS treatment. But under 1.0 per cent EMS, the later formed branches gave maximum positive variants. The maximum and minimum values for negative variants were found to be distributed among adjacent

branches, shifting to the later branch-categories in the higher exposure. For positive variants also, the second branch-category registered the maximum and the third, the minimum value, denoting that they were the most variant and the least variant branch categories respectively. Under 30 kR fifth branch-category registered the maximum and third branch-category, the minimum positive variants. For $V_2$ and $V_3$ only positive variants were created by the different treatments. In $V_2$, maximum positive variants were registered by the second branch-category under 0.5 per cent EMS and the bulk progeny under 1.0 per cent EMS. For gamma ray treatment, the earlier formed branches registered a maximum of positive variants with the minimum values in the later formed branches. In $V_3$ the third and the fifth branch categories registered the maximum value under 0.5 and 1.0 per cent EMS.

For fruit length in general, variability was found to be greater in the earlier formed branches and lesser in the later formed ones, as far as EMS treatment was concerned. For gamma irradiation, the later formed branches gave more of positive variants and less of negative variants. In all the three varieties, for 0.5 per cent EMS, the fourth branch category gave a minimum of negative variants, with the third branch-category registering a maximum in $V_1$ and $V_2$ and the

first in $V_3$ respectively. But under 1.0 per cent EMS, the third branch category in general, registered a minimum of negative variants. Positive variation in general, was maximum in the earlier formed branches under 0.5 per cent and in the middle and later formed branches under 1.0 per cent EMS. For gamma irradiation, the bulk progeny registered maximum positive variants with the middle formed branches giving a minimum. Under both 20 and 30 kR in $V_1$, the fourth branch-category recorded minimum negative variants with the middle formed branches recording a maximum. In $V_2$ the fifth and the first branch categories respectively registered maximum negative variants under 20 and 30 kR with the second and the bulk progeny respectively recording a minimum. So for fruit length, the different varieties responded almost uniformly to mutagen treatment as far as phenotypic distribution was concerned.

For fruit weight, the middle and the later formed branch-categories under 0.5 and 1.0 per cent EMS respectively registered a maximum of positive and a minimum of negative variants in $V_1$. For gamma irradiation, the effect was specific in that the first branch-category in both the exposures registered a maximum of positive and minimum of negative variants. In $V_2$, the earlier and the middle formed branches registered maximum positive variants with a corresponding decrease in negative variants for EMS treatment. For gamma irradiation, the earlier formed branches in general gave more of positive and less of negative variants.

The fifth and the second branch-categories registered maximum positive and minimum negative variants respectively under 0.5 and 1.0 per cent EMS in $V_3$.

For seed number per fruit in general, the later formed branches and the bulk progeny registered a minimum of negative variants and the earlier and the middle formed branches registered a maximum of positive variants, under both the concentrations of EMS. In the case of physical mutagen treatment, the earlier formed branches, especially the first branch category registered maximum positive variants followed by minimum negative variants in both the exposures.

The fourth branch-category registered a maximum of positive variants and the third branch-category a minimum of the same in chemical mutagen treatment for $V_1$, in the case of number of fruits per plant. Negative variation was found to be maximum in the bulk progeny. For physical mutagen treatment, the first branch category registered maximum negative variants in both the exposures with the first and the fourth branch-categories recording maximum positive variants under 20 kR and 30 kR exposures respectively. In $V_2$, the first and the fifth branch-categories registered a maximum of positive variants and the fourth and the fifth branch-categories recorded a minimum of negative variants

under 0.5 and 1.0 per cent EMS respectively. The corresponding values for gamma irradiation were distributed among the third and the second branch-categories and the second and the first categories respectively. In $V_3$ plants with greater number of fruits as compared to the control were more frequent in the second branch-category where as plants with lesser number of fruits in comparison to the control were greater in the later formed branch for 0.5 per cent EMS. Both positive and negative variations under 1.0 per cent EMS were found to be maximum in the bulk progeny, denoting that it was the branch category with the highest degree of variability. In other words, mutagen sensitivity was maximum for the character concerned under the given dose, for whole plant seed collection.

In the case of yield per plant, negative variants were maximum in the middle formed branches and the bulk progeny for the different concentrations of EMS in the three varieties, with a minimum of negative variants in the earlier and later formed branches. In $V_1$ and $V_2$ positive variants were maximum in the first branch-category and minimum in the third, for 0.5 per cent EMS. For 1.0 per cent EMS, the second and fifth branch-categories recorded a maximum and the fifth and first branch categories recorded a minimum of positive variants under the same two

varieties. In $V_3$, the second and the first branch-categories respectively recorded the maximum and minimum values for 0.5 and 1.0 per cent EMS under positive variants. For gamma irradiation in $V_1$ the first and fourth branch categories recorded a maximum of positive variants and the first and the second branch categories recorded a minimum value for the same under 20 kR and 30 kR gamma ray exposures respectively. In $V_2$ the second branch-category recorded a maximum of positive variants with a corresponding minimum of negative variants under both the exposures of gamma rays. The corresponding values for negative variants were distributed among the later formed branches and the bulk progeny respectively.

Different characters studied in the present investigation were found to respond differently to induced variation. Variability was found to increase considerably for all characters in treatments with gamma rays as well as EMS. Increase in variability following mutagenic treatment was observed in several quantitative characters in rice. (Oka et al. 1958; Bateman, 1959; Kao et al. 1960; Matsuo and Onosawa, 1961; Kawai, 1962; Chari, 1963, Matsuo et al. 1964). Increase in variability could be explained to be due to mutation of polygenes governing the quantitative characters. Genetic variability was found

to increase in barley with increasing doses of X-ray (Gaul, 1965a, 1967) and gamma rays (Gupta, 1970) and Arbidopsis with increasing concentrations of EMS (Bhatia and Van Der Veen, 1965).

Although variability in general is enlarged, there are considerable differences in the reported results concerning the frequency of occurrence of mutations with both positive and negative effects. The increase in variability without significant difference in the mean values made Oka et al. (1958), Matsuo and Onozawa, (1961) and Yamaguchi (1964) and Sharma and Saini (1970) to suggest that mutations with positive and negative effects occurred with approximately equal frequency. Gonzalez and Frey (1965) found that variability was shifted in either direction and Gregory (1965, '68) stated that the distribution of quantitative variability was symmetrical. However, Goud (1967 b) in bread wheat, Bhatia and Van Der Veen (1965) and Lawrence (1965) in Arabidopsis and Brock (1970) in subterranean clover observed that the variability was more in the positive direction, indicating either a large number of mutations or a high degree of individual effect of mutations in the positive direction.

Increase in variability in the treated population compared to control met with in the present investigation clearly shows a better scope for selection of desirable mutants both in negative and positive directions from the segregating population of chillies induced by gamma rays and EMS.

# SUMMARY

## SUMMARY

The present investigation was carried out in the Department of Agricultural Botany, College of Agriculture, Vellayani during 1982-83. Induced polygenic variability with respect to various growth parameters was assessed in the $M_2$ generation in three varieties of chillies using $^{60}Co$-gamma rays and Ethyl methane sulphonate (EMS). The extent of diplontic selection was also assessed by raising $M_2$ generation, on $M_1$ branch category-wise. The experiment was laid out in split plot design with two replications. Data were collected on (1) Plant height (2) number of branches per plant (3) fruit length (4) fruit weight (5) number of seeds per fruit (6) number of fruits per plant and (7) yield per plant. The extent of induced variability with respect to these polygenic traits were assessed in detail in the segregating generation. In addition to mean value shift, the frequency of negative and positive variants compared to control was also taken into consideration.

The tabulated data were analysed statistically following Fischer (1935). Percentage frequencies were transformed by the angular transformation as proposed by Snedecor (1956). From the ANOVA it was found that in all the three varieties tested both the mutagens considerably reduced the length and weight of individual fruits as well as the number of

seeds per fruit. But plant height, number of branches per plant, number of fruits per plant and consequently yield per plant were found to be increased. A dose dependent increase or decrease could be noted in almost all the varieties.

1. Plant height in general was found to be enhanced by mutagen treatment. EMS showed a greater positive shift in mean plant height as compared to gamma rays, in the different varieties. Maximum frequency of negative variants was noted in the bulk progeny whereas positive variants were comparatively high in the earlier formed branches.

2. Mean number of branches recorded a positive shift. In general in the higher concentration of EMS, plant type was more compact than under the lower concentration whereas the case was reversed for gamma ray treatments. Negative variants were absent in $V_2$ and $V_3$ where there was a low frequency of positive variants and a higher frequency of control types.

3. In general, negative shift in mean fruit length was observed in the varieties tested. In the two different concentrations of EMS, majority of the $M_1$ branch categories recorded a negative shift. Gamma ray exposures also followed the same trend although not to the same extent.

Among the three varieties tested, $V_2$ alone was found to be favourably affected by mutagen treatment, for the character concerned.

4. Mean fruit weight was found to be drastically reduced in all the three varieties by the two mutagens tried. Reduction in mean fruit weight was greater for gamma irradiation as compared to EMS treatment and in both cases, the higher doses gave a more drastic reduction. Among the different characters analysed, fruit weight alone showed significant negative shift in mean value.

5. Seed number per fruit also recorded a general decrease due to mutagen treatment, the effect being more pronounced under gamma irradiation compared to EMS treatment. The effects produced by EMS and gamma rays in the lower and higher doses were comparable in that the higher doses always led to a decrease in number of branches showing positive shift.

6. In general, mean fruit number per plant was nehanced due to mutagen treatment in the different varieties. EMS produced a greater enhancement. For physical mutagen treatment, a dose dependent decrease in the number of fruits per plant was noted under different $M_1$ branch-categories.

7. For yield per plant $V_1$ recorded a complete negative shift in mean values and $V_2$ and $V_3$ recorded a complete positive shift. Although $V_1$ recorded a negative shift in mean values, yield can be eventually increased by restricting selection to the earlier formed branches which registered maximum frequency of positive variants. For $V_2$ and $V_3$ also, the frequency of positive variants was greater in the earlier formed branches.

The shift in mean values and the increase in variability for the different quantitative characters in the segregating generation due to EMS and gamma rays, provide scope for a positive response to selection and further improvement in this crop for increasing production. Detailed analysis on the extent of variability created by the mutagen in the later segregating generations in the different branch-categories and the selection of desirable types are suggested as the future line of work in the varieties tested.

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* Original not seen.

# ESTIMATION OF INDUCED VARIABILITY IN CHILLIES

*By*

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**ABSTRACT OF A THESIS**

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ABSTRACT

The mutagenic effect of $^{60}$Co-gamma rays and Ethylmethane sulphonate on three different chilli varieties have been studied in detail in $M_2$ generation using two moderate doses of gamma rays (20 and 30 kR) and two concentrations of EMS (0.5 and 1.0 per cent). The presence and extent of chimeras and their relation to induced variability was assessed by raising $M_1$ branch-wise progenies in $M_2$ generation. The experiment was conducted during 1982-84 at the Department of Agricultural Botany, College of Agriculture, Vellayani. The $M_1$ generation was laid out in RBD and $M_2$ in split-plot design with proper randomisation and replications. The crop was raised and maintained following the Package of Practices recommended. The polygenic traits analysed in $M_2$ generation include plant height, number of branches per plant, fruit yield per plant and length and weight of fruits. The data collected were statistically analysed for proper interpretation of the results obtained.

It has been observed in almost all the polygenic traits that the extent of variability created vary depending on the genotypes, mutagen and their doses and character under observation. The mean values were found to shift both in negative and positive directions to

control values. Significant shift in mean values depending on the type of $M_1$ branch category clearly demonstrates that there existsthe mechanism of diplontic selection in this particular crop variety, when exposed to mutagens. But the extent of selection varies depending on the mutagen and their doses and the genotypes concerned.

A significant negative shift in mean value was noted only in the case of fruit weight under both the concentrations of EMS and 20 kR gamma rays whereas a positive or negative insignificant shift was noted in all other characters under both the mutagens. When $V_2$ under EMS and $V_3$ in gamma rays showed a negative shift, Positive shift in mean value was noted in majority of the cases for number of branches per plant. Fruit length and weight and number of seeds per fruit showed a negative shift in majority of the cases analysed, but fruit number and yield per plant showed a reverse trend. The shift in mean value under the different $M_1$ branch categories varied depending on the varieties, mutagens and their doses and also the character under study.

The phenotypes were found to be distributed both in negative and positive directions to control group in all the characters analysed. The frequency distribution whether

negative or positive varied depending on the mutagen and their doses, the genotypes and character under study.

In majority of the cases the maximum frequencies of positive variants under both the concentrations of EMS and under 0.5 per cent for negative variants were found to be in the early formed branches when it was in the later ones is the case of negative variants under 1.0 per cent EMS. In the case of gamma rays this general trend was not observed. The data analysed clearly demonstrate the existence of diplontic selection and promises wide scope for positive selection response either in negative or positive directions.