GAMMA RAY INDUCED POLYGENIC VARIABILITY IN BHINDI

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Gamma ray induced polygenic variability in Bhindi" 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 of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Gamma ray induced polygenic variability in Bhindi" is a record of research work done independently by AHMED REGINA 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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INTRODUCTION

INTRODUCTION

The successful exploitation of atomic radiations for inducing genic alterations is one of the most modern and potent lines of crop improvement programme. The green revolution - partly a product of induced mutations has already proved beyond doubt that atomic energy can be successfully utilized for genetic engineering and for tailoring better varieties of crop plants. Gaul (1964) has pointed out that by induced mutation all morphological and physiological characters within the species boundary and beyond this can be altered in any organism. Brock (1971) clearly demonstrated that we can induce any mutation that occurred naturally and probably many which have either never occurred naturally or have been lost from natural population.

Crop improvement programmes have been exploiting the two major factors of evolution namely recombination and selection to great advantage for quite some time. The extensive exploitation of these factors in breeding demanded use of many refined techniques. Once a cultivar is produced through hybridization, further improvement in quantitative characters can only be achieved through micromutations which are induced in enormous numbers.

The term mutation ('mutare' in latin means 'to change') was used for the first time by DeVries (1900) and he put forth the idea of producing mutations artificially for use in plant breeding. The usefulness of creating mutations artificially was grasped at once by many plant breeders and a period followed in which considerable effort was directed towards utilizing this new discovery in practical breeding.

In any population, the extent of improvement expected by selection depends on the genetic variability present in the population. Among the different methods of creating variation both in nature and in the laboratory, the use of various sources of radiation has opened up important channel into which our energies for the improvement of agricultural crops can be divested. Gottschalk (1978) in his paper on 'prospects and limits of mutation breeding' clearly stated several advantages of this method of breeding, which are not observed in conventional breeding programmes. It is possible to increase the genetic variability of a species within a short time. Distinct resistance genes may be obtained, which are not available as source for specific resistance principle. The adaptability of many mutants to altered environmental conditions as related to that of the mother variety provides them with good chance for practical utilization, when cultivated under different ecological or climatic conditions. Sufficient evidence has been built up in recent years to indicate that beneficial and valuable mutations can be induced for improvement of various crops.

The knowledge about the genetic nature of DNA, gained from works on the genetics of virus and bacteria, provided stimulus for interest in mutant specificity. Though artificial induction of mutation in crop plants to create more variability has been taken up ever since the discovery of mutagenic effects of ionizing radiations, much of the attention had been devoted, in the past decades only to the extraction of macromutations. The meagre usefulness of macromutants in mutation breeding led plant breeders to try to alter the spectrum of mutation yield by using different mutagens. While changing the nature of a macromutant by using specific mutagens is appealing, there is little foundation for it in the laws of evolution, as they apply to plant improvement. In contrast, the induction of many mutations, each with small effect on quantitative characters, permits the full operation of the laws of evolution, and is therefore the logical alternative to the induction of generally degenerative macromutant (Gregory, 1966).

It is our present knowledge that quantitative characters, which constitute majority of economically important traits, are generally controlled by the so called polygenes, which are a series of genes whose individual effect is too small, but through similar and supplementary effects can have important effects on total variability. Greater attention is being paid now to gather detailed information on the induced polygenic mutations to assess their performance in later generations following mutagenic treatments and also to evolve selection procedures. Systematic studies on the induced polygenic variability in the progenies of the mutagen treated material have resulted in the successful evolution of improved strains in many crops.

A wider variability in the spectrum of mutations could be expected from hybrid irradiation than from the irradiation of pure bred seeds as demonstrated by Krull and Frey (1961) in Oats. Hence, the chances of recovering beneficial mutants from the progency of irradiated population of hybrids are more. A comparative study of the subsequent generations of the irradiated populations of pure bred and hybrid seeds can bring about much promising result which will eventually help in the crop improvement programmes.

Abelmoschus esculentus (Moench) commonly known as Okra or Bhindi is an important vegetable crop of Afro-Asian countries. It is a proteinaceous vegetable with wide adaptability to varying environmental conditions. Bhindi is a secondary polyploid with a high chromosome number of 2n = 130 (Joshi et al. 1957). The reports on spontaneous or induced mutations in this crop are very few as opined by Bhatia and Abraham (1983). The presence of more than a pair of homologous chromosomes impart a buffering effect leading to greater stability and hence, there is a higher rate of repairing of mutations. But it is evident that the breeding material can be made more sensitive to mutagens, by creating an imbalance in the genetic make up through the process of hybridization. The prospects of inducing desirable mutants in bhindi have not been explored in detail. In order to find out the possibility of inducing useful variability in this crop by using gamma rays, a study has been undertaken in the Department of Agricultural Botany, College of Agriculture, Vellayani during 1982-83. The present investigation is a continuation of this project.

The main objectives of the present study include:

1. To assess the extent of induced polygenic variability in the segregating generations of M_3 and M_4.

2. To make a comparative study of the response of pure bred and hybrid seeds to gamma rays in M_3 and M_4 generations.

3. To compare segregation patterns in hybrids and irradiated populations of pure breds and hybrids, and

4. To exploit the variability to isolate out desirable plant types having maximum expressions in yield attributing characters and higher yield.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The uses of X rays for genic manipulation were first reported by Muller (1927) on *Drosophila* and Stadler (1928) on barley. Other physical agents like ultra violet rays (Altenburg, 1934; Stadler and Sprague, 1936; Stadler, 1941; Stadler and Roman, 1943), fast neutrons (Mackey, 1954; Ehrenberg, 1954). beta rays (Ehrenberg *et al.*, 1949), gamma rays (Sparrow and Singleton, 1953) and thermal neutrons (Caldecott *et al.* 1954) have since been used extensively to create variability in plant populations for having a positive response to selection.

Mutagenic effects of a number of chemicals also have been studied by different workers. The mutagenic effect of mustard gas on *Drosophila* was shown by Auerbach and Robson (1944). Since then a number of mutagenic chemicals have been studied, of which Methyl methane Sulphonate (Heiner *et al.*, 1960; D'Amato *et al.*, 1962) and Ethyl methane sulphonate (Arnason *et al.*, 1962; Froese- Gertzen *et al.*, 1963)were found to be highly mutagenic. The availability of a wide range of both physical and chemical mutagens prompted investigators to probe into the relative advantages and disadvantages of the different mutagens (Swaminathan, 1969a,b). Sigurbjornsson and Micke (1969) reported that most of the varieties developed by mutation breeding was the result of irradiation with ionizing radiation.

Gamma rays and induced mutagenesis

The effects of gamma ray irradiation of cotton have been studied by Younis and Hammouda (1961). They exposed the seeds to high doses of Caesium-137 and noticed reduction in emergence, inhibition of growth, retardation of flowering and reduction in number of flowers and bolls produced/plant. Ibragimov and Popova (1962) found that exposing seeds of cotton strain '108F' to small dosages of ^{60}Co gamma ray had a stimulating effect on growth and development of the plant, giving higher yield and longer fibre than the control. Kabulov *et al.* (1962) and Pate and Duncan (1962) showed that gamma irradiation of cotton pollen was an effective means of inducing mutation at several marked loci, where changes from dominant to recessive were desired. Stimulatory or heterotic effects resulting from pollination with irradiated pollen was also indicated. Further investigation on gamma ray irradiation of cotton were done by Nazerov *et al.* (1961) Bhute (1964), Constantin (1964), Nandanvankar and

Thombre (1964), Dhesi (1966) and Gulamov and Narimov (1966).

Louis and Kadambavanasundaram (1973a) reported a reduction in germination percentage and an increase in delay for germination, following gamma irradiation of cowpea seeds. Sree Rangaswamy et al. (1973) observed that the greengram plants treated with gamma rays were shorter than the parents and those treated with 60 kR were the shortest. The effects of gamma rays and EMS in red gram were studied by Alikhan and Veeraswamy (1974) and found that chlorophyll mutations were maximum at 24 kR and 70 mm treatments respectively. Susumu et al. (1975) reported an increase in protein content in soybean due to gamma irradiation.

Fautrier (1976) observed that in lucerne, no plant survived in treatments above 120 kR of gamma rays. One short statured lodging resistant mutant was selected from rice variety 'Calrose' irradiated with 25 kR cobalt gamma ray (Rutgar., 1977). Gamma irradiation of greengram varieties indicated variation in the mutagenic sensitivity in the M_1 generation (Ratnaswamy et al., 1978). Parial (1977) reported that chronic gamma irradiation was more effective in inducing potentially useful mutants in pea.

Twenty true breeding morphological mutants were isolated in the M_2 generation, following exposure of sesame

(*Sesamum indicum* L.) seeds to gamma rays (Murthy, 1980). By irradiation with 30 kR gamma rays a photoperiod insensitive mutant (Rasmi) was obtained in cotton which flowered in about 50 days and matured in 150 days irrespective of location and season (Raut and Panwar, 1980). A high yielding very early mutant (MUP-1) was isolated from the subsequent generation of the gamma irradiated population of pea (*Pisum sativum*) (Gupta *et al*.1981). Kulik and Shkvarnikov (1982) obtained a mutant variety in *Lycopersicon esculentum* with early and high yielding characters by gamma irradiation.

Genic status and radiosensitivity

Gustafsson (1944) observed that among seeds of various cultivated plants treated with X-rays, the critical dosage' ranged from 5000 r for seeds of sun flower to 90,000 r for seeds of rutabaga and white mustard. Sparrow and Gunkel (1956) have reported, varying levels of tolerance among 79 species of plants to chronic radiation. The radiosensitivity of an organism appears to be influenced by its genotype, age of the tissue, stage of chromosome and chromosome number (Smith, 1958). Nilan (1956), Lamprecht (1956, 1958), Gelin *et al*. (1958), Smith (1961), Sparrow (1961), Konzak *et al*. (1961a) and Sparrow *et al*. (1965) reported that any change in the genotypic level can induce significant changes in the radiosenisitivity which influence not only the total rate, but also the spectrum of recoverable mutation. Variation in respect to radiation response among different genotypes was observed by Bianchi et al. (1963) in tomato, Mikaelson and Brunner (1968) in barley and Mujeeb and Siddiqui (1973) in pea. Gamma irradiation of greengram varieties indicated variation in the mutagenic sensitivity in the M_1 generation (Ratnaswamy et al., 1978) Ramalingam (1980) reported that the spectrum of mutation differed according to variety, mutagen and interaction between variety and dose of a particular mutagen.

The frequency and spectrum of induced mutations was greater in aged seeds compared to fresh seeds (Gustafsson, 1938). Sparrow and Singleton (1953) found young plants to be more radiosensitive than mature plants and meiotic cells to be more sensitive to radiation than mitotic cells.

Stadler (1929) had shown that the frequency of chlorophyll deficients was lower in species with higher chromosome number in wheat and oats. Swaminathan (1965) reported that polyploids are in general, more resistant to radiation than related diploids. Sparrow et al. (1965) suggested that the greater resistance reported for polyploids than for closely related diploids resulted more from their reduced interphase chromosome volumes than from the protective effect of genetic redundancy.

However, with neutron irradiation, a decidedly higher frequency of mature plant character mutant was obtained in hexaploid wheat than in diploid barley (Mackey, 1954). Radiosensitivity of haploid plants was found to be higher than that of diploids (Tanaka, 1970). The diploids in turn, were reported to be more sensitive than the respective autotetraploids (Yamaguchi and Kobayashi, 1960; Yamaguchi, 1964 and Sree Rangasamy, 1970).

External factors affecting mutation spectrum and frequency

Environmental factors have been found to influence the genetic effects of radiation and there are potential importance in practical application, since they offered an opportunity for additional control over the mutation process (Smith, 1958). Ehrenberg et al. (1953) reported that the soaked seeds of barley were more sensitive to X radiation than dormant seeds stored under ordinary laboratory conditions. The works of Caldecott (1955) and Ehrenberg (1955) indicated that moisture content in the embryos of irradiated seeds affected the radiation response in resulting seedlings. The mechanism by which seed water content influences radiation effects in seeds appears to involve in part, the mobility and action of free radicals and oxygen (Conger, 1961 and 1963; Conger et al., 1966; Ehrenberg, 1961).

Sax and Enzman (1939), studying the effect of temperature on chromosome breakage in Tradescantia microspores, found a gradual decrease over the range 30-38°C. Caldecott and Smith (1952 b) found that heat applied to barley seeds prior to irradiation reduces the injurious effects. Stadler (1931), Nybom et al. (1953) and Nilan (1954) reported that when seeds were irradiated at dry ice or liquid air temperature, the frequency of induced chromosomal aberrations reduced, whereas the visible seedling mutation frequency were unchanged or even increased. X-irradiation at high temperature reduced the frequency of both lethal gene mutations and translocations in several organisms (Lea, 1955), Heat shock treatments immediately after irridation has been found to reduce damage in terms of M_1 seedling height and chromosome aberration frequency (Gaul, 1957 a and b; Konzak et al., 1960) without decreasing mutation frequencies (Gaul, 1957 a and b; Khostova, 1966; Konzak et al. 1961a) . Santos (1965) working on mung bean (Phaseolus aureus) concluded that with heat treatment, especially post irradiation, a much higher dose of gamma rays could be applied to seeds.

The effect of Oxygen on radiosensitivity was reported by Thoday and Reed (1947). A reduction in oxygen concentration reduced not only the number of mutations and chromosome aberrations but also the level of general radiation damage to cells. Different ionizing radiations vary widely in their response tooxygen, X particle being insensitive to oxygen, while gamma rays are more effective in the absence of oxygen. The discovery of the effect of oxygen on mutation and chromosome breakages has focussed attention on the possibility that at least a part of the effect of radiation may follow from the release of chemical substances, positively peroxidases, which may have a direct effect on the chromosome and on the gene (Williams, 1964).

The review of Nilan (1956) indicates that there is increasing evidence for the production of modifying effects with respect to the frequency of mutation, the differential production of intragenic changes as against chromosome breaks and the spectrum of mutations, by altering the chemical and physical conditions before, after or during irradiation.

Nature and types of mutation

Mutations, according to Gustafsson (1970) can be divided into the following main categories 1) Genome mutations (Alterations of Chromosome number), 2) Chromosome mutations and 3) Extranuclear mutations.

Natarajan (1966) reported that in some organisms haploid cells could be produced by chemicals, eg. after treatment with diethylpyrocarbonate. Some mutants induced by colchicine in Sorghum are considered to be the result of gene mutation and mitotic chromosome reduction (a sort of haploidy) followed by diploidization (Ross, 1965). In barley, a break in the centromere region gives rise to an extra chromosome, when both chromosome arms behave like separate chromosomes, thus increasing the basic number from 7 to 8 (Hagberg and Hagberg, 1968).

Evans (1966) has formulated the view that radiation does not produce direct chromosome breakage at all, and that chromosome exchanges induced by radiation or chemical agents or occurring spontaneously at mitosis (mitotic crossing over) or at meiosis (meitotic crossing over) are basically similar events. Translocation and inversions have greatly contributed to species differentiation in nature. The so-called chlorophyll or chloroplast mutants are conspicuous type of plant lethals (Gustafsson, 1940; Walles, 1967 a), which arise after all kinds of mutagen treatments, primarily in diploids. Ionizing radiations often exert a more radical action on chromosome constitution than do several of the chemical mutagens, but are no doubt, also capable of inducing gene mutations.

Different gene loci respond to radiations in a different manner (Hagberg _et al_., 1958; Lundqvist _et al_., 1968) Narsinghani and Sudhir (1976) reported that mitotic cells of gamma ray treated peas indicated chromosomal alterations, which were dose dependent. In meiosis, translocated rings and chains of 4,6 and 8 chromosomes, paracentric and pericentric inversions, fragments, laggards and unequal distribution of chromosomes were observed.

Induction of cytoplasmic mutations by means of different mutagens is rather rare, although scattered data (Von Wettstein 1961; Hagemann and Scholz, 1962) prove that such properties may be artifically induced. Favret and Ryan (1964 and 1966) were able to isolate mutants of barley showing plasmatic male sterility from X irradiated and EMS treated materials.

Induced polygenic mutations

Genic alterations created in polygenically controlled traits is referred to as micromutation. These are obviviously of great interest to plant breeders since almost all economically important characters in plants are governed by polygenes. Gregory (1955) working with peanuts, a self pollinated legume of amphidiploid origin, induced a remarkable increase in the genotypic variance in the 'fitness' character, yield of pods, by X ray treatment of seeds (Fitness character, as used herein, means a character which when mutated results in a change in the frequency with which individuals bearing the character appear in subsequent generations). At the same time, however, it was shown that population means was substantially reduced. Similar results have been obtained in soybean (Rawling *et al.*, 1958; Papa *et al.* 1961) oats (Griffiths and Johnston, 1962) barley (Gaul, 1963) wheat (Swaminath, 1963) and rice (Sakai and Suzuki, 1964).

Rawling *et al.* (1958) after treating the seeds of soybean with X ray and thermal neutron observed significant increase in genetic variability in all the treatments, for all the characters studied, except yield, Oka *et al.* (1958) observed significant changes in mean values for heading date and plant height, while there was a marked increase in genetic component of variance. The consistency of population means suggested that polygenic mutations in plus and minus directions appeared with approximately equal frequency. Bateman (1959) however, pointed out that mean did infact change and altered means and variance could be explained by assuming all mutations in one direction. He also reported that there was an excess of mutation in positive direction. Gaul and Mittelstenscheid (1961) observed 2-3 times increase in variance in irradiated M_2 barley material than in unirradiated control. The average single plant yield was similar in irradiated and unirradiated progenies. Similar illustrations are available for pod and leaflet dimensions in peatnut (Loesch, 1964; Emery et al. 1964) and seed size in rice, oats and soybean (Rawling et al., 1958; Krull and Frey, 1961; Papa et al., 1961; Yamaguichi, 1962; Abrams and Frey, 1964). Neverthless, mean heading date may be shifted towards lateness in small grains (Krull and Frey, 1961; Matsuo and Onozawa, 1961; Sakai and Suzuki, 1964; Gaul, 1965). Borojevic (1965) in wheat reported that M_5 analysis of selected lines revealed significant difference between lines and not within lines. Jalil and Yamaguchi (1965) studied the variation of quantitative characters in the irradiated progonies of two rice varieties and their hybrids.

Brock (1965) showed that in species which have previously been subjected to breeding and selection, random mutation resulted in an increase in variance and a shift in the mean value away from the direction of previous selection. Improved yields following selection in irradiated populations have been reported for peanuts (Gregory, 1955, 1956; Bilquez et al., 1965; Emery et al. 1965) barley (Gaul, 1961, 1965) and rice (Matsuo and Onozawa, 1961). From a comprehensive programme of yield testing with barley, Gaul (1963, 1965) found some mutant lines with means less than the control and some with means almost equal to the control.

Kumar (1967) in his studies on diploid and tetraploid barley treated with EMS and gamma rays observed enlarged variance in all the treatments as compared to control. The coefficient of variability estimates also revealed that the induced variability in M_2 generation is of higher magnitude in diploid than in tetraploid barley. Borojevic and Borojevic (1969) reported an increase in genetic variability induced by mutagens in wheat. Ramaswamy (1973) observed in blackgram, a negative shift in the mean in M_2 generation and the same approaching control or slightly high in M_3. The variance was reported to increase in all traits in M_2, except for number of seeds and grain yield in gamma and EMS treatments. Rao and Giriraj (1975) in bhindi reported that either decrease or increase in mean value over tho control was observed in the irradiated population. Increase in polygenic variability induced through radiation in wheat was recorded by Dhoruksne and Bnowal (1976). Shakoor <u>et al.</u> (1978) have stated that the magnitude of broadsense heritability estimates for plant height appeared to be related to the radiation exposure and were usually of a higher order indicating the possibility of exercising effective selection in M_2 generation.

Virk *et al.* (1978) noticed significant increase in variation after exposure of pure breeding and hybrid genotypes and also found that the variation from hybridization and irradiation were generally not cumulative. Ramakanth *et al.* (1979) reported that in *Dolichos lablab* variance was maximum at 30 kR for seed weight and flowering time, whereas for grain weight, maximum variance was at 40 kR.

Kamannavar (1985) reported that treatment with mutagens in chilli reduced the means of all quantitative characters studied, with some exceptions viz. days to flowering, plant height etc. Induced mutations in both plus and minus directions indicated that there was increased variability in respect of quantitative characters. Lekha Rani (1985) observed that the extent of variability created in all the polygenic traits vary depending on genotypes, mutagen and their doses and the character under observation. Mahishi (1985) concluded that mutagens like gamma rays can induce polygenic mutations in cowpea in sufficient frequency, resulting in an increase in variance for polygenic traits towards both positive and negative directions. Both negative and positive shift in mean value for different polygenic characters compared to control values, in the irradiated population of bhindi was noted depending on the genotypes (Mareen, 1985).

Comparative merits on hybrid seed irradiation

Gregory (1956) suggested that radiation induced variance is cumulative with that induced by hybridization. Comparisons were also made by irradiating the hybrids as well as pure lines (Gregory, 1961). Joshva *et al.* (1967) observed the hybrids of Norin-6 X PTB-10 to be more effective than the parents to gamma irradiation. On the other hand, Boyle (1968) reported that the hybrids of *Agropyron* sp. were strikingly and consistently more resistant to higher doses of irradiation than their parents. Siddiqui (1971) undertook studies to determine the effects of irradiation in inducing interchanges in the hybrids of cotton species and found that the range of distribution of plot means was invariably wider in the treated population, for almost all the characters, when compared to their respective controls. Increased genetic variability was observed in the irradiated diploid and tetraploid crosses, but the magnitude of variability was higher in the former. This increased variability was attributed to micromutations, enhanced recombination frequency and release of hidden genetic variability.

Emery and Wynne (1976) studied the response of selection for pod yield in the hybrid peanut population after irradiation, both prior to and after hybridization.

Milkovski <u>et al.</u> (1976) were able to obtain the largest number of useful mutants under the dose of 10 kR for varieties and 30 kR for hybrids involving four varieties and interspecific hybrids of cotton. Peter (1976) studied the role of irradiation with gamma rays in hybrids of cotton and reported that mean values were reduced for yield of cotton lint, boll weight and seed index.

Burton and Hanna (1977) reported some positive heterotic effect resulting from crossing specific radiation induced pearl millet mutants with their normal inbred parent. A significant increase in variation in treated pure breeding and hybrid genotypes was revealed by Virk <u>et al.</u> (1978) in their study with gamma ray irradiated rice and wheat. The magnitude of induced variation in the pure breeding lines of wheat for grain number and grain yield was either equal or greater than by the conventional segregation following hybridization. In rice, the two types of variation were almost the same for yield, but in hybrid population, the variation was greater for plant height and tiller number. The amount of variability due to segregation was either supplemented or balanced by irradiation induced variation.

By combining hybridization and induced mutation, a new wheat cultivar, 'Altimir 67' with high productivity and resistance against important diseases was obtained

(Savov, 1980). Khan et al. (1981) reported that irradiation of seeds from the hybrids of cotton with 15-35 kR gamma rays resulted in the production of dwarf mutants with more hairs and better fibre quality. Wilt resistant mutants were selected from F_7M_7 of a cross between the cultivated variety' purple giant' and the variety 'insanum' of solanum melongena (Gopimony et al., 1982). Sharma et al. (1982) reported that ranges and variances increased with EMS treatment in some spring wheat crosses, suggesting the efficiency of mutagen treatment of F_1 seeds. Grafia and Santos (1983) isolated high yielding line of Vigna radiata, with multifoliate leaves and large yellow seeds from the F_7 of a cross between a low yielding multifoliate mutant and MG50-10A.

Alfonso et al. (1984) reported that the multifoliate leaf mutant developed by EMS treatment of seeds possessed reduced cleistogamy which offered possibilities for cross breeding. The cultivar 'Ljulin' of pepper was developed by combining mutagenesis, heterosis and interspecific hybridization (Milkova and Daskalov, 1984). Intermutant hybridization involving mutants of the Oletorius (tossa jute) variety JRO 632 led to five promising strains, with increased fibre yield (Rao et al., 1984). A dwarf bushy nonloding and determinate type tomato mutant named 'Anobik' was obtained from a gamma ray treated local cultivar, which was used to cross with the recommended variety 'Oxheart' and recombinants with more fruits with large size were obtained (Shaikh et al. (1984). Mahishi (1985) suggested that mutation and intervarietal hybrization, the two modes of inducing variability, could be combined with profit for generating additional genetic variation. Mareen (1985) reported that hybrid materials of bhindi were more sensitive to mutagen compared to pure breds.

M_1 seed sterility in relation to character expression in segregating generation

Mutagen induced sterility may be caused by 1) chromosome mutation 2) factor mutations 3) Cytoplasmic mutations and 4) physiological effects. Chromosome mutations are probably the major origin of all mutagen induced sterility (Gaul, 1970).

Evidence has been presented in barley that cytologically observed translocation frequency is insufficient to explain the total extent of sterility. This conclusion derives on the one hand from sterility investigations on a large number of defined translocation heterozygotes (Burnham et al., 1954; Tsuchiya, 1960) and on the other hand, from the comparison of meiotic observations with sterility counts on barley (Gaul, 1957c; Gaul 1963).

Studying the effect of X rays on mutation frequency in spikes with different sterility Gaul (1958, 1964) concluded that mutation frequency is independent of the degree of induced sterility. The mutation rate in the spikes having high sterility was comparable to that of completely fertile spikes. He suggested that selection of more fertile spikes which do not possess severe chromosomal aberrations, will be a good approach towards maximization of mutation frequency. Similar results have been reported by Bekendam (1961) in rice, Hildering and Van Der Veen (1966) in tomatoes. Ehrenberg, Gustafsson and Lundqvist (1961) however, demonstrated that spikes belonging to different sterility classes showed different mutation rates. They compared the effect of X rays, EI and EMS and showed that while X-ray and EI induced highest mutation rates at about 50% sterility, the maximum mutation by EMS was attained in the spikes having about 35% fertility. Kivi (1965) studied the effect of X and gamma rays in barley and obtained maximum mutations in spikes having medium fertility (31-70%). This is supported by the work of Sharma and Bansal (1970) in barley. They obtained the highest mutation frequency at 50% fertility after gamma irradiation.

Patterns on induced polygenic character segregations

Wide range of variability in the M_2, M_3 and M_4 generations of irradiated tobacco was reported by Patel and Swaminathan (1961). Somatic segregation in the VM_2 and VM_3 generation of potato was studied by Rudorf and Wohrmann (1963) following ^{60}Co gamma irradiation of pre-germinated eye sports. Swaminathan (1963) opined that by suitable selection procedures the mutants with wide range of variability can be selected out from segregating generations in wheat. Estimates of variance in M_2, M_3 and M_4 progenies showed that a) mean values are usually depressed in relation to control if no selection is exercised, but if selection is made the mean tend to approach the normal b) variance is considerably higher in the irradiated population, but varies with the crop and c) increase in the total variance as well as the fixable part of variance was greater in the M_3.

Ehrenberg et al. (1964) studied the variation in metric traits in M_2, M_3 and M_4 generations of X-irradiation in oats. He observed a significant decrease in the average tillering/row in the M_4. The variance of tillering/row was not found to increase, which meant that the effect was chiefly due to a shift in the mean values. Increased mean value of the treated population along with variability was observed by Matsuo et al. (1964) in M_6 of Norin-29 rice variety. Okabe (1964) recorded significant divergence of the line means in M_3 and the family means in M_4. Increased genetic variance in M_4 generation was reported by Sakai and Suzuki (1964) in X-rayed paddy.

Increased frequency of mutants in M_3 with respect to panicle length was reported by Siddiqui and Swaminathan (1968) in EMS treated Oryza sativa. Marked variation in the individuals of the first progeny gave progressive micromutation for grain yield frequency in M_4 of irradiated wheat (Anon, 1971). Selected families in M_4 and M_5 generation of variety Nora of spring wheat after gamma ray, fast neutron and EMS treatment gave 10-13% yield increase (Fromgner, 1971). Increased genetic variance for characters like height, ear length etc. was found in the M_3 progenies of two lines each irradiated with 8 kR and 16 kR in maize by Sutka and Bulint (1971). The mutants IRATOM-24 and IRATOM-38 in rice, having high protein content, were selected from advanced generation of mutation (M_{10}) (Shaikh, 1975).

When tomato cuttings were treated with 10^{-6} g/ml of N-nitroso-N- dimethyl urea, the third generation plants (S_3) obtained exceeded the untreated control in yield and fruit number/plant, though the variation in fruit weight was little greater than in control (Berezoskii et al., 1981). Kotvics (1981) reported that early maturing mutants selected from M_2, M_3 and M_4 generations of gamma ray irradiated population of soybean were low seed yielders. Three M_5 and two M_6 mutant lines were selected from EI and DMS treated population of Phaseolus vulgaris (Vardanyam et al. (1982).

The highest genotypic coefficients of variation and values of heritability were recorded in the M_3 generation of mutagen treated mungbean (Phaseolus aureus) (Khan, 1984). Miah et al. (1984) reported that early maturing, high yielding rice mutants were selected from the popular variety 'Nizersail' after treatment with gamma rays of EMS in M_8 and M_9 generation. The yield performance of mutants obtained by gamma irradiation in Vigna unguiculata was studied in M_3 and M_4 generation and found that there was significant difference between the mutants and the original variety (Vasudevan et al., 1984). Sivaraman et al. (1985) observed higher frequency of mutants in M_3, M_4 and M_5 generation of selected EMS treated groundnut for economically important characters.

Induced mutations in Bhindi

Kuwada (1967) reported that resistance to phytophthora was induced by irradiating seeds of Abelmoschus manihot with ^{60}Co gamma rays and X rays. Characters such as plant height, stem thickness and number of nodes varied according to the dose and dose rate of irradiation. Patil (1969) isolated dwarf mutants and mutants with altered phyllotaxis in okra using X rays. Nandpuri *et al.* (1971) observed increased variation for height of plant, number of days taken for flowering and yield in the M_1 generation after seed irradiation in okra using gamma rays. Plants treated with 30 kR gamma rays attained significantly more height and produced increased yield. One bushy mutant was observed in the progeny of a plant treated with 60 kR gamma rays. Rao and Giriraj (1975) studied the effect of irradiation on seedling characters in bhindi. He observed no relation between the dose and the mean of any character, but there was an increase in variability indicating the release of new variability by irradiation. Induced polygenic variation in fruit length in *Abelmoschus esculentus*, with different mutagens was studied by Yashvir (1977). Koshy and Abraham (1978) reported the developmental and morphological abnormalities in Okra, following treatment with ^{60}Co gamma rays. Mutants with supernumerary inflorescence in Okra was reported by Fatokun *et al.* (1979). Jambhale and Nerkar (1979) studied the inheretance of induced 'chlorina' mutant in Okra and indicated that this mutation is controlled by a single gene.

Following gamma irradiation of *Abelmoschus esculentus* cultivar 'Pusa Sawani' ' Palmaltisect', a mutant characterised by the presence of 3-5 leaflets on most leaves, basal branching, small leaves and flowers, dwarf habit and small fruits with 6-7 riges was isolated (Jambhale and Nerkar, 1980). Bhatia and Abraham (1983) conducted studies on induced mutation in Okra. Mutants having altered leaf characters were studied in the F_2 generation after back crossing to the parent Pusa Sawani. A mutant with fruits bearing stiff prickly trichomes was induced in Okra variety 'Vaishali Vadhu' by treatment of the seeds with 40 kR gamma rays and its inheritance was studied (Jambhale and Nerkar, 1984) Genic status in relation to radiosensitivity, mutation frequency and spectrum in Bhindi was studied by Mareen (1985) and reported wide variation in radiosensitivity among different varieties of Bhindi. Cross breds were found to be more sensitive compared to inbreds.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation on gamma ray induced polygenic variability in Bhindi (*Abelmoschus esculentus*, Moench) was carried out in the Department of Agricultural Botany, College of Agriculture, Vellayani during 1983-84. This project was taken up as a continuation of the P.G. project for the year 1981-83, entitled 'Genic status in relation to radiosensitivity, mutation frequency and spectrum in Bhindi'.

A. Materials

Three pure bred varieties of Bhindi, viz., Pusa Sawani (PS), Co-1 and Kilichundan (KC) and their crosses in all possible combinations (6 Nos) were used in the present study. The details of genotypes chosen for the study are presented in Table 1. The present study includes the third and fourth generations of ^{60}Co gamma irradiated pure breds, hybrids and their controls.

B. Methods

Selection of seed material

Well developed seeds collected from fully ripened fruits of normal-looking healthy plants of M_2 were used for the study. Healthy seeds having uniform dryness, size and colour were selected.

Raising M_1 generation in the previous study

The gamma ray treated (30 kR @ 60 kR/h) and the control, pure and cross bred seeds were pre-soaked in water for twelve hours and sown. Thirty seeds each were planted in rows at a spacing of 45 x 40 cm after a basal dose of cowdung. Proper randomization of treatments were done in each replication. The experiment was laid out in RBD with two replications. Fertilizers were applied at the rate of 25:8:30 kg NPK per hectare. Full dose of P and half doses of N and K were given two weeks after sowing. After forty five days of sowing, the remaining half doses of N and K were given. A moderate spacing and fertilizer status were given to check excessive vegetative growth. Special care was taken to provide uniform field conditions for these plants till harvest. Irrigation was provided as and when required.

Raising M_2 generation

Based on M_1 seed sterility the population of each treatment was categorized under three heads:

1. 0-15% - Low sterility group.
2. 16-30% - Medium sterility group
3. Above 30% - High sterility group.

Five plants each from each sterility class were selected per treatment from each replication and two fruits each were collected from these plants for raising M_2 generation. The seeds of the fruits selected from each plant were bulked together and thirty seeds were collected at random. The selected seeds were uniformly dried and sown in rows, each row representing one M_1 plant. There were thirty plants in each progeny row. The fertilizer dose and mode of application and crop management were as recommended in package of practices recommendations of the Kerala Agricultural University (Anon, 1983). Special care was taken to provide uniform field conditions for the entire crop till harvest.

<u>Collection of seed material for raising M_3 generation</u>

From the second generation, fifteen healthy plants having comparatively higher yield were selected per treatment per replication. The flowers of these plants were selfed to avoid contamination with foreign pollen. Selfing was done by covering the flowers with butter paper cover on the previous day of flower opening. The covers were retained for five days and then removed. The selfed and properly labelled fruits were allowed to have full maturity and harvested separately. Two fruits were selected from each plant, dried and stored for extraction of seeds. Only the middle fruits were selected for further studies.

The seed sterility percentage of the selected plants were calculated. Three plants from each M_1 sterility group per treatment per replication were finally selected to raise the third generation. The selected fruits were uniformly dried and seeds extracted. The seeds of the two fruits selected from each plant were bulked together and twenty seeds were collected at random from each group.

Raising M_3 generation

The seeds were sown in progeny rows at aspacing of 60 cm between rows and 45 cm between plants. There were twenty plants in each row/replication and one hundred and fifty rows, including control in each replication. Proper randomisation of treatments were done in each replication. The experiment was laid out in RBD with two replications.

Farm yard manure at the rate of 12 t per hectare was incorporated as the basal dressing. At the time of sowing ammonium sulphate, superphosphate and muriate of potash were applied at the rate of 125 kg/ha, 50 kg/ha and 50 kg/ha respectively. One month after sowing, another dose of ammonium sulphate at the rate of 125 kg/ha was given. Irrigation was given as and when required.

Plant protection

Carbaryl (Sevin) 0.02% was sprayed twice before fruit setting to control shoot borers.

Observations on M_3 generation

The following observations on quantitative traits were taken from all the available plants in the population, excluding border plants.

1. Height of the plant The plant height from the ground level to the top-most bud leaf was measured after the final harvest and expressed in centimetres.

2. Days to flowering Number of days taken from sowing to the opening of the first flower in each plant was observed.

3. Number of branches Total number of branches produced per plant was counted after the final harvest and recorded.

4. Number of leaves Total number of leaves produced per plant, from the base to the tip of the plant including the

branches was counted after the final harvest.

5. Length of fruit Two fruits per plant were harvested from ten plants selected at random from each row. The length was measured from base to tip and expressed in centimetres.

6. Weight of fruit The fruits were weighed. The mean weight of fruits taken from a single plant were calculated in grams.

7. Number of fruits per plant The total number of fruits produced by each plant was counted and the mean calculated.

8. Yield per plant The yield obtained per plant was calculated based on the average weight of fruits and the total number of fruits produced per plant.

Classification of M_3 phenotypes

M_3 phenotypes were grouped 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.

Phenotypic classes

I. Plant height

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

1. Negative variant:

Dwarf	(below 40 cm height, PS)
	(" 50 cm " Co-1)
	(" 35 cm " Kc)
2. Control group (Medium)	(40- 60 cm height, PS)
	(50- 70 cm height, Co-1)
	(35- 55 cm height, Kc)
3. Positive variant (Tall)	(above 60 cm height, PS)
	(above 70 cm " Co-1)
	(above 55 cm " Kc)

Based on the number of days taken to flowering they were abo grouped under three different classes.

1. Negative variant (Early flowering)	(Less than 41 days, PS)
	(Less than 42 days, Co-1)
	(Less than 42 days, Kc)
2. Control group (Intermediate)	(41- 44 days, PS)
	(42- 45 days, Co-1)
	(42- 45 days, Kc)
3. Positive variant (Late flowering)	(above 44 days, PS)
	(above 45 days, Co-1)
	(above 45 days Kc)

Similarly, in the case of all other characters, the M_3 plants were classified under three categories, ie.,

i. plants falling in the positive group,
ii. plants falling in the control group and
iii. plants falling in the negative group

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

Raising M_4 generation

Selection of plants in the third generation was done strictly based on yield potentiality. The treatments which were found to be poor yielders were not carried over to the fourth generation. Table 2 gives the details of the treatments selected out to study their performance in the fourth generation.

Selfed seeds collected from the fruits of all the selected plants in M_3 generation were dried and sown in progeny rows in two replications. There were thirty plants in each progeny row. The fertilizer application and crop management were done as per the package of practices recommendations of the Kerala Agricultural University (Anon, 1983). Special care was taken to provide uniform field conditions for the entire crop till harvest.

Observations on M_4 plants

Detailed observation on the following quantitative traits were taken from all the normal looking plants, excluding border plants.

1. Height of the plant
2. Days to flowering
3. Number of branches / plant
4. Number of leaves / plant
5. Length of fruit
6. Weight of fruit
7. Number of fruits / plant and
8. Yield / plant

Observations in M_4 generation were made following the same technique adopted for M_3 generation.

The frequency of individuals falling under each of the M_4 phenotypic classes were also calculated.

Statistical analysis

Analysis of variance of the data was done following Fischer (1935). Percentage values were transformed by the angular transformation as proposed by Snedecor (1956).

In the third generation, the mean values were analysed by using 18 x 2 RBD. The outline of the analysis of variance table, showing the source of variation and corresponding degrees of freedom is given below:

Source	Degrees of freedom
Block	1
Treatment	17
Error	17
Total	35

From the same experiment, in order to study the variation in mean value under the different M_1 sterility groups for the nine irradiated treatments, analysis was done as that of a split plot design, treating the sterility classes as sub plot. The outline of the analysis of variance of the data was as follows:-

Source	Degrees of freedom
Replication	1
Between treatments	8
Error (a)	8
Between sterility groups	2
Main x Sub	16
Error (b)	18
Total	53

Analysis of M_3 phenotypic classes was done as a factorial in RBD with fifteen treatments (excluding the control inbreds), three phenotypic classes and two replications. The outline of analysis of variance is given below.

Source	Degrees of freedom
Replication	1
Between treatments (T)	14
Between phenotypic classes (P)	2
T x P	28
Error	44
Total	89

Analysis of M_3 phenotypic classes under the different M_1 sterility classes was also done as a factorial in RBD with nine treatments, three sterility groups, three phenotypic classes and two replications. The split up of the degree of freedom due to various sources of variation is given below:-

Source	Degrees of freedom
Replication	1
Between treatments (T)	8
Between sterility groups (S)	2
T x S	16
Between phenotypic classes (P)	2
T x P	16
S x P	4
T x S x P	32
Error	80
Total	161

Test for proportions

To have a detailed understanding of the relationship between the sterility group and phenotypic classes test for proportions was conducted. The test criterion used was

$$= \frac{|p_1 - p_2|}{SE(p_1-p_2)}$$

Where $SE(p_1-p_2) = \sqrt{\frac{pq}{n}}$

$$p = \frac{n_1p_1 + n_2p_2}{n_1 + n_2} \quad q = 1-p \;, \; n = n_1 + n_2$$

(Panse and Sukhatme, 1957)

In the fourth generation, the mean values were analysed using 17 x 2 RBD. The outline of analysis of variance table showing source of variation and corresponding degrees of freedom is given below:

Source	Degrees of freedom
Block	1
Treatment	16
Error	16
Total	33

Analysis of phenotypic classes under the different treatment was done as a factorial in RBD with fourteen treatments, three phenotypic classes and two replications. The outline of analysis of variance is as follows:

Source	Degrees of freedom
Replication	1
Between treatments	13
Between phenotypic classes	2
T x P	26
Error	41
Total	83

Table 1. Details of genotypes included for mutation analysis in M_3 generation

Sl.No.	Name of the genotype
1	Pusa Sawani
2	Co-1
3	Kilichundan
4	Pusa Sawani x Co-1
5	Pusa Sawani x Kilichundan
6	Co-1 x Pusa Sawani
7	Kilichundan x Pusa Sawani
8	Kilichundan x Co-1
9	Co-1 x Kilichundan

Table 2. Treatments selected out from third generation for performance analysis.

1.	Pusa Sawani	- Control
2.	Pusa Sawani	- 30 kR
3.	Kilichundan	- Control
4.	Kilichundan	- 30 kR
5.	Co-1	- Control
6.	Co-1	- 30 kR
7.	PS x Co-1	- Control
8.	PS x Co-1	- 30 kR
9.	PS x Kc	- Control
10.	PS x KC	- 30 kR
11.	Kc x PS	- Control
12.	Kc x PS	- 30 kR
13.	Kc x Co-1	- Control
14.	Kc x Co-1	- 30 kR
15.	Co-1 x Kc	- Control
16.	Co-1 x Kc	- 30 kR
17.	Co-1 x PS	- 30 kR
18.	Co-1 x PS	- 30 kR

RESULTS

RESULTS

1. Mean character expressions in the third generation

1.1. Plant height

The mean height of plants under the different genotypes for control and 30 kR exposure of gamma rays is given in table 3. Statistical analysis of the data showed significant variation among the treatments.

In the control population of the three inbreds, the mean plant height ranged from 47.07 cm in Kilichundan to 65.06 cm in Co-1. Pusa Sawani showed an intermediary plant height (56.82 cm). Compared to Pusa Sawani and Co-1, a significant reduction in plant height was noted in Kilichundan. Pusa Sawani showed a significant reduction in plant height compared to Co-1.

The plant height in the gamma ray irradiated population of the three inbreds ranged from 43.83 cm to 61.09 cm in Kilichundan and Co-1 respectively. The plant height of Pusa Sawani was 55.74 cm. The three inbreds did not show any significant difference due to the effect of gamma rays, when compared to their respective controls.

The plant height in cross bred controls (F_3 population) ranged from 52.15 cm in PS x CO-1 to 77.66 cm in KC x Co-1. PS x Co-1 (52.15 cm) and Co-1 x PS (54.95 cm)

Table 3. Mean plant height and frequency distribution of variants (Percentage) in the third generation.

Treatments		Plant height (cm)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Savani (PS)	56.82	-	100	-
	Kilichundan (KC)	47.07	-	100	-
	Co-1	65.06	-	100	-
M_3	PS	55.74	16.42	48.80	34.70
	KC	43.83	14.84	42.74	42.72
	Co-1	61.09	27.60	43.82	28.58
F_3	PS x Co-1	52.15	20.33	55.83	23.84
	PS x KC	59.58	10.50	49.37	40.13
	Co-1 x PS	54.95	15.89	50.23	33.88
	KC x PS	71.47	10.88	43.91	45.21
	KC x Co-1	77.66	9.09	36.46	54.45
	Co-1 x KC	75.76	11.58	43.28	45.14
F_3M_3	PS x Co-1	56.60	14.06	36.67	49.27
	PS x KC	67.99	10.41	40.85	48.74
	Co-1 x PS	53.24	18.02	50.03	31.95
	KC x PS	76.40	5.00	40.66	54.34
	KC x Co-1	85.68	10.37	38.09	51.54
	Co-1 x KC	66.90	8.91	44.91	46.18

F value 22.59*

CD value 7.19

	F value	CD value
Between treatments (T)	0.24	-
Between phenotypic classes (P)	24.11*	6.85
T x P interaction	0.40	-

* Significant at 5% level.

recorded significant reduction, compared to Co-1, but there was no significant difference from that or Pusa Sawani. In the cross PS x Kc, the observed plant height (59.58 cm) was significantly higher than that of one of its parents. Kilichundan (47.07 cm), but it did not show any significant difference from Pusa Sawani (56.92 cm). In the reciprocal cross, KC x PS, the plant height was significantly higher (71.47 cm) than that of both the parents. The crosses Co-1 x KC (75.76 cm) and KC x Co-1 (77.66 cm) recorded significantly higher value compared to both the parents.

The plant height in F_3M_3 ranged from 53.24 cm in Co-1 x PS to 85.68 cm in KC x Co-1. PS x CO-1 recorded 56.60 cm which was not significantly different from the treated parents. The plant height in F_3M_3 involving Co-1 x PS (53.24 cm) failed to show any significant difference compared to the M_3 population of Pusa Sawani, but it recorded a significant reduction from treated Co-1 (61.09 cm). PS x KC (67.99 cm) and KC x PS (76.40 cm) recorded significant increase over the M_3 generation of their parents. When KC x Co-1 showed a plant height of 85.68 cm, which was significantly higher than both the treated parents, Co-1 x KC recorded only 66.90 cm, which was significantly higher only to Kilichundan.

Irradiated population of PS x KC and KC x Co-1 showed significantly higher value than their F_3 generations, while Co-1 x KC recorded a significant reduction. Other crosses, PS x Co-1, Co-1 x PS and KC x PS showed no significant difference compared to their F_3 generations.

1.2. Days to flowering

Table 4 represents the mean number of days taken to flowering under the different treatments. Statistical analysis of the data revealed significant difference among the treatments.

The mean number of days taken to flowering in the control population of the three inbreds ranged from 42.10 in Pusa Sawani to 44.82 in Co-1. A significantly higher value was noted in Co-1. Compared to Pusa Sawani, Kilichundan took a significantly longer period (44.08) to flower.

In the M_3 population, the range in mean value was 42.81 to 44.31 in Pusa Sawani and Co-1 respectively. The mean number of days for Kilichundan was 43.93. Irradiated inbreds did not show any significant variation among themselves and also compared to their respective controls.

The mean number of days to flowering in the F_3 population ranged from 42.50 in PS x Co-1 to 45.45 in KC x PS. The mean value recorded by PS x Co-1 was significantly

Table 4. Mean number of days taken to flowering and frequency distribution of variants (Percentage) in the third generation.

Treatments		Number of days to flowering.	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	42.10	-	100	-
	Kilichundan (KC)	44.08	-	100	-
	Co-1	44.82	-	100	-
M_3	PS	42.81	34.76	35.67	29.57
	KC	43.93	18.87	30.91	50.22
	Co-1	44.31	29.41	32.99	37.60
F_3	PS x Co-1	42.50	23.05	45.84	31.11
	PS x KC	43.81	14.06	52.61	33.33
	Co-1 x PS	43.07	26.16	40.86	32.98
	KC x PS	45.45	19.18	40.58	40.25
	KC x Co-1	44.22	14.88	38.91	46.21
	Co-1 x KC	44.68	25.29	40.61	34.10
F_3M_3	PS x Co-1	42.38	46.44	36.76	16.80
	PS x KC	44.62	17.53	28.98	53.49
	Co-1 x PS	43.53	31.51	42.14	26.35
	KC x PS	45.21	13.97	20.87	65.16
	KC x Co-1	43.69	18.71	25.49	55.80
	Co-1 x KC	43.99	18.14	37.96	43.90

F value 2.42*

CD value 1.86

	F value	CD value
Between Treatments (T)	0.016	-
Between phenotypic classes (P)	10.07*	5.45
T x P interaction	1.18	—

* Significant at 5% level.

lower than that of Co-1, but not with Pusa Sawani. The reciprocal cross, Co-1 x PS failed to show any significant variation (43.07) compared to their parents. When the mean value recorded by KC x PS (45.45) was significantly higher to Pusa Sawani (42.10), its reciprocal cross, PS x KC (43.81) showed no significant difference from both the parents. The crosses KC x Co-1 (44.22) and its reciprocal, Co-1 x KC (44.68) did not show any significant variation compared to their parents.

In the F_3M_3 population, the mean number of days to flowering ranged from 42.38 in PS x Co-1 to 45.21 in KC x PS. When PS x Co-1 recorded a significantly lower value (42.38) than that of the treated Co-1, its reciprocal cross, Co-1 x PS showed an insignificant mean value (43.53) compared to their irradiated parents. The mean value observed in PS x KC (44.62) failed to show any significant difference from the M_3 mean data of the parents. But KC x PS recorded a mean value of 45.21 which was significantly higher to treated Pusa Sawani, but not varied from treated Kilichundan. The F_3M_3 population of the crosses involving Kilichundan and Co-1 recorded mean values of 43.69 and 43.99 in KC x Co-1 and Co-1 x KC respectively, both of which did not show any significant difference from the M_3 population of the parents.

In general, no significant difference in the mean value was observed in the F_3M_3 populations, compared to their respective F_3 generations.

1.3. <u>Number of leaves per plant</u>

The mean number of leaves per plant in the third generation for the different treatments are presented in table 5. Statistical analysis of the data showed no significant variation among the treatments.

In control population, the mean number of leaves per plant ranged from 10.25 (Kilichundan) to 13.09 (Pusa Sawani). But it ranged from 11.75 (Kilichundan) to 12.74 (Pusa Sawani) in the M_3 population. The mean value for the number of leaves in Pusa Sawani and Co-1 tended to decreased due to gamma ray exposure, while in Kilichundan, it increased from 10.25 to 11.75.

The range in mean number of leaves in the F_3 population was 11.25 in PS x KC to 13.73 in KC x Co-1. In F_3M_3, it ranged from 11.68 to 14.05 in PS x Co-1 and KC x PS respectively.

An insignificant increase in the mean number of leaves was noted in F_3M_3 for PS x KC, Co-1 x PS and KC x PS. A reverse trend was noticed in PS x Co-1, KC x Co-1 and Co-1 x KC.

Table 5. Mean number of leaves per plant and frequency distribution of variants (percentage) in the third generation.

Treatments		Number of leaves/ plant	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	13.09	-	100	-
	Kilichundan (KC)	10.25	-	100	-
	Co-1	12.96	-	100	-
M_3	PS	12.58	11.76	58.00	30.24
	KC	11.75	13.08	64.56	22.37
	Co-1	12.74	9.17	58.07	32.76
F_3	PS x Co-1	12.57	14.41	40.94	44.65
	PS x KC	11.25	23.16	50.34	26.50
	Co-1 x PS	11.48	23.46	50.77	25.77
	KC x PS	13.43	14.06	41.10	44.84
	KC x Co-1	13.73	14.76	42.75	42.49
	Co-1 x KC	13.17	21.59	37.34	41.07
F_3M_3	PS x Co-1	11.68	13.20	58.02	28.78
	PS x KC	12.92	14.32	61.49	24.19
	Co-1 x PS	13.08	16.01	50.14	33.85
	KC x PS	14.05	5.92	50.90	43.18
	KC x Co-1	13.50	11.32	54.39	34.29
	Co-1 x KC	12.95	11.49	45.18	43.33

F value	1.55
CD value	-

	F value	CD value
Between treatments (T)	0.02	-
Between phenotypic classes (P)	83.76*	3.72
T x P interaction	1.28	-

* Significant at 5% level.

1.4. <u>Number of branches per plant</u>

Table 6 represents the mean number of branches produced per plant under the different treatments. Statistical analysis showed no significant variation among the treatments for the mean number of branches per plant.

In the inbred control population, the mean number of branches ranged from 0.55 to 1.20 in Pusa Sawani and Kilichundan respectively. A mean value of 0.81 was recorded in Co-1. The range of mean value in the M_3 was 0.67 in Kilichundan to 1.03 in Co-1. When the mean value showed an insignificant increase in treated Pusa Sawani and Co-1, it exhibited a reduction in Kilichundan.

The mean number of branches ranged from 0.35 (PS x KC) to 0.85 (KC x PS) in F_3 and from 0.55 (PS x KC) to 1.22 (KC x PS) in F_3M_3 population.

The mean values, due to gamma ray exposures, increased from 0.53 to 0.77 in PS x Co-1, 0.35 to 0.55 in PS x KC, 0.69 to 1.14 in Co-1 x PS, 0.85 to 1.22 in KC x PS and 0.65 to 0.74 in KC x Co-1. But in the cross Co-1 x KC, it decreased from 0.77 to 0.72.

1.5. <u>Length of fruit</u>

The mean data for length of fruit under the different treatments are given in table 7. Statistical analysis

Table 6. Mean number of branches per plant under different treatments and under different M_1 sterility groups.

	Treatments	Number of branches/ plant	M_1 sterility classes		
			Low	Medium	High
Control	Pusa Sawani (PS)	0.55	-	-	-
	Kilichundan (KC)	1.20	-	-	-
	Co-1	0.81	-	-	-
M_3	PS	0.87	0.68	1.20	0.72
	KC	0.67	0.57	0.67	0.76
	Co-1	1.03	1.13	1.08	0.87
F_3	PS x Co-1	0.53	-	-	-
	PS x KC	0.35	-	-	-
	Co-1 x PS	0.69	-	-	-
	KC x PS	0.85	-	-	-
	KC x Co-1	0.65	-	-	-
	Co-1 x KC	0.77	-	-	-
F_3M_3	PS x Co-1	0.77	1.06	0.58	0.67
	PS x KC	0.55	0.23	0.56	0.85
	Co-1 x PS	1.14	1.11	0.95	1.35
	KC x PS	1.22	0.97	1.11	1.58
	KC x Co-1	0.74	0.87	0.75	0.61
	Co-1 x KC	0.72	0.71	0.64	0.81

F value 2.21
CD value -

	F value	CD value
Between treatments (T)	1.67	-
Between Sterility Groups (S)	0.42	-
T x S interaction	0.95	-

showed significant difference among the treatments.

The mean length of fruit, in control population ranged from 13.91 cm in Pusa Sawani to 17.09 cm in Kilichundan. The mean value in Co-1 was 14.16 cm. The mean fruit length in Pusa Sawani was not significantly different from that of Co-1, but it was significantly lower than that of Kilichundan. Kilichundan showed a significantly higher value compared to Co-1 also.

In the M_3 population, the mean length of fruit ranged from 14.55 cm in Pusa Sawani to 16.25 cm in Kilichundan. Kilichundan recorded a significantly higher value, compared to Pusa Sawani, but showed no significant difference from Co-1 (14.98 cm). When compared to the control population, the irradiated population did not show any significant difference with respect to the length of fruits.

The range in mean length of fruit in F_3 was 14.11 cm in Co-1 x PS to 18.07 cm in KC x PS. The crosses involving Co-1 and Pusa Sawani did not show any significant difference in the mean length of fruit, compared to their parents. The cross PS x KC recorded a mean value of 16.03 cm which is significantly higher than that of Pusa Sawani, but not different from Kilichundan. Similar effect was noticed

Table 7. Mean fruit length and frequency distribution of variants (percentage) in the third generation.

	Treatments	Fruit length (cm)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Con-trol	Pusa Sawani (PS)	13.91	-	100	-
	Kilichundan (KC)	17.09	-	100	-
	Co-1	14.16	-	100	-
M_3	PS	14.55	18.37	43.51	38.12
	KC	16.25	10.64	39.05	50.31
	Co-1	14.98	11.20	57.00	31.80
F_3	PS x Co-1	15.17	17.52	36.63	45.85
	PS x KC	16.03	30.41	41.19	28.40
	Co-1 x PS	14.11	28.11	42.13	29.76
	KC x PS	18.07	11.77	29.50	58.73
	KC x Co-1	16.90	10.11	38.78	51.11
	Co-1 x KC	14.94	24.92	52.06	23.02
F_3M_3	PS x Co-1	14.67	13.49	50.47	36.05
	PS x KC	17.49	11.21	40.31	48.48
	Co-1 x PS	14.55	10.78	42.11	47.11
	KC x PS	16.68	13.38	29.09	57.53
	KC x Co-1	17.56	11.03	37.49	51.48
	Co-1 x KC	17.17	11.86	34.03	54.11

F value 11.31*

CD value 1.27

	F value	CD value
Between treatments (T)	0.015	-
Between phenotypic classes (P)	57.63*	3.85
T x P interaction	1.72	_

* Significant at 5% level.

in the reciprocal cross, KC x PS also. The mean value recorded by KC x Co-1 (16.90 cm) was significantly higher to Co-1, but not different from Kilichundan. Its reciprocal cross, Co-1 x KC showed a significantly lower value (14.94 cm) compared to Kilichundan, but not different from Co-1.

In the F_3M_3 population, the mean length of fruit ranged from 14.55 cm to 17.56 cm in Co-1 x PS and KC x Co-1 respectively. The mean values recorded by PS x Co-1 (14.67 cm) and Co-1 x PS (14.55 cm) were not significantly different from their M_3 population. PS x KC and its reciprocal cross (KC x PS) showed mean values of 17.49 cm and 16.68 cm respectively. These values were significantly higher to treated Pusa Sawani, but not to treated Kilichundan. KC x Co-1 (17.56 cm) was found to be superior to irradiated parents. With respect to the length of fruit, Co-1 x KC (17.17 cm) recorded significant increase over the M_3 generation of Pusa Sawani but it showed no significant difference from Kilichundan.

1.6. <u>Weight of fruit</u>

Table 8 shows the mean weight of fruit under the different treatments. The various treatments have brought out significant variation in the weight of fruits.

Table 8. Mean fruit weight and frequency distribution of variants (percentage) in the third generation.

Treatments		Fruit weight (g)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	16.57	-	100	-
	Kilichundan (KC)	18.58	-	100	-
	Co-1	15.63	-	100	-
M_3	PS	16.70	16.24	33.56	50.20
	KC	19.81	12.28	27.06	60.66
	Co-1	16.77	18.63	27.97	53.40
F_3	PS x Co-1	16.76	15.72	24.83	59.45
	PS x KC	20.15	16.40	27.50	56.10
	Co-1 x PS	17.30	20.27	22.76	56.97
	KC x PS	22.94	16.84	19.99	63.17
	KC x Co-1	21.01	18.40	35.06	46.54
	Co-1 x KC	19.11	19.92	27.48	52.60
F_3M_3	PS x Co-1	16.46	14.77	39.50	45.73
	PS x KC	21.75	10.00	30.92	59.08
	Co-1 x PS	17.62	9.29	22.42	68.29
	KC x PS	22.37	13.93	25.09	60.98
	KC x Co-1	22.39	11.07	33.39	55.54
	Co-1 x KC	22.05	12.59	29.39	58.02

F value	7.86*
CD value	2.65

	F value	CD value
Between treatments (T)	0.013	-
Between phenotypic classes (P)	145.45*	3.15
T x P interaction	0.87	–

* Significant at 5% level.

The weight of fruit observed in the control population of the inbreds was in the order 15.63 g to 18.58 g in Co-1 and Kilichundan respectively. Kilichundan recorded a significant increase in weight of fruit over Co-1 and an insignificant increase over Pusa Sawani (16.57 g). No significant difference was observed between Co-1 and Pusa Sawani with respect to weight of fruit.

In the M_3 population, the mean weight of fruit ranged from 16.70 g in Pusa Sawani to 19.81 g in Kilichundan. M_3 generation of Pusa Sawani and Co-1 (16.77 g) exhibited a significant reduction in fruit length compared to Kilichundan. The three inbreds did not show any significant difference due to the effect of gamma rays.

The range of fruit weight in the F_3 generation was 16.76 g in PS x Co-1 to 22.94 g in KC x PS. PS x Co-1 (16.76 g) and its reciprocal cross Co-1 x PS (17.30 g) failed to record any significant difference from either of their parents. When PS x KC showed a significant increase)20.15 g) over Pusa Sawani and an insignificant increase over Kilichundan, its reciprocal cross KC x PS exhibited a significant increase 22.94 g) over both the parents. Crosses involving Kilichundan and Co-1 recorded mean values of 21.01 g (KC x CO-1) and 19.11 g (Co-1 x KC), both of which were significantly higher than Co-1, but not different from Kilichundan.

The F_3M_3 generation exhibited a range of 16.46 g in PS x Co-1 to 22.39 g in KC x Co-1. Crosses involving Pusa Sawani and Kilichundan recorded significantly higher value compared to the M_3 generation of Pusa Sawani. They also showed an insignificant increase over treated Kilichundan. PS x Co-1 (16.46 g) and Co-1 x PS (17.62 g) failed to show any significant difference in fruit weight compared their M_3 generation, KC x Co-1 (22.39 g) and Co-1 x KC (22.05 g) showed significant increase over M_3 generation of Co-1 and an insignificant increase over treated Kilichundan. All the crosses failed to show any significant variation due to the effect of gamma rays.

1.7. Number of fruits per plant

The mean number of fruits per plant for the different treatments in the third generation are given in table 9. Statistical analysis showed significant difference among the treatments.

Maximum value for the mean number of fruits in inbreds was exhibited by Kilichundan (5.17) and the minimum by Pusa Sawani (4.68). The difference in mean value between Pusa Sawani and Co-1 (4.78 g) was insignificant.

The mean number of fruits in the M_3 generation ranged from 4.52 in Co-1 to 5.04 in Kilichundan. The

Table 9. Mean number of fruits per plant and frequency distribution of variants (percentage) in the third generation.

Treatments		Number of fruits/ plant	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	4.68	-	100	-
	Kilichundan (KC)	5.17	-	100	-
	Co-1	4.78	-	100	-
M_3	PS	4.69	12.68	53.49	33.83
	KC	5.04	12.89	59.88	27.23
	Co-1	4.52	10.84	52.95	36.21
F_3	PS x Co-1	4.70	30.98	45.75	23.27
	PS x KC	5.38	18.60	58.08	23.32
	Co-1 x PS	4.54	28.54	49.70	21.75
	KC x PS	6.43	17.67	45.53	36.80
	KC x Co-1	5.33	16.26	49.89	33.85
	Co-1 x KC	6.06	17.71	44.21	38.08
F_3M_3	PS x Co-1	4.58	21.87	52.61	25.52
	PS x KC	6.40	7.27	53.12	39.61
	Co-1 x PS	4.63	14.62	54.82	30.56
	KC x PS	6.80	6.39	50.83	42.78
	KC x Co-1	6.29	14.15	43.08	42.77
	Co-1 x KC	5.68	12.73	43.75	43.52

F value 14.53*

CD value 0.595

	F value	CD value
Between treatments (T)	0.013	-
Between phenotypic Classes (P)	63.11*	4.002
T x P interaction	1.00	-

* Significant at 5% level.

gamma ray exposed inbreds did not show any significant difference among themselves and also when compared to their respective controls.

The range of the mean value for the number of fruits in F_3 was 4.54 in Co-1 x PS to 6.43 in KC x PS. The crosses PS x Co-1 (4.70), Co-1 x PS (4.54) and KC x Co-1 (5.33) recorded no significant difference from their respective parents. When PS x KC (5.38) recorded a significant increase over Pusa Sawani, one of its parents, its reciprocal cross, KC x PS (6.43) exhibited increase over both the parents. Co-1 x KC also recorded significantly higher value (6.06) compared to their parents.

In F_3M_3, the mean number of fruits ranged from 4.58 to 6.80 in PS x Co-1 and KC x PS respectively. When the crosses involving Pusa Sawani and Co-1 recorded mean values of 4.58 (PS x Co-1) and 4.63 (Co-1 x PS), those involving PS and KC recorded mean values of 6.40 (PS x KC) and 6.80 (KC x PS), which were significantly higher to the gamma ray exposed inbreds. Irradiated population of KC x Co-1 (6.29) and Co-1 x KC (5.68) also showed significant increase over the M_3 generation of the parents.

A gamma ray induced significant increase in the number of fruits was noticed in PS x KC and KC x Co-1. Co-1 x PS and KC x PS showed an insignificant increase due to the effect of gamma rays. But the F_3M_3 generation of PS x Co-1 and Co-1 x KC recorded an insignificant decrease compared to their respective F_3 population.

1.8 <u>Fruit yield per plant</u>

Table 10 represents the mean fruit yield per plant for the different treatments. The treatments exhibited significant variation among themselves.

The yield in the control population of the inbreds was in the order of 74.65 g in Co-1 to 95.97 g in Kilichundan. Kilichundan exhibited an insignificant increase over Pusa Sawani (77.48 g) and Co-1.

The mean yield in M_3 ranged from 75.67 g in Co-1 to 100.27 g in Kilichundan. The M_3 generation of three inbreds did not show significant difference among themselves and also when compared to the respective controls.

The range of yield in F_3 was 78.77 g in PS x Co-1 to 115.88 g in Co-1 x KC. PS x Co-1 (78.77 g) and Co-1 x PS (79.05 g) recorded no significant variation from their parents. PS x KC (108.41 g) recorded a significant increase over Pusa Sawani, but showed no significant difference

Table 10. Mean fruit yield per plant and frequency distribution of variants (percentage) in the third generation.

Treatments		Fruit yield/ plant (g)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control.	Pusa Sawani (PS)	77.48	-	100	-
	Kilichundan (KC)	95.97	-	100	-
	Co-1	74.65	-	100	-
M_3	PS	78.40	20.04	23.62	56.34
	KC	100.27	13.01	47.62	39.37
	Co-1	75.67	19.91	35.15	44.94
F_3	PS x Co-1	78.77	31.16	38.08	30.76
	PS x KC	108.41	12.55	44.88	42.57
	Co-1 x PS	79.05	29.22	44.17	26.61
	KC x PS	147.77	9.14	46.88	43.98
	KC x Co-1	112.06	14.05	26.86	59.09
	Co-1 x KC	115.88	24.35	40.99	34.66
F_3M_3	PS x Co-1	75.89	37.25	38.05	24.70
	PS x KC	140.55	21.22	20.89	57.89
	Co-1 x PS	85.86	25.24	34.83	39.93
	KC x PS	151.14	13.45	26.55	60.00
	KC x Co-1	142.86	20.61	20.29	59.10
	Co-1 x KC	125.81	16.09	30.55	53.36

F value 9.74*

CD value 26.60

	F value	CD value
Between treatments (T)	0.01	-
Between phenotypic classes (P)	13.88*	6.11
T x P interaction	0.90	-

* Significant at 5% level.

from Kilichundan. But KC x PS (147.77 g) showed a significantly higher value, compared to both the parents. KC x Co-1 (112.06 g) and Co-1 x KC (115.88 g) recorded significant increase over Co-1 and an insignificant increase over Kilichundan.

In F_3M_3 population, the mean yield ranged from 75.89 g to 151.14 g in PS x Co-1 and KC x PS respectively. PS x Co-1 (75.89 g) and Co-1 x PS (85.86 g) recorded an insignificant difference from their M_3 generation. But PS x KC (140.55 g) and KC x PS (151.14 g) recorded significantly higher values compared to their M_3 population. When KC x Co-1 (142.86 g) showed significant increase over both the treated parents, Co-1 x KC recorded only 125.81 g which was significantly superior only to Co-1. Except PS x Co-1, all the other crosses exhibited increase in the yield, due to the effect of gamma rays, out of which PS x KC and KC x Co-1 showed significant increase over their cross bred F_3 population.

2. Phenotypic Frequency Distribution of variants in the third generation

2.1. Plant height

The frequency distribution of plant height variants (in percentage) in the different treatments are presented in table 3. Statistical analysis of the data showed significant variation among the three phenotypic classes. No significant difference was noted among the varians treatments and also in the interaction of treatments with the different phenotypic classes.

Distribution of both positive and negative variants were found in all the treatments. In F_3 population, maximum frequency of negative variants was recorded by PS x Co-1 (20.33%) and the minimum by KC x Co-1 (9.09%). Co-1 x PS KC x Co-1 and PS x KC recorded a lower frequency of negative variants, compared to their reciprocal crosses. The negative variants in the M_3 generation were maximum for Co-1 (27.60%) followed by Pusa Sawani (16.42%) and Kilichundan (14.84%). The frequency of negative variants in the F_3M_3 generation ranged from 5.00% (KC x PS) to 18.02 % (Co-1 x PS). Compared to F_3 and M_3, F_3M_3 generation recorded a lower frequency of negative varients.

In the F_3M_3 generation, crosses such as PS x Co-1 Co-1 x KC, PS x KC and KC x PS showed lower values for negative variants, when compared to their F_3 population, whereas Co-1 x PS and KC x Co-1 recorded a higher value.

The frequency distribution of positive variants ranged from 23.84% to 54.45% in the cross bred populations of PS x Co-1 and KC x Co-1 respectively. Among the F_3 populations, Co-1 x PS, KC x Co-1 and KC x PS recorded higher frequency of positive variants compared to their reciprocals. When the percentage of positive variants in M_3 ranged from 28.58 (Co-1) to 42.42 (KC), in F_3M_3, it was 31.95 (Co-1 x PS) to 54.34 (KC x PS). Compared to the respective F_3 generation, gamma ray irradiated populations of PS x Co-1, Co-1 x KC, PS x KC and KC x PS registered higher frequencies of positive variants. But in crosses Co-1 x PS and KC x Co-1, the frequency of positive variants decreased due to the effect of gamma rays.

Compared to the negative variants significant increase in the frequency of positive variants was noticed in all the treatments, irrespective of the genetic make up.

Higher frequency of individuals came under the control group in all the M_3 populations, three of the F_3s (PS x Co-1, Co-1 x PS and PS x KC) and two of the F_3M_3s

(PS x Co-1 and Co-1 x PS). In all the other treatments, positive variants were found to be higher when compared to control and negative variants.

2.2. Days to flowering

The frequency distribution of the number of days to flowering (in percentage) for the different treatments are given in table 4. On Statistical analysis, the data revealed significant difference among the three phenotypic classes. The effect due to the treatments and the interaction exhibited no significant variation.

Both positive and negative variants were observed in all the treatments. The negative variants in the F_3 population ranged from 14.06% in PS x KC to 26.16% in Co-1 x PS. Higher frequency of negative variants were found in Co-1 x PS, Co-1 x KC and KC x PS, when compared to their reciprocals. In the M_3 generation, the range of negative variants was 18.87% (Kilichundan) to 34.76% (Pusa Sawani) whereas in F_3M_3, the negative variants ranged from 13.97% in KC x PS to 46.44% in PS x Co-1. In F_3M_3, all the crosses except Co-1 x KC and KC x PS recorded a higher frequency of negative variants for the number of days to flowering, when compared to their respective F_3 populations.

The frequency of positive variants in F_3 ranged from 31.11% to 46.21% in PS x Co-1 and KC x Co-1 respectively, whereas in M_3, it was 29.57% (Pusa Sawani) to 50.22% (Kilichundan) and in F_3M_3, it was 16.80% (PS x Co-1) to 65.16% (KC x PS). Among all the treatments, irradiated populations of Kilichundan, KC x Co-1, PS x KC and KC x PS registered more than 50% of positive variants. Compared to the F_3 generation, F_3M_3 of PS x Co-1 and Co-1 x PS recorded lesser frequency of positive variants, whereas the rest of the crosses exhibited a higher value.

Individuals coming under the control group were higher in number in F_3 than in the M_3 population. In F_3M_3, Co-1 x KC, PS x KC and its reciprocal cross exhibited frequencies which were significantly higher to that of negative variants, but lower than that of positive variants.

2.3. <u>Number of leaves per plant</u>

Table 5 represents the frequency distribution of the number of leaves for the various treatments. Statistical analysis showed significant difference among the three phenotypic classes. The treatments and the interaction effects were found to be insignificant.

The frequency of phenotypesgot distributed both in positive and negative directions compared to control values. Among the F_3 population, maximum negative variants was seen in Co-1 x PS (23.46%) and the minimum in KC x PS (14.06%). Higher frequencies of negative variants were exhibited by Co-1 x PS, Co-1 x KC and PS x KC compared to their reciprocals. When the frequency of negative variants ranged from 9.17% (Co-1) to 13.08% (Kilichundan) in the M_3 generation, in F_3M_3, it was 5.92% in KC x PS to 16.01% in Co-1 x PS. Due to the effect of gamma rays, the number of negative variants created was lessor, with regards to the number of leaves.

The maximum frequency of positive variants was recorded in KC x PS (44.84%) and the minimum in Co-1 x PS (25.77%) in the F_3 generation. Frequency of positive variants recorded by PS x Co-1, KC x Co-1 and KC x PS was higher compared to their reciprocals. In M_3, highest frequency of positive variants was shown by Pusa Sawani (30.24%) followed by Co-1 (32.76%) and Kilichundan (22.37%). In F_3M_3, the frequency ranged from 28.78% (PS x Co-1) to 43.33% (Co-1 x KC). The frequency of positive variants increased due to the effect of gamma rays in Co-1 x PS and Co-1 x KC, while all the other crosses showed a reduction. Except in the case of Co-1 x PS and PS x KC, all the other treatments recorded significantly higher frequency of positive variants over the negative variants.

Except in the F_3 population of PS x Co-1, Co-1 x KC and KC x PS, all the other treatments had maximum frequency in the control group compared to the negative and positive variants. More than 50 per cent of the individuals recorded control values, as far as the number of leaves are concerned. This was noted in the case of Co-1 x PS and PS x KC(F_3) and in the irradiated populations of Pusa Sawani, PS x Co-1, Co-1 x PS, KC x Co-1, PS x KC and KC x PS.

2.4. Length of fruit

The frequency distribution of fruit length variants (in percentage) for the different treatments are given in table 7. Statistical analysis of the data showed significant variation among the three phenotypic classes. The major treatments and their interaction with phenotypic classes showed no significant difference.

The frequency of negative variants in the F_3 ranged from 10.11% in KC x Co-1 to 30.41% in PS x KC. Crosses PS x Co-1, KC x Co-1 and KC x PS had higher frequency of negative variants compared to the reciprocals. In M_3, maximum negative variants were produced in Pusa Sawani (18.37%) and the minimum in Kilichundan (10.64%). The range in frequency of negative variants in F_3M_3 was 10.78% in Co-1 x PS to 13.49% in PS x Co-1.

In crosses PS x Co-1, Co-1 x PS, Co-1 x KC and PS x KC, gamma rays considerably reduced the frequency of negative variants; where as in irradiated KC x Co-1 and KC x PS, there was a higher frequency of negative variants.

The frequency of positive variants ranged from 23.02% (Co-1 x KC) to 58.73% (KC x PS) in F_3 population. Comparatively higher frequency was noted in PS x Co-1, KC x Co-1 and KC x PS. As regards the M_3 population, maximum frequency of positive variants was registered in Kilichundan (50.31%) and the minimum in Co-1 (31.80%). In F_3M_3, KC x PS recorded the maximum frequency (57.53%) and PS x Co-1 the minimum (36.05%). Gamma ray was effective in increasing the frequency of positive fruit length variants in Co-1 x PS, Co-1 x KC KC x Co-1 and PS x KC. But in PS x Co-1 and KC x PS, the percentage of positive variants decreased due to the effect of the irradiation.

To the exclusion of the F_3 population of Co-1 x PS, Co-1 x KC and PS x KC, all the treatments showed significantly higher frequency of positive variants than that of the negative variants.

Higher frequency of control types were noticed in the M_3 population of Pusa Sawani and Co-1, F_3 of Co-1 x PS, Co-1 x KC and PS x KC and F_3M_3 of PS x Co-1.

2.5. <u>Weight of fruit</u>

Table 8 represents the frequency distribution of the three phenotypes in the weight of fruits for the different treatments. Significant differences were observed for the frequency of the three phenotypes, but the major treatments and the interaction were not significant.

Both positive and negative variants were produced in all the treatments. The frequency of these variants varied with the treatments. In F_3, the percentage of negative variants ranged from 15.72% in PS x Co-1 to 20.27% in Co-1 x PS. Compared to the reciprocal crosses, PS x Co-1, KC x Co-1 and PS x KC recorded lesser frequency of negative variants. In M_3 generation, the highest value of negative variants was seen in Co-1 (18.63%) and the lowest in Kilichundan (12.28%). In F_3M_3, PS x Co-1 recorded the highest value (14.77%) and the lowest in Co-1 x PS (9.29%). In all the crosses, number of individuals included under the negative variants decreased due to the effect of gamma rays.

The frequency of positive variants in F_3 ranged from 46.54% in KC x Co-1 to 63.17% in KC x PS. Higher frequency of positive variants was recorded in PS x Co-1, Co-1 x KC and KC x PS, compared to the reciprocals. In M_3, the range of positive variants was 50.20% to 60.66% in Pusa Sawani and Kilichundan respectively. But in F_3M_3, frequency of positive variants ranged from 45.73% in PS x Co-1 to 68.29% in Co-1 x PS. Compared to the F_3 generation, F_3M_3 of PS x Co-1 and KC x PS registered a reduction in the frequency of positive variants, where as all the other crosses recorded an increase.

In all the treatments, the frequency of positive variants was significantly higher than that of the negative variants. The control groups had significantly lower values in all the treatments compared to positive variants.

2.6. Number of fruits per plant

The frequency distribution of fruit number variants, for the different treatments are given in table 9. Statistical analysis revealed significant difference among the phenotypic classes. There was no significant different among treatments and in the interaction.

Both positive and negative variants were found in all the treatments. Among the F_3 populations, maximum negative variants was recorded by PS x Co-1 (30.98%) and the minimum by KC x Co-1 (16.26%). Compared to the reciprocal crosses, PS x Co-1, Co-1 x KC and PS x KC exhibited higher frequency of negative variants. In M_3, Kilichundan recorded the highest value of negative variants (12.89%) followed by Pusa Sawani (12.68%) and Co-1 (10.84%). The percentage of negative variants in F_3M_3 ranged from 6.39% in KC x PS to 21.87 in PS x Co-1. In all the crosses, frequency of negative variants decreased due to the effect of gamma rays.

The frequency of positive variants in F_3 ranged from 21.75% to 38.08% in Co-1 x PS and Co-1 x KC respectively. PS x Co-1, Co-1 x KC and KC x PS recorded higher percentage of positive variants, when compared to the reciprocals.

In M_3, the maximum positive variants was recorded by Co-1 (36.21%) followed by Pusa Sawani (33.83%) and Kilichundan (27.23%) whereas in F_3M_3, the frequency of positive variants ranged from 25.52% in PS x Co-1 to 43.52% in Co-1 x KC. A gamma ray induced increase in the frequency of positive fruit number variants was noticed in all the treatments.

In all the three inbreds, the M_3 population recorded a significant increase in the frequency of positive variants compared to the negative. In F_3, when PS x Co-1 and Co-1 x PS had significantly lesser frequency of positive variants than the negative variants, all the other crosses produced significantly higher frequency of positive variants. In F_3M_3, all the crosses except PS x Co-1, recorded higher frequency of positive variants compared to negative variants.

To the exclusion of Co-1 x KC and KC x Co-1, all the other treatments had significantly higher frequency of individuals belonging to the control group compared to negative and positive variants.

2.7. Yield per plant

Data regarding the frequency distribution of yield variants for the different treatments are given in table 10. Significant difference was noticed among the three phenotypic classes. But the major treatments and the interaction failed to show any significant variation.

The frequency distribution of both positive and negative variants was observed in all the treatments. In F_3 population, maximum negative variants was noticed in PS x Co-1 (31.16%) and the minimum in KC x PS (9.14%). When PS x Co-1, Co-1 x KC and PS x KC showed negative variants in the order of 31.16% , 24.35% and 12.55% respectively, their reciprocals, Co-1 x PS, KC x Co-1 and KC x PS recorded lower frequencies of 29.22%, 14.05% and 9.14% respectively. The frequency of negative variants ranged from 13.01% (Kilichundan) to 20.04% (Pusa Sawani) in the M_3 generation, whereas in F_3M_3, it ranged from 13.45% in KC x PS to 37.25% in PS x Co-1. Compared to F_3 generation, Ps x Co-1, KC x Co-1, PS x KC and Kc x PS in F_3M_3 produced a higher frequency of negative variants, Co-1 x PS and Co-1 x KC had lesser frequency of negative variants.

Frequency of positive variants was the highest in KC x Co-1 (59.09%) and lowest in Co-1 x PS (26.61%) among the F_3. PS x Co-1, KC x Co-1 and KC x PS recorded higher frequency of positive variants, compared to the reciprocal crosses. In M_3, the percentage of positive variants ranged from 39.37 in Kilichundan to 56.34 in Pusa Sawani, whereas in F_3M_3, the range was from 24.70 in PS x Co-1 to 60.00 in KC x PS. Gamma ray had effected in increasing the frequency of positive variants in all the crosses except in PS x Co-1.

In M_3, the frequency of positive variants was significantly higher than that of negative variants. In F_3, Co-1 x KC, KC x Co-1, PS x KC and KC x PS showed significant increase in the frequency of positive variants, over the negative variants. But in PS x Co-1 and its reciprocal cross, no significant difference was there between the negative and positive variants. PS x Co-1 in F_3M_3 showed a significant reduction in the frequency of positive variants compared to negative variants. A reverse trend was noticed in all the other crosses.

PS x Co-1, Co-1 x PS and Co-1 x KC in F_3 had significantly higher number of individuals falling under the control groups. In M_3, PS x KC had significantly higher frequency in the control group, when compared to the frequency of positive variants. In F_3M_3, KC x Co-1, PS x KC and their reciprocals exhibited significant reduction in the number of individuals in the control group, compared to positive segregants.

3. <u>Mean character expression under the three M_1 sterility classes</u>.

3.1. <u>Plant height</u>

The mean plant height for the different genotypes under the three M_1 sterility classes is given in table 11. Statistical analysis showed significant difference among the various treatments and the three M_1 sterility classes. The treatment X sterility class interaction also showed significant variation.

The treatments exhibited variation in the mean plant height, depending on the sterility classes in the M_1 generation. The mean plant height in low sterility class ranged from 44.78 cm in Kilichundan to 78.75 cm in KC x Co-1, whereas in the medium class, it ranged from 42.24 cm in

Table 11. Mean plant height and frequency distribution of variants (Percentage) under different M_1 sterility groups in the third generation.

	Treatments	Plant height (cm) M_1 sterility groups			Frequency distribution of variants M_1 sterility groups								
					Low			Medium			High		
		Low	Medium	High	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
M_3	Pusa Sawani (PS)	56.12	53.66	57.48	15.32	50.39	34.29	19.05	53.97	26.98	14.92	42.27	42.81
	Kilichundan (KC)	44.78	42.24	44.47	17.44	38.07	44.49	13.03	34.01	52.96	14.05	56.14	29.81
	Co-1	64.36	64.34	54.57	21.38	44.78	33.84	29.18	45.57	25.25	32.22	41.11	26.67
F_3M_3	PS x Co-1	55.04	63.44	51.32	18.75	28.75	52.50	6.82	35.46	57.72	16.61	45.81	37.58
	PS x KC	54.75	76.35	72.89	17.71	49.59	32.70	8.23	34.22	57.55	5.30	38.74	55.96
	Co-1 x PS	48.48	55.98	55.27	19.40	61.04	19.56	10.38	49.08	40.54	24.29	39.96	35.75
	KC x PS	77.78	79.91	71.49	6.18	34.44	59.38	3.78	39.02	57.27	3.54	48.53	47.93
	KC x Co-1	78.75	100.81	77.47	7.90	41.75	50.35	16.67	28.69	54.65	6.55	43.83	49.62
	Co-1 x KC	65.21	69.23	66.27	10.66	43.15	46.19	10.61	47.05	42.34	5.45	44.55	50.00

	F value	CD value
Between treatments (T)	21.89*	7.66
Between sterility groups (S)	9.43*	3.60
T x S interaction	2.84*	10.79

* Significant at 5% level.

	F value	CD value
Between Treatments (T)	0.05	-
Between sterility groups (S)	0.03	-
Between phenotypic classes (P)	36.98*	7.14
T x S interaction	0.005	-
T x P interaction	1.16	-
S x P interaction	0.27	-
T x S x P interaction	0.35	-

Kilichundan to 100.81 cm in KC x Co-1. The range was 44.47 cm (Kilichundan) to 77.47 cm (KC x Co-1) in the high sterility classes. The crosses KC x PS and KC x Co-1 exhibited significant increase in plant height, in all the three sterility classes, when compared to their respective parents.

In Pusa Sawani, the maximum plant height was noticed in the high sterility group (57.48 cm) followed by low sterility group (56.12 cm) and the minimum in the medium class (53.66 cm). In Kilichundan, the maximum plant height was in low sterility class and the minimum in medium class. Co-1 had approximately equal heights under low and medium sterility classes, but a significantly lower plant height in high sterility class.

In F_3M_3, all the treatments showed the highest plant height in medium sterility class, irrespective of the genotypes. In PS x Co-1, the low (55.04 cm) and the high (51.32 cm) sterility classes showed significant reduction in plant height, compared to the medium (63.44 cm) sterility class. In PS x KC, the medium (76.35 cm) and high (72.89 cm) sterility classes did not exhibit any significant difference but the low sterility class showed a significant reduction (54.75 cm) in plant height. Co-1 x PS also showed the same trend. In KC x PS, significantly higher plant height was noticed in low and medium sterility classes, compared to the high sterility class. A significant increase in plant height was noticed in the medium sterility class over the low and high sterility classes in KC x Co-1. But in Co-1 x KC, the low sterility class exhibited a significantly lower plant height, compared to the medium sterility group, but no significant difference from the high sterility class.

Among the three inbreds, Kilichundan recorded the lowest and Co-1, the highest mean plant height in the low and medium sterility classes. But in the high sterility group Pusa Sawani recorded the highest and Kilichundan the lowest mean values.

The mean plant height for various genotypes under medium sterility class (67.33 cm) was significantly higher than the low (60.58 cm) and high (61.24 cm) sterility classes.

3.2. Days to flowering

Table 12 gives the mean number of days taken to flowering for the different genotypes under the three M_1 sterility classes. There was no significant difference among the treatments and the different M_1 sterility classes. The treatment x sterility class interaction also showed no signi-

Table 12. Mean number of days taken to flowering and frequency distribution of variants (Percentage) under different M_1 sterility groups in the third generation.

	Treatments	Number of days to flowering M_1 sterility groups			Frequency distribution of variants M_1 sterility groups								
		Low	Medium	High	Low			Medium			High		
					negative variants	control group	positive variants	negative variants	control group	positive variants	negative variants	control group	Positive Variants.
M_3	Pusa Sawani (PS)	42.41	42.94	43.07	39.81	27.55	32.64	31.74	39.03	29.23	32.75	40.44	26.81
	Kilichundan (KC)	44.08	43.94	43.77	29.42	36.46	34.12	29.99	39.48	30.53	23.77	49.45	26.78
	Co-1	43.93	44.47	44.54	34.31	33.70	31.99	26.61	34.74	38.65	27.32	30.54	42.14
F_3M_3	PS x Co-1	41.69	42.37	43.10	56.25	34.69	9.06	43.70	39.20	17.10	39.37	36.37	24.26
	PS x KC	44.00	44.68	45.18	31.29	26.12	42.59	17.25	42.35	40.40	23.51	36.85	39.64
	Co-1 x PS	42.38	46.07	42.15	38.73	40.94	20.33	21.07	45.30	33.63	34.73	40.18	25.09
	KC x PS	45.52	45.62	44.49	12.66	40.90	46.44	22.22	19.84	57.94	19.08	40.88	40.04
	KC x Co-1	43.58	43.49	43.99	29.38	39.11	31.51	20.00	45.84	34.16	35.07	42.26	22.67
	Co-1 x KC	43.72	44.17	44.10	30.62	45.42	23.96	27.53	48.61	23.86	32.17	45.33	22.50

	F. value	CD value
Between treatments (T)	1.58	-
Between sterility groups (S)	1.88	-
T x S interaction	1.08	-

	F value	CD value
Between treatments (T)	0.01	-
Between sterility groups (S)	0.003	-
Between phenotypic classes (P)	6.56*	4.18
T x S interaction	0.008	-
T x P interaction	3.004*	9.66
S x P interaction	1.18	-
T x S x P interaction	0.59	-

* Significant at 5% level.

ficant difference.

The different genotypes showed variation for the mean number of days to flowering depending on M_1 sterility classes. In the low sterility class, the mean number of days ranged from 41.69 (PS x Co-1) to 45.52 (KC x PS). It was 42.94 (Pusa Sawani) to 46.07 (Co-1 x PS) in the medium class and 42.15 (Co-1 x PS) to 45.18 (PS x KC) in the high sterility class.

In Pusa Sawani, the mean value for the number of days to flowering ranged from 42.41 in low sterility class to 43.07 in high sterility group, where as in Kilichundan it was 43.77 in high sterility class to 44.08 in low sterility class. In Co-1, the trend was as in Pusa Sawani ie. 43.93 to 44.54 in low and high sterility classes respectively.

Among the various crosses, PS x Co-1 and PS x KC recorded the highest mean values of 43.10 and 45.18 in the high sterility class and the lowest mean values of 41.69 and 44.00 in low sterility class respectively. But the crosses, Co-1 x PS and KC x PS showed highest mean values of 46.07 and 45.62 in the medium class and the lowest of 42.15 and 44.49 in the high sterility class, respectively. The maximum mean value was observed in the high sterility group and the minimum in the medium sterility class in KC x Co-1. Co-1 x KC recorded highest value in the medium sterility class and the lowest in the low sterility class.

Considering the three sterility classes, the medium class recorded the highest mean value of 44.19. The low sterility class showed the lowest value of 43.48.

3.3. Number of leaves per plant

The mean number of leaves per plant, for the different treatments under the three M_1 sterility classes is given in table 13. Statistical analysis showed no significant difference among the genotypes, the three sterility classes and also in their interaction.

In the low sterility group, the mean value ranged from 11.56 in PS x KC to 13.27 in Co-1 x PS, where as in the medium sterility class the range was 11.94 in PS x Co-1 to 15.05 in KC x PS. In the high sterility group it was 10.88 in Kilichundan to 14.24 in KC x PS.

Among the three inbreds, Pusa Sawani had maximum mean value, in the medium sterility class (13.35), followed by high (12.66) and low sterility classes (11.73). In Kilichundan, the high sterility classes showed the minimum value(10.88), and the medium sterility class showed the

Table 13. Mean number of leaves per plant and frequency distribution of variants (Percentage) under different M_1 sterility groups in the third generation.

Treatments	Number of leaves/plant M_1 sterility groups			Frequency distribution of variants M_1 sterility groups								
				Low			Medium			High		
	Low	Medium	High	negative variants	control group	positive variants	negative variants	control group	positive variants	negative variants	control group	positive variants
Pusa Savani (PS)	11.73	13.35	12.66	16.68	56.36	26.96	5.95	62.20	31.85	12.65	55.45	31.90
Kilichundan (KC)	11.90	12.47	10.88	8.50	63.90	27.60	8.87	67.94	23.19	21.87	61.82	16.31
Co-1	13.18	13.02	12.02	7.16	61.99	30.88	7.11	58.23	34.66	13.22	54.00	32.78
PS x Co-1	11.96	11.94	11.13	10.60	55.38	34.02	14.07	58.48	27.45	14.91	60.21	24.88
PS x KC	11.56	13.76	13.45	21.25	65.42	13.33	14.57	58.63	26.80	7.15	60.42	32.43
Co-1 x PS	13.27	12.83	13.15	15.55	52.06	32.39	14.80	53.64	31.56	17.68	44.72	37.60
M_3 KC x PS	12.85	15.05	14.24	9.45	45.89	44.66	5.66	58.58	35.76	2.63	48.75	49.12
KC x Co-1	12.88	14.68	12.95	11.13	50.77	38.10	11.91	51.43	36.67	10.92	60.96	28.12
Co-1 x KC	12.47	13.12	13.27	11.80	47.74	40.46	11.74	49.02	39.24	10.91	38.77	50.32

	F value	CD value
Between treatments (T)	0.55	-
Between sterility groups (S)	3.31	-
T x S interaction	0.71	-

	F value	CD value
Between Treatments (T)	0.013	-
Between sterility groups (S)	0.11	-
Between phenotypic classes (P)	110.39*	5.18
T x S interaction	0.04	-
T x P interaction	1.31	-
S x P interaction	0.41	-
T x S X P interaction	0.35	-

* Significant at 5% level.

maximum (12.47). In Co-1, the highest value was recorded in low sterility class (13.18) followed by medium and high sterility classes.

Among the various crosses, PS x KC, KC x PS and KC x Co-1 recorded the maximum mean value in the medium sterility class and the minimumin the low sterility group. In the case of PS x Co-1 and Co-1 x PS the mean value was observed to be highest in the low sterility group, followed by the high and medium sterility classes. But in Co-1 x KC, high sterility group recorded the maximum mean value and the low sterility group the minimum.

Among the three sterility classes, highest mean value was shown by the medium sterility class (13.36) followed by high (12.64) and low (12.42) sterility classes.

3.4. Number of branches per plant

The mean data on the number of branches per plant for the different treatments under the three M_1 sterility classes are given in table 6. No significant difference was there among the treatments, the different sterility classes and in their interactions, as revealed by statistical analysis.

Sterility class dependent variation was noticed among the different genotypes in the mean number of branches. In the low sterility class, the mean value ranged from 0.23 in PS x KC to 1.13 in Co-1. The range was 0.56 in PS x KC to 1.20 in Pusa Sawani in the medium sterility class and 0.61 (KC x Co-1) to 1.58 (KC x PS) in the high sterility group.

In Pusa Sawani, the highest mean value was recorded in the medium sterility class (1.20) followed by high (0.72) and low (0.68) sterility classes. In Kilichundan, the mean value varied from 0.57 in low sterility class to 0.76 in high sterility class. But, in Co-1 low sterility class recorded the highest mean value (1.13) and the high sterility class recorded the minimum (0.87).

Among the various crosses, PS x Co-1 and KC x Co-1 recorded the highest mean values in the low sterility class. All the other crosses exhibited the highest mean value in the high sterility group. PS x Co-1, Co-1 x PS and Co-1 x KC had their lowest mean value in the medium sterility class. In PS x KC and KC x PS, the low sterility class represented the lowest mean value, but in KC x Co-1 the lowest value was noticed in high sterility class.

As regards the three inbreds in the low sterility class, Kilichundan had the lowest mean value and Co-1, the highest. When the lowest and highest values were in Kilichundan and Pusa Sawani, respectively, in the medium sterility class, they were in Pusa Sawani and Co-1 in the high sterility class.

Considering the three sterility classes, the high sterility class exhibited the highest mean value (0.91) and the low sterility class showed the lowest value (0.81).

3.5. <u>Length of fruit</u>

Table 14 represents the mean length of fruits for the different genotypes, under three M_1 sterility classes. Statistical analysis showed significant difference among the treatments and the different sterility classes. No significant difference was there in the treatment x sterility class interaction.

Depending upon the different sterility classes, the mean length of fruit for the different genotypes varied. Among all the genotypes in the low sterility group, the highest value was observed in Co-1 x KC (18.71 cm) and the lowest in Pusa Sawani (14.23 cm). When the mean value in the medium sterility group ranged from 14.14 cm in PS x Co-1

Table 14. Mean fruit length and frequency distribution of variants (percentage) under different M_1 sterility groups in the third generation.

	Treatments	Fruit length (cm) M_1 sterility groups			Frequency distribution of variants M_1 sterility groups								
					Low			Medium			High		
		Low	Medium	High	negative variants	control group	positive variants	negative variants	control group	positive variants	negative variants	control group	positive variants
M_3	Pusa Sawani (PS)	14.23	14.95	14.47	21.63	41.68	36.69	18.68	48.03	33.29	14.79	40.81	44.40
	Kilichundan (KC)	16.12	17.32	15.32	8.30	45.67	46.03	5.49	31.30	63.21	18.12	40.19	41.69
	Co-1	15.19	14.80	14.94	8.71	49.61	41.68	9.39	63.16	27.45	15.51	58.22	26.27
F_3M_3	PS x Co-1	15.28	14.14	14.60	8.80	49.62	41.58	18.58	46.87	34.55	13.09	54.93	31.98
	PS x KC	16.78	18.67	17.02	14.54	44.31	41.15	12.34	34.48	53.18	6.75	42.14	51.11
	Co-1 x PS	14.29	15.28	14.07	11.54	38.92	49.54	10.87	46.18	42.95	9.93	41.21	48.86
	KC x PS	17.76	18.77	16.51	13.40	30.96	55.64	9.25	24.38	66.37	17.48	31.94	50.58
	KC x Co-1	16.87	19.63	16.17	12.36	41.03	46.61	6.79	24.41	68.80	13.95	47.04	39.01
	Co-1 x KC	18.21	16.10	17.19	7.06	33.02	59.92	22.22	37.41	40.37	6.31	31.65	62.04

	F value	CD value
Between treatments (T)	30.52*	0.72
Between sterility groups (S)	4.29*	0.75
T x S interaction	1.39	-

	F value	CD value
Between Treatments (T)	0.01	-
Between sterility groups (S)	0.02	-
Between phenotypic classes (P)	121.46*	4.12
T x S interaction	0.03	-
T x P interaction	2.55*	9.51
S x P interaction	0.40	-
T x S x P interaction	1.03	-

* Significant at 5% level.

to 16.93 cm in KC x Co-1, the range was 14.07 cm (Co-1 x PS) to 17.19 cm (Co-1 x KC) in the high sterility group.

The mean fruit length in Pusa Savani was insignificantly higher in the medium sterility class (14.95 cm) compared to the low (14.23 cm) and high (14.47 cm) sterility classes. In Kilichundan also the highest mean value was recorded in the medium sterility class (17.32 cm) which was significantly higher to that of the low (16.12 cm) and high (15.32 cm) sterility classes. But, the mean value in the medium sterility class of Co-1 (14.80 cm) recorded an insignificant reduction from the other two classes.

The mean value in PS x Co-1 ranged from 14.14 cm in the medium sterility class to 15.28 cm in the low sterility group. A significant increase in the mean value was noticed in the medium sterility class of PS x KC(18.67 cm) over the low (16.78 cm) and high (17.02 cm) sterility classes. Similarly, in the crosses Co-1 x PS, KC x PS and KC x Co-1 the medium sterility classes recorded a significant increase over the other two classes in the mean length of fruits. In these three crosses, the minimum value was recorded in the high sterility group. Co-1 x KC recorded the lowest mean value in the medium sterility group (16.10 cm) which was significantly lower to the low (18.21 cm) and high (17.19 cm) sterility classes.

The inbred Kilichundan recorded significantly higher value in all the three sterility groups compared to Co-1 and Pusa Sawani. In the low and high sterility groups, Pusa Sawani recorded the least mean, whereas in medium sterility group, Co-1 showed the minimum value.

The crosses KC x PS and KC x Co-1 recorded significant increase in length of fruits in all the three sterility groups, compared to their parents. In the case of Co-1 x KC when the low and high sterility classes showed a significant increase over the parents, the medium class recorded a significant reduction, compared to Kilichundan. Medium and high sterility classes in PS x KC recorded a significant increase over the parents, whereas in PS x Co-1, the low sterility class showed significant increase.

Among the three sterility classes, the medium class gave the highest mean value (16.63 cm) followed by the low sterility group (16.08 cm) and the high sterility group (15.59 cm).

3.6. Weight of fruit

Table 15 represents the mean weight of fruits for the different genotypes under the M_1 sterility classes. There was significant difference among the treatments, the different sterility classes and in the treatment x sterility class interaction.

Table 15 Mean fruit weight and frequency distribution of variants (percentage) under different M_1 sterility groups in the third generation

	Treatments	Fruit weight (g)			Frequency distribution of variants								
		M_1 sterility groups			M_1 sterility groups								
					Low			Medium			High		
		Low	Medium	High	negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants	Negative variants	Control group	Positive variants
	Pusa Sawani (PS)	17.15	17.07	15.88	16.42	30.40	53.18	15.60	35.90	48.50	16.70	34.39	48.91
M_3	Kilichundan (KC)	20.63	20.57	18.22	13.62	24.17	62 21	13.55	22 25	64.20	9.66	34.76	55.58
	Co-1	16.90	16.74	16.68	20.06	28.94	51 00	15.61	23.71	60.68	20.21	31 25	48 54
	PS x Co-1	17 92	15.63	15 83	12 39	31.11	56.50	15.52	42.58	41.90	16.41	44.81	38.78
	PS x KC	19.49	22 94	22 82	10 54	33 05	56.41	11.86	27.71	60 43	7.59	31.99	60.42
$F\ M_3$	Co-1 x PS	16 59	18 75	17 53	11 01	23 22	65.17	7.94	18 52	73 54	8 32	25 53	60.15
	KC x PS	20 76	24.46	21 90	18.21	25.31	56.48	11.10	23.19	65.71	12.48	26 78	60.74
	KC x Co-1	21 89	21.97	20 32	9.82	41.21	48.97	10.43	26.56	63.01	12.96	32 41	54.63
	Co 1 x KC	22.81	20.64	22 71	8 56	29.58	61.86	16.68	28.63	54 69	12.53	29 96	57 51

	F value	CD value
Between treatments (T)	8.57*	0.72
Between sterility groups (S)	5.34*	0.74
T x S interaction	3.74*	2.22

	F value	CD value
Between treatments (T)	0.045	-
Between sterility groups (S)	0.003	-
Between phenotypic classes (P)	291.19*	3.04
T x S interaction	0.012	-
T x P interaction	2.57*	7.02
S x P interaction	1.09	-
T x S x P interaction	0 60	-

* Significant at 5% level

The different genotypes under the three M_1 sterility classes showed variation in the mean weight of fruit. In the low sterility class, the range of mean fruit weight was 16.59 g in Co-1 x PS to 22.81 g in Co-1 x KC. When the mean value in medium sterility group ranged from 15.63 g in PS x Co-1 to 24.46 g in KC x PS, it was 15.83g (PS x Co-1) to 22.82g (PS x KC) in the high sterility group.

In Pusa Sawani, Kilichundan and Co-1, the highest mean values of 17.15 g, 20.63 g and 16.90 g respectively were noticed in the low sterility class and the lowest mean values of 15.88 g, 18.22 g and 16.68 g were observed in the high sterility class. There was significant difference between the lowest and the highest values in Pusa Sawani and Kilichundan, but not in Co-1.

A significant increase in mean value was noted in PS x Co-1 under the low sterility group (17.92 g), compared to other two classes. In crosses Co-1 x PS, KC x PS and KC x Co-1, the medium sterility class showed significantly higher value compared to the low and high sterility classes. When PS x KC recorded the maximum mean value (22.94 g) in the medium sterility group, Co-1 x KC showed the highest value in the low sterility class. The lowest mean value was observed in the low sterility class in PS x KC(19.49 g), Co-1 x PS (16.59 g) and KC x Co-1 (21.89 g). In PS x Co-1 and Co-1 x KC, the medium sterility group recorded the least mean values. In crosses PS x KC, Co-1 x PS, KC x PS and KC x Co-1, the medium and high sterility classes recorded significantly higher mean values compared to their parents.

The medium sterility class showed the highest mean value (20.20 g) for the fruit weight, which was significantly higher than the low (19.35 g) and high (19.10 g) sterility classes.

3.7. Number of fruits per plant

The mean number of fruits per plant for the different genotypes under the three M_1 sterility classes is given in table 16. Statistical analysis showed significant difference among the treatments. The difference between the three sterility classes and treatment x sterility class interaction were not significant.

Depending on the M_1 sterility classes, the different treatments exhibited variation in the mean number of fruits. In the low sterility group, the mean number of fruits ranged from 4.54 (Co-1) to 6.45 (KC x PS). In the medium and high sterility groups, the ranges were 4.24 (PS x Co-1) to 7.05 (KC x Co-1) and 4.29 (Co-1) to 7.02 (KC x PS) respectively.

Table 10 Mean number of fruits per plant and frequency distribution of variants (percentage) under different M_1 sterility groups in the third generation

	Treatments	Number of fruits per plant — M_1 sterility groups: Low	Medium	High	Frequency distribution of variants — M_1 sterility groups — Low: negative variants	Control group	positive variants	Medium: negative variants	control group	positive variants	High: negative variants	control group	positive variants
M_3	Pusa Sawani (PS)	4.68	4.77	4.62	10.34	60.54	29.12	13.79	52.19	34.02	13.90	47.73	38.37
	Kilichundan (KC)	5.50	5.17	4.46	7.20	56.04	36.76	15.21	54.19	30.60	16.25	69.42	14.33
	Co-1	4.54	4.71	4.29	10.34	53.14	36.52	8.00	50.11	41.89	14.17	55.58	30.25
F_3	PS x Co-1	5.07	4.24	4.43	16.26	50.32	33.42	25.37	55.46	19.17	23.97	52.06	23.97
	PS x KC	5.71	6.62	6.89	7.09	62.71	30.20	7.62	50.81	41.57	7.10	45.82	47.08
	Co-1 x PS	4.67	4.88	5.00	14.79	54.81	30.10	11.26	52.59	36.15	17.80	57.06	25.14
	KC x PS	6.45	6.92	7.02	8.83	50.25	40.92	6.83	51.36	41.81	3.51	50.88	45.61
	KC x Co-1	5.53	7.05	6.29	8.85	51.34	39.81	15.60	31.43	52.97	18.03	46.45	35.52
	Co-1 x KC	5.67	5.68	5.71	14.30	42.66	43.04	13.13	45.21	41.66	10.75	43.38	45.87

	F value	CD value
Between treatments (T)	18.61*	0.58
Between sterility groups (S)	0.81	-
T x S interaction	1.08	-

	F value	CD value
Between treatments (T)	0.05	-
Between sterility groups (S)	0.002	-
Between phenotypic classes (P)	141.64*	4.07
T x S interaction	0.03	-
T x P interaction	1.92*	9.39
S x P interaction	0.58	-
T x S x P interaction	0.65	-

* Significant at 5% level

In Pusa Sawani, the maximum number of fruits was produced in the medium sterility class (4.77) followed by low (4.68) and high sterility classes (4.62). When the low sterility class recorded the highest mean value in Kilichundan (5.50), the medium sterility class recorded it in Co-1 (4.71). In both Kilichundan and Co-1, the lowest values were observed in the high sterility class. Among the three inbreds in the low and medium sterility groups, Kilichundan showed the highest mean value and Co-1, the lowest. But in the high sterility group, the maximum mean value was observed in Pusa Sawani and the minimum in Co-1.

When the mean number of fruits, ranged from 4.27 (medium sterility class) to 5.07 (high sterility class) in PS x Co-1, it ranged from 4.67 (low sterility class) to 5.00 (high sterility class) in the reciprocal cross, Co-1 x PS. In the crosses PS x KC, Co-1 x PS, KC x PS and Co-1 x KC, the high sterility group showed the highest mean value for the number of fruits and the low sterility group showed the lowest mean value.

The medium sterility class showed the highest mean value of 5.56 followed by the high (5.41) and the low (5.31) sterility classes . But the differences among them were not significant.

3.8. Yield per plant

Table 17 gives the mean yield of fruits per plant as affected by the three M_1 sterility classes. Statistical analysis showed significant difference among the genotypes. No significant difference was there among the three sterility classes and the main treatments x sterility class interaction.

With respect to the different M_1 sterility classes, the mean value varied in the different genotypes. The mean fruit yield ranged from 76.68 g in Co-1 to 133.65 g in KC x PS, in the low sterility group. In the medium sterility class, the range was from 66.37 g (PS x Co-1) to 178.25 g (KC x Co-1) and in the high sterility group, it was from 70.09 g (PS x Co-1) to 158.92 g (PS x KC).

In Pusa Sawani and Co-1, the maximum values of 81.65 g and 78.89 g respectively were observed in the medium sterility class and the minimum of 73.31 g and 71.44 g were seen in the high sterility group. In Kilichundan, the low sterility group showed the maximum mean value (113.37 g) followed by medium (106.33 g) and high (81.10 g) sterility classes. In the low sterility class, Kilichundan exhibited a significant increase in mean value over Pusa Sawani and Co-1, but

Table 17. Mean fruit yield per plant and frequency distribution of variants (Percentage) under different M_1 sterility groups in the third generation.

	Treatments	Fruit yield/plant (g) M_1 sterility groups			Frequency distribution of variants M_1 sterility groups								
		Low	Medium	High	Low			Medium			High		
					negative variants	control group	positive variants	negative variants	control group	positive variants	negative variants	control group	positive variants
M_3	Pusa Sawani (PS)	80.23	81.65	73.31	17.75	23.83	58.42	20.60	24.05	55.35	21.78	23.00	55.22
	Kilichundan (KC)	113.37	106.33	81.10	10.48	43.64	45.88	13.25	43.09	43.66	15.31	56.13	28.56
	Co-1	76.68	78.89	71.44	18.42	36.33	45.25	13.34	35.98	50.68	27.98	33.14	38.88
F_3M_3	PS x Co-1	91.22	66.37	70.09	30.03	38.32	31.65	41.61	41.80	16.59	40.12	34.03	25.85
	PS x KC	110.86	151.85	158.92	28.56	16.64	54.80	15.84	20.43	63.73	19.26	25.60	55.14
	Co-1 x PS	77.59	91.79	88.19	20.25	40.88	38.87	21.91	36.91	41.18	33.56	26.72	39.72
	KC x PS	113.65	169.36	150.41	13.16	26.92	59.92	16.42	23.97	59.61	10.75	28.77	60.48
	KC x Co-1	122.53	178.25	127.80	28.82	20.89	50.29	16.95	16.39	66.66	16.06	23.59	60.35
	Co-1 x KC	130.73	117.09	129.62	18.69	26.97	54.34	13.65	34.81	51.54	15.92	29.88	54.20

	F value	CD value
Between treatments (T)	10.80*	27.09
Between sterility groups (S)	2.67	-
T x S interaction	2.04	-

	F value	CD value
Between treatments (T)	0.017	-
Between sterility groups (S)	0.0005	-
Between phenotypic classes (P)	30.54*	6.09
T x S interaction	0.004	-
T x P interaction	2.36*	14.07
S x P interaction	0.112	-
T x S x P interaction	0.23	-

* Significant at 5% level.

in the medium sterility class, significant increase was there in Kilichundan, only when compared to Co-1. Kilichundan failed to exhibit any significant difference from Pusa Sawani and Co-1 in the high sterility group.

Among the various crosses, PS x Co-1 and Co-1 x KC had their maximum mean values in the low sterility group (91.22 g and 130.73 g respectively) and the minimum in the medium sterility group (66.37 g and 117.09 g respectively). In the crosses Co-1 x PS, KC x PS and KC x Co-1, the medium sterility group exhibited the maximum mean value, followed by high sterility group. The least values were recorded in the low sterility group. In PS x KC, the highest value (158.92 g) was recorded in the high sterility group and the lowest value (110.92 g) in the low sterility group. Among all the genotypes, the highest mean yield was recorded by KC x Co-1 in the medium sterility class. PS x KC, KC x Co-1 and KC x PS showed significantly higher yield compared to the parents in the medium and high sterility groups. When PS x Co-1 and Co-1 x PS failed to show any significant difference from their parents in all the three M_1 sterility classes, Co-1 x KC recorded a significant increase in mean yield over the parents in the high sterility groups.

Considering the mean values in the different sterility classes, the medium sterility class stood first with a mean value of 115.73 g, then came the high (105.65 g) and the low (104.09) sterility classes.

4. Phenotypic frequency distribution under different M_1 sterility groups

4.1. Plant height

The frequency distribution of plant height variants under different M_1 sterility groups for the different treatments are given in table 11. Statistical analysis showed significant difference among the three phenotypic classes. The data showed no significant variation in the frequency distribution among treatments, treatments x sterility group, treatment x phenotypic class, sterility group x phenotypic class and treatment x sterility group x phenotypic class interactions.

In the low sterility group, the frequency of negative variants ranged from 6.18% (KC x PS) to 21.38% (Co-1). PS x Co-1, Co-1 x PS, KC x PS and PS x KC had comparatively higher percentage of negative variants, when there were only a lower frequency in KC x Co-1 and Co-1 x KC. The maximum frequency of positive variants was noted in KC x PS (59.38%)

followed by PS x Co-1 (52.5%). A lower frequency was observed in Co-1 x PS (19.56%). More number of positive variants was created in crosses of KC x Co-1 also. The frequency of individual coming under the control group ranged from 28.75% in PS x Co-1 to 50.39% in PS, in the low sterility group. Here, all the treatments except Co-1 x PS had significantly higher frequency of positive variants compared to negative variants.

In the medium sterility group, maximum negative variants was observed in Co-1 (29.18%) and the minimum in KC x PS (3.78%). In general, a comparatively lower frequency of negative variants was observed in the medium sterility group. The frequency of positive variants ranged from 25.25% (Co-1) to 57.72% (PS x Co-1). Kc, KC x Co-1, PS x KC and KC x PS exhibited higher percentage of positive variants. In the control group, the frequency ranged from 28.69% in KC x Co-1 to 53.97% in PS. To the exclusion of Co-1, all the other treatments had significantly higher percentage of positive variants, compared to negative variants.

The frequency of negative variants in the high sterility class ranged from 3.54% in KC x PS to 32.22% in Co-1. Crosses of PS and Co-1 showed a comparatively higher percentage of negative variants, whereas Co-1 x KC, KC x Co-1 and PS x KC had only lower frequency of negative variants. The frequency of positive variants in the high sterility group ranged from 26.67%(Co-1) to 55.96% (PS x KC). Co-1 x KC, KC x PS and their reciprocals recorded comparatively higher percentage of positive variants. The maximum frequency of individuals included under the control group was noted in KC (56.14%) and the minimum in PS x KC (38.74%). All the treatments except Co-1 had significantly higher frequency of positive variants, compared to that of the negative variants in the high sterility group.

To have a critical analysis on the relationship between the three sterility classes in each phenotypic class, a test of proportion was done. The result of this test is given in table 18.

In the negative phenotypic class, significant difference was observed between the low and medium sterility groups, low and high sterility groups and the medium and high sterility groups. In the control group also, significant difference was there between the low and medium, low and high and medium and high sterility classes. In the frequency of positive phenotypic class, there was significant difference between low and medium sterility group and low and high sterility groups. But the difference between the medium and high sterility groups

Table 18. Test of proportions between the M_1 sterility groups within the different phenotypic classes

Phenotypic classes		M_1 sterility groups		
		Low (S_1)	Medium (S_2)	High (S_3)
Negative variants (P_1)	S_1		5.09*	2.95*
	S_2	9.39*		2.16*
	S_3	5.47*	3.96*	
Control group (P_2)	S_1		6.34*	2.67*
	S_2	3.02*		3.68*
	S_3	0.89	2.13*	
Positive variants (P_3)	S_1		2.99*	3.92*
	S_2	1.73		0.93
	S_3	3.29*	1.56	

(Diagonal in each block: above – Plant height; below – Number of days to flowering)

* Significant at 5% level.

was found to be insignificant.

4.2. Days to flowering

Table 12 represents the frequency distribution of the variants in the number of days taken to flowering under the three different M_1 sterility groups, for the different treatments. Statistical analysis showed significant difference among the three phenotypic classes and in the treatment x phenotypic class interaction. The treatments and the various other interactions analysed revealed no significant differences.

The low sterility group had maximum frequency of negative variants in PS x Co-1 (56.25%) followed by PS (39.81%). The minimum frequency of negative variants was noted in KC x PS (12.66%). The frequency of positive variants ranged from 9.06% in PS x Co-1 to 46.44% in KC x PS. PS x KC had a comparatively higher percentage of positive variants. All the other treatments exhibited an intermediary value for positive variants. In the control group, the frequency ranged from 26.12% in PS x KC to 45.42% in Co-1 x KC. Compared to the frequency of negative variants, a significantly higher percentage of positive variants was noticed in KC, PS x KC and KC x PS. But in PS, PS x Co-1, Co-1 x PS and Co-1 x KC the percentage frequency of positive variants was significantly lower than that of negative variants in the low sterility group.

In the medium sterility group, the frequency of negative variants ranged from 17.25% (PS x KC) to 43.70% (PS x Co-1). A comparatively lower frequency of negative variants was noticed in Co-1 x PS, KC x Co-1 and KC x PS. Maximum positive variants in the medium sterility group was noticed in KC x PS (57.94%) and the minimum in PS x Co-1 (17.10%). A comparable frequency of positive variants was observed in PS, Co-1 x PS, KC and Co-1 x KC. In the control group, the frequency ranged from 19.84% in KC x PS to 48.61% in Co-1 x KC. Co-1, Co-1 x PS, KC x Co-1, PS x KC and KC x PS had significantly higher value of positive variants, compared to negative variants.

In the high sterility group, the percentage of negative variants ranged from 19.08 (KC x PS) to 39.37 (PS x Co-1). PS, Co-1 x PS, Co-1 x KC and KC x Co-1 exhibited higher frequency of negative variants, compared to other treatments. The frequency of positive variants ranged from 22.50% in Co-1 x KC to 42.14% in Co-1. KC x Co-1 and PS x Co-1 had lower frequency of positive variants. The frequency of phenotypes included under the control group ranged from 30.54%(Co-1) to 49.45% (KC). A significant reduction in the frequency of positive variants was observed in PS, PS x Co-1, Co-1 x PS, Co-1 x KC and KC x Co-1 when compared to the frequency of negative variants. But Co-1, PS x KC and KC x PS showed a significant increase in the frequency of positive variants.

The result of test of proportion is given in table 18. In the negative phenotypic class, there exist a significant difference between the low and medium, low and high and medium and high sterility groups. In the control group, significant difference was noticed only between the low and medium, and the medium and high sterility groups. Significant difference in the frequency of positive variants was observed only between the low and high sterility groups.

4.3. Number of leaves per plant

The frequency distribution of the leaf number variants under the three M_1 sterility classes for the different treatments are given in table 13. There was significant difference between the three phenotypic classes. The treatments and the various interactions showed no significant difference.

In the low sterility group, the frequency of negative variants was in the order of 7.16% in Co-1 to 21.25% in PS x KC. Comparatively higher frequency of negative variants was noticed in PS and Co-1 x PS. But in KC and KC x PS, the frequency of negative variants was nearer to the minimum value. In the case of positive variants, the frequency was maximum in KC x PS (44.66%) followed by Co-1 x KC (40.46%).

The minimum value for positive variants was noticed in PS x KC (13.33%). In general, a higher percentage of positive variants was observed in the various crosses (except in PS x KC) compared to the treated inbred parents.

In the control group, PS x KC (65.42%) had the highest frequency followed by KC x Co-1. The minimum frequency was recorded in KC x PS (45.89%). All the treatments showed a significantly higher value for the frequency of positive variants compared to the negative variants, to the exclusion of PS x KC, where there was a significant reduction.

In the medium sterility class, the frequency of negative variants ranged from 5.66% (KC x PS) to 14.80% (Co-1 x PS). Comparatively higher frequency of negative variants was observed in PS x Co-1 and PS x KC. But, it was lower in PS, Co-1 and KC. The range of positive variants was 23.19% to 39.24% in KC and Co-1 x KC respectively. The frequency of positive variants created in PS, Co-1, Co-1 x PS, KC x Co-1 and KC x PS was comparatively higher. The frequency in the control group ranged from 49.02% in Co-1 x KC to 67.94% in KC. Significantly higher frequency of positive variants was observed in all the treatments, compared to the negative variants.

High sterility group showed maximum frequency of negative variants in KC (21.87%) and the minimum in KC x PS (2.63%). PS x Co-1, Co-1 and Co-1 x PS had comparatively higher frequency of negative variants. The frequency of positive variants ranged from 16.31% to 50.32% in KC and Co-1 x KC respectively. The frequency of positive variants were higher in Co-1, Co-1 x PS, PS x KC and KC x PS also. In the high sterility group, all the treatments, except KC, had significantly higher percentage of positive variants compared to negative variants. In the control group, the frequency ranged from 38.77% in Co-1 x KC to 61.82% in KC.

Table 19 represents the result of test of proportion. In the negative phenotypic class, there was significant difference between the low and medium, and the medium and high sterility classes. In the control group, significant difference was there between the low and medium and the low and high sterility groups, whereas between the medium and high sterility groups, there was no significant difference. In the positive phenotypic class, there was significant difference between the low and medium and the medium and high sterility classes. The difference between the low and high sterility classes was not significant.

Table 19. Test of proportions between the M_1 sterility groups within the different phenotypic classes

Phenotypic classes		M_1 sterility groups		
		Low (S_1)	Medium (S_2)	High (S_3)
Negative variants (P_1)	S_1		4.38*	1.38
	S_2	1.19	Number of leaves / Length of fruit	3.00*
	S_3	0.32	0.86	
Control group (P_2)	S_1		4.86*	5.16*
	S_2	6.46*	Number of leaves / Length of fruit	0.31
	S_3	2.69*	3.78*	
Positive variants (P_3)	S_1		5.05*	1.94
	S_2	5.04*	Number of leaves / Length of fruit	3.12*
	S_3	5.26*	0.22	

* Significant at 5% level

4.4. Length of fruits

The frequency distribution of fruit number variants, under the different M_1 sterility groups are presented in table 14. Statistical analysis revealed significant difference between the three phenotypic classes and in the treatment x phenotypic class interaction. But there was no significant different among the treatments and the other interactions.

In the low sterility group, the frequency of negative variants ranged from 7.06% in Co-1 x KC to 21.63% in PS. In Co-1 x KC and PS x Co-1 the percentage of negative variants were only negligible. In the case of positive variants, the frequency was maximum in Co-1 x KC (59.92%) followed by KC x PS, and minimum in PS (36.69%). The frequency in the control group ranged from 30.96% in KC x PS to 49.62% in PS x Co-1. Compared to the frequency of negative variants, positive variants were significantly higher in all the treatments, under the low sterility group.

The frequency of negative variants in the medium sterility group ranged from 5.49% to 22.22% in KC and Co-1 X KC respectively. The frequency for negative variants was nearer to the minimum value in Co-1, KC x Co-1 and KC x PS. In PS and PS x Co-1, a comparatively higher frequency of negative variants was noticed. The frequency of positive variants was maximum in KC x Co-1 (68.80%) and minimum in Co-1

(27.45%). Higher frequency of positive variants was observed in KC, PS x KC and KC x PS. But in PS and PS x Co-1 the percentage of positive variants was comparatively lower. The frequency in the control group ranged from 24.41% in KC x Co-1 to 63.16% in Co-1. All the treatments exhibited significant increase in the frequency of positive variants over the negative variants.

In the high sterility group, the frequency of negative variants ranged from 6.31% (Co-1 x KC) to 18.12%(KC). Lower frequency of negative variants was also noticed in Co-1 x PS and PS x KC. But KC x PS and Co-1 x PS recorded comparatively higher values of negative variants. The frequency of positive variants in the high sterility group was maximum in Co-1 x KC (62.04%) followed by PS x KC and KC x PS with the minimum in Co-1 (26.27%). In the control group, the frequency ranged from 31.65% (Co-1 x KC) to 58.22% (Co-1). All the treatments had significantly higher frequency of positive variants, compared to negative variants.

The result of test of proportion is given in table 19. In the negative phenotypic class there was no significant difference between the low and medium, the low and high and the medium and high sterility groups. But in the control group, there was significant difference among the three sterility groups. In the frequency of positive phenotypes significant variation was observed between the low and medium and the low and high sterility groups. But between the medium and high sterility groups, there was no significant difference.

4.5. Weight of fruits

Table 15 represents the frequency distribution of fruit weight variants under the different M_1 sterility classes for the different treatments. The data expressed significant variation among the three phenotypic classes and in the treatment x phenotypic class interaction. The treatments and the various other interactions were not significant.

In the low sterility group the range in frequency of negative variants was 8.56% (Co-1 x KC) to 20.06% (Co-1). KC x Co-1 and PS x KC recorded comparatively lower frequency of negative variants. But Ps and KC x PS produced higher number of negative variants. The frequency of positive variants ranged from 48.97% (KC x Co-1) to 65.17% (Co-1 x PS). When KC, Co-1 x KC, PS x KC, KC x PS and PS x Co-1 recorded higher percentage of positive variants, Co-1 x PS showed comparatively lower value. In the control group, the maximum frequency was observed in KC x Co-1 (41.21%) and the minimum in Co-1 x PS (23.22%). Compared to the frequency of negative variants, a significantly higher frequency of positive variants was noticed in all the treatments in the low sterility group.

The frequency of negative variants ranged from 7.94% (Co-1 x PS) to 16.68% (Co-1 x KC) in the medium sterility group. In PS, PS x Co-1 and Co-1, the frequency of negative variants was nearer to the maximum observed. Maximum frequency of positive variants was observed in Co-1 x PS (73.54%) followed by KC x PS (65.71%) and the minimum frequency in PS x Co-1 (41.90%). In general, a higher frequency of positive variants was observed in majority of the treatments in the medium sterility group, compared to the low sterility group. In the control group, the frequency ranged from 18.52% in Co-1 x PS to 42.58% in PS x Co-1. A significantly higher percentage of positive variants was seen in all the treatments compared to negative variants.

In the high sterility group, the frequency of negative variants ranged from 7.59% (PS x KC) to 20.21% (Co-1). PS and PS x Co-1 recorded comparatively higher frequency of negative variants. But co-1 x PS and KC recorded lower values for negative variants. The frequency of positive variants in the high sterility group ranged from 38.78% (PS x Co-1) to 66.15%(Co-1 x PS). In KC, Co-1 x KC, PS x KC and KC x PS, the frequency of positive variants was comparatively higher. In the control group, the maximum frequency was observed in PS x Co-1 (44.81%) and the minimum in Co-1 x PS (25.53%).

The test of proportion results are presented in table 20. In the negative phenotypic class, there was significant difference between the low and medium and the low and high sterility groups. But, the medium and high sterility groups did not exhibit any significant difference among themselves. In the control group, significant difference was there between the low and medium and the medium and high sterility groups. The positive phenotypic class showed significant difference between the low and medium and the low and high sterility classes.

4.6. <u>Number of fruits per plant</u>

The frequency distribution of fruit number variants under the three M_1 sterility classes, for the different treatments are depicted in the table 16. Statistical analysis showed significant variation among the three phenotypic classes and the treatment x phenotypic class interaction. But, there was no significant variation among the treatments and the various other interactions.

Table 20. Test of proportions between the M_1 sterility groups within the different phenotypic classes.

Phenotypic classes		M_1 sterility groups: Low (S_1)	Medium (S_2)	High (S_3)
Negative variants (P_1)	S_1		3.18*	2.24*
	S_2	0.64	Weight of fruit / Number of fruits	0.94
	S_3	1.89	2.54*	
Control group (P_2)	S_1		6.15*	1.22
	S_2	7.71*	Weight of fruit / Number of fruits	4.94*
	S_3	4.69*	3.03*	
Positive variants (P_3)	S_1		4.64*	5.25*
	S_2	3.72*	Weight of fruit / Number of fruits	0.61
	S_3	4.55*	0.83	

* Significant at 5% level.

In the low sterility group, the frequency of negative variants ranged from 7.09% in PS x KC to 16.26% in PS x Co-1. Comparatively higher frequency of negative variants was noted in Co-1 x PS and Co-1 x KC. But in KC, KC x Co-1 and KC x PS, the frequency of negative variants was less. Maximum positive variants in the low sterility group was noted in Co-1 x KC (43.04%) followed by KC x PS (40.92%) and the minimum in PS (29.12%). Comparable values for positive variants were observed in PS x Co-1, Co-1 x PS and PS x KC. The frequency of individuals coming under the control group ranged from 42.66% in Co-1 x KC to 62.71% in PS x KC. A significantly higher number of positive variants was created in all the treatments when compared to negative variants.

The maximum frequency of negative variants under medium sterility group was shown by PS x Co-1 (25.37%) and the minimum by KC x PS (6.83%). When Co-1 and PS x KC showed a lower value for negative variants, KC and KC x Co-1 recorded a comparatively higher value. The frequency of positive variants ranged from 19.17% in PS x Co-1 to 52.97% in KC x Co-1 in the medium sterility group. In the control group, the frequency ranged from 31.43% (KC x Co-1) to 55.46% (PS x Co-1). All the treatments, except PS x Co-1 had significantly higher frequency of positive variants, compared to negative variants.

In the high sterility group, the frequency of negative variants ranged from 3.51% (KC x PS) to 23.97% (PS x Co-1). Comparatively higher percentage of negative variants was observed in Co-1 x PS, KC and KC x Co-1. Maximum positive variants was recorded in PS x KC (47.08%). Co-1 x KC and KC x PS also had comparable frequency of positive variants. The minimum frequency of positive variants was shown by KC (14.33%). All the treatments except PS x Co-1 and KC, had significantly higher percentage of positive variants, compared to the frequency of negative variants.

The result of test of proportion is given in table 20. In the negative phenotypic class, no significant difference was there between the low and medium, and the low and high sterility groups. But, the medium and high sterility groups exhibited significant variation. In the control group significant variation was there between the low and medium, low and high and the medium and high sterility groups. In the positive phenotypic class, the low and medium and the low and high sterility groups exhibited significant difference.

4.7. Yield per plant

The frequency distribution of yield variants under the different M_1 sterility classes, for the different treatments are given in table 17. Statistical analysis revealed significant variation among the three phenotypic classes and in the treatment x phenotypic class interaction. The treatments and the various other interactions showed no significant differences.

In the low sterility group, the frequency of negative yield variants ranged from 10.48%(KC) to 30.03% (PS x Co-1). Comparable frequency of negative variants was recorded in KC x Co-1 and PS x KC. Maximum frequency of positive variants was noticed in KC x PS(59.92) and the minimum in PS x Co-1 (31.65%). PS, Co-1 x KC, KC x Co-1 and PS x KC also recorded comparatively higher frequency of positive variants. In the control group, the frequency ranged from 16.64% in PS x KC to 43.64% in KC. In general, significantly higher percentage of positive variants was observed, when compared to negative variants in the low sterility groups.

In the medium sterility group, PS x Co-1 (41.61%) recorded the maximum frequency of negative variants followed by Co-1 x PS (21.91%). The minimum frequency of negative variants was recorded in Co-1 (13.34%. KC, Co-1 x KC, KC x Co-1, PS x KC and KC x PS had comparatively lower frequency of negative variants. The frequency of positive variants ranged from 16.59% in PS x Co-1 to 66.66% in KC x Co-1. Higher frequency of positive variants was noted in PS, Co-1, Co-1 x KC, PS x KC and KC x PS. In the control group, the frequency ranged from 16.39% (KC x Co-1) to 43.09%(KC). In all the treatments except PS x Co-1, there was a significant increase in the percentage of positive variants, compared to negative variants.

In the high sterility group, the frequency of negative variants was maximum in PS x Co-1 (40.12%) and minimum in KC x PS (10.75%). A comparatively higher frequency of negative variants was noted in Co-1 and Co-1 x PS. But in KC, Co-1 x KC and KC x Co-1 the frequency of negative variants was comparatively lower. In the case of positive variants, the frequency ranged from 25.85% in PS x Co-1 to 60.48% in KC x PS. The frequency exhibited by PS, Co-1 x KC, KC x Co-1 and PS x KC was nearer to the maximum value of 60.48%. In the control group, the percentage value ranged from 23%(PS) to 56.13%(KC). The frequency of positive variants was significantly higher to that of negative variants.

The test of proportion result is presented in table 21. In the negative phenotypic class, there was significant difference between the low and medium and the medium and high sterility classes. But, there was no significant difference between the low and high sterility groups. In the control group, significant variation was exhibited by the low

Table 21. Test of proportions between the M_1 sterility groups within the different phenotypic classes.

Fruit yield per plant

Phenotypic classes		M_1 sterility groups	
		Medium (S_2)	High (S_3)
Negative variants (P_1)	Low (S_1)	4.88*	0.56
	Medium (S_2)		4.32*
Control group (P_2)	S_1	4.53*	3.50*
	S_2		1.03
Positive variants (P_3)	S_1	4.71*	4.66*
	S_2		0.05

* Significant at 5% level.

and medium and the low and high sterility groups. The medium and high sterility groups showed no significant difference. In the positive phenotypic class, same trend as seen in the control group was observed.

5. Mean character expressions in the fourth generation

5.1. Plant height

The mean plant height in the fourth generation for the different genotypes under control and when exposed to 30 kR gamma rays are given in table 22. Statistical analysis showed significant variation among the treatments.

The mean plant height in the control population of the inbreds ranged from 54.29 cm in KC to 73.92 cm in Co-1. PS and KC showed a significant reduction in plant height compared to Co-1.

In the M_4 generation of inbreds, the range in mean value was 51.79 cm in Co-1 to 73.52 cm in KC, where KC showed a significant increase in plant height over Co-1 and PS. When KC recorded a significant increase in plant height, due to the effect of gamma rays, Co-1 recorded a significant reduction. No significant difference was exhibited by PS in the irradiated and control populations.

The mean plant height in the F_4 population showed a wider range of 51.48 cm in PS x KC to 87.42 cm in Co-1 x KC.

Table 22. Mean plant height and frequency distribution of variants (percentage) in the fourth generation.

Treatments		Plant height (cm)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	58.34	-	100	-
	Kilichundan (KC)	54.29	-	100	-
	Co-1	73.92	-	100	-
M_4	PS	56.50	6.41	58.41	35.18
	KC	73.52	0	20.97	79.03
	Co-1	51.79	5.19	75.24	19.57
F_4	PS x Co-1	60.79	0.005	52.83	47.17
	PS x KC	51.48	13.05	67.67	19.28
	KC x PS	61.45	2.89	48.76	48.35
	KC x Co-1	86.50	0	9.98	90.02
	Co-1 x KC	87.42	0	12.72	87.28
F_4M_4	PS x Co-1	60.20	0.72	56.71	42.57
	PS x KC	52.35	11.87	62.04	26.09
	Co-1 x PS	83.96	0.72	25.09	74.19
	KC x PS	64.90	6.12	38.82	55.06
	KC x Co-1	87.70	0	11.85	88.15
	Co-1 x KC	77.31	0	14.0	86.0

F value 8.62*

CD value 13.66

	F value	CD value
Between treatments (T)	0.40	-
Between phenotypic classes (P)	328.46*	3.52
T x P interaction	13.13*	13.16

* Significant at 5% level

In F_4M_4, the mean plant height ranged from 52.35 cm in PS x KC to 87.70 cm in KC x Co-1. Co-1 x PS (83.96 cm) and KC x Co-1 recorded mean values which were significantly higher to that of the M_4 generation of the parents.

Due to the effect of gamma rays an insgnificant increase in plant height was observed in all the crosses except Co-1 x KC, where a significant reduction was noticed.

5.2. Days to flowering

Table 23 represents the mean number of days to flowering, for the different treatments in the fourth generation. Statistical analysis showed significant difference in the mean number of days to flowering among the different treatments.

In the control population of the inbreds, the mean value ranged from 40.86 to 42.23 in Co-1 and KC respectively. In the M_4 population, the range was 37.91 in KC to 41.21 in Co-1. In M_4, KC took significantly lesser number of days to flower, when compared to Co-1 and PS, also it showed a significant reduction in the mean value, due to the effect of gamma rays.

In the F_4 population, the mean number of days to flowering ranged from 38.51 in PS x Co-1 to 42.81 in PS x KC. PS x Co-1 and KC x Co-1 recorded significantly lower mean values compared to the respective parents.

Table 23. Mean number of days taken to flowering and frequency distribution of variants (percentage) in the fourth generation.

	Treatments	Number of days to flowering	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	40.93	-	100	-
	Kilichundan (KC)	42.23	-	100	-
	Co-1	40.86	-	100	-
M_4	PS	40.24	60.92	22.53	16.55
	KC	37.91	85.35	11.25	3.40
	Co-1	41.21	56.65	28.74	14.61
F_4	PS x Co-1	38.51	80.69	10.33	8.98
	PS x KC	42.81	39.70	29.45	30.85
	KC x PS	42.72	36.79	29.69	33.52
	KC x Co-1	38.63	88.54	6.78	4.68
	Co-1 x KC	40.12	71.50	21.02	7.48
F_4M_4	PS x Co-1	39.57	71.30	22.07	6.63
	PS x KC	44.29	15.34	36.58	48.08
	Co-1 x PS	39.52	68.72	22.50	8.78
	KC x PS	43.98	17.60	41.09	41.31
	KC x Co-1	39.36	81.34	12.22	6.44
	Co-1 x KC	38.14	85.86	12.14	2.00
F value	-	13.05*		F value	CD value
CD value	-	1.51	Between treatments (T)	0.17	-
			Between phenotypic Classes (P)	203.45*	3.24
			T x P interaction	12.05*	12.13

* Significant at 5% level.

In the F_4M_4 generation, the mean values ranged from 38.14 to 44.29 in Co-1 x KC and PS x KC respectively. Crosses involving PS and KC exhibited significantly higher mean values for the number of days to flowering, when compared to the M_4 generation of the parents. Co-1 x KC registered a significantly lower mean value (38.14). Compared to the F_4 generation, all the other crosses exhibited insignificant increase in the mean number of days to flowering, due to the effect of gamma rays.

5.3. Number of leaves per plant

Table 24 shows the mean number of leaves per plant for the different treatments in the fourth generation. Significant difference among the treatments for the mean number of leaves was noticed.

In the control population of the inbreds, the mean number of leaves ranged from 11.29 in PS to 14.92 in KC. A significant increase in mean value was recorded by KC over PS and Co-1.

In the M_4 generation, the range for the mean number of leaves was 11.39 in Co-1 to 13.70 in KC. Co-1 recorded a significantly lower mean value compared to KC, but no significant difference was there compared to PS. When KC and Co-1 produced insignificantly lesser number of leaves in the

Table 24. Mean number of leaves per plant and frequency distribution of variants (percentage) in the fourth generation.

	Treatments	Number of leaves / plant	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	11.29	-	100	-
	Kilichundan (KC)	14.92	-	100	-
	Co-1	12.15	-	100	-
M_4	PS	13.36	4.63	43.13	52.24
	KC	13.70	4.40	48.73	46.87
	Co-1	11.39	24.70	52.85	22.45
F_4	PS x Co-1	12.22	11.74	58.02	30.24
	PS x KC	12.57	7.28	55.34	37.38
	KC x PS	16.09	1.08	30.39	68.53
	KC x Co-1	14.52	6.64	33.79	59.57
	Co-1 x KC	13.96	4.00	63.61	32.39
F_4M_4	PS x Co-1	11.91	18.27	58.40	23.33
	PS x KC	12.48	8.44	47.53	44.03
	Co-1 x PS	16.49	6.31	23.66	70.03
	KC x PS	16.44	2.42	18.65	78.93
	KC x Co-1	14.87	3.14	31.89	64.97
	Co-1 x KC	16.02	0.67	26.67	72.67

F value 6.26*

CD value 2.15

	F value	CD value
Between treatments (T)	0.19	-
Between phenotypic Classes (P)	182.22*	3.56
T x P interaction	6.21*	13.34

* Significant at 5% level.

gamma ray irradiated population, PS recorded insignificantly higher number of leaves.

The mean numoer of leaves in the F_4 generation ranged from 12.22 in PS x Co-1 to 16.09 in KC x PS. The crosses PS x Co-1 (12.22) and KC x PS (16.09) exhibited mean values which are insignificantly higher than that of the respective parents. KC x Co-1 and its reciprocal crosses recorded insignificantly lower mean number of leaves compared to KC and higher mean values compared to Co-1.

In F_4M_4, the mean number of leaves ranged from 11.91 in PS x Co-1 to 16.49 in Co-1 x PS. A significant increase in the mean values was noticed in Co-1 x PS, KC x PS and Co-1 x KC when compared to their parents, where as in KC x Co-1. Only an insignificant increase was noticed. Gamma ray induced insignificant increase in the mean number of leaves was noticed in crosses KC x PS, KC x Co-1 and Co-1 x KC. But in PS x Co-1 and PS x KC, an insignificant decrease in the mean numoer of leaves was recorded.

5.4. Number of branches per plant

The mean values for the number of branches per plant under the different treatments are given in table 25. Statistical analysis showed significant difference among the treatments for the mean number of branches.

Table 25. Mean number of branches per plant in the fourth generation.

Treatments		Number of branches/ plant
	Pusa Sawani (PS)	0.47
Control	Kilichundan (KC)	2.25
	Co-1	0.45
	PS	1.18
M_4	KC	1.01
	Co-1	0.91
	PS x Co-1	0.54
	PS x KC	0.43
F_4	KC x PS	0.58
	KC x Co-1	1.40
	Co-1 x KC	0.88
	PS x Co-1	0.63
	PS x KC	0.70
F_4M_4	Co-1 x PS	1.47
	KC x PS	0.45
	KC x Co-1	1.10
	Co-1 x KC	2.48

F value 9.56*

CD value 0.59

* Significant at 5% level.

The mean value for the number of branches ranged from 0.45 (Co-1) to 2.25 (KC), in the control population of the inbreds. KC produced significantly higher number of branches, when compared to PS and Co-1. In the M_4 population, the mean number of branches ranged from 0.91 to 1.18 in Co-1 and PS respectively. The populations in M_4 did not exhibit any significant difference among themselves. PS recorded a significant increase in the mean number of branches, due to the effect of gamma rays. KC recorded a significant reduction where as Co-1 showed no significant difference.

In F_4 generation, the range of the mean number of branches was 0.43 in PS x KC to 1.40 in KC x Co-1. All the crosses involving KC registered a significant reduction in the mean number of branches compared to KC.

The mean number of branches in F_4M_4 ranged from 0.45 (KC x PS) to 2.48 (Co-1 x KC). Co-1 x KC produced significantly higher number of branches compared to the parents. KC x PS recorded a mean value of 0.45, which was significantly lower to that of PS, but not significantly different from KC. All the other crosses exhibited no significant difference in the mean number of branches, when compared to their parents.

Gamma ray induced significant difference in the mean number of branches was absent in all the crosses, except in Co-1 x KC where a significant increase in the mean value was noticed.

5.5. <u>Length of fruits</u>

The mean length of fruits for the different treatments in the fourth generation is given in table 26. Significant difference was there among the treatments in the mean length of fruits.

In the control population of the inbreds, the mean length of fruit ranged from 13.99 cm to 19.41 cm in Co-1 and KC respectively. The mean length of fruits in Co-1 was significantly lower than that of KC and PS.

The range of length of fruit was 16.31 cm in PS to 17.38 cm in KC in the M_4 generation. KC exhibited an insignificant increase in the length of fruit over PS and Co-1. Compared to the control population of the inbreds, the irradiated population exhibited a significant increase in fruit length in Co-1 and a significant reduction in KC. PS showed no significant difference between the control and exposed population in fruit length.

The mean length of fruits ranged from 14.98 cm in Co-1 x KC to 17.11 cm in KC x PS in the F_4 generation.

Table 26. Mean fruit length and frequency distribution of variants (percentage) in the fourth generation.

Treatments		Fruit length (cm)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	15.61	-	100	-
	Kilichundan (KC)	19.41	-	100	-
	Co-1	13.99	-	100	-
M_4	PS	16.31	9.07	32.96	57.97
	KC	17.38	5.42	25.63	68.95
	Co-1	17.22	1.38	21.71	76.91
F_4	PS x Co-1	16.13	5.38	39.72	54.90
	PS x KC	16.70	1.93	36.18	61.89
	KC x PS	17.11	6.60	28.51	64.89
	KC x Co-1	16.13	7.00	42.84	50.16
	Co-1 x KC	14.98	17.63	49.12	33.25
F_4M_4	PS x Co-1	16.25	11.80	38.25	49.95
	PS x KC	16.99	8.24	23.99	67.78
	Co-1 x PS	18.18	3.91	19.10	76.99
	KC x PS	16.67	9.08	16.23	74.69
	KC x Co-1	17.65	0.03	32.84	67.13
	Co-1 x KC	19.17	0	3.45	96.55

F value 7.83*

CD value 1.46

	F value	CD value
Between treatments (T)	0.44	-
Between phenotypic classes (P)	399.76*	2.98
T x P interaction	7.35*	11.15

* Significant at 5% level.

Compared to KC all the crosses involving it registered significantly lower mean values for fruit length. Among all the crosses of Co-1, PS x Co-1 and KC x Co-1 recorded significantly higher mean fruit length compared to Co-1.

The maximum mean fruit length in F_4M_4 was shown by Co-1 x KC (19.17 cm) and the minimum by PS x Co-1 (16.25 cm). Co-1 x KC had significantly longer fruits, when compared to the M_4 generation of the parents. When Co-1 x PS (18.18 cm) recorded a mean value which is insignificantly higher to that of the irradiated parents, its reciprocal cross PS x Co-1 showed an insignificant reduction in fruit length from the irradiated parents. Crosses involving KC and PS recorded no significant difference in fruit length in the M_4 generation of the parents.

Due to effect of gamma rays, a significant increase in fruit length was noticed in Co-1 x KC and KC x Co-1, while in crosses PS x Co-1 and PS x KC the observed increase in mean value was insignificant.

5.6. <u>Weight of fruit</u>

Table 27 gives the mean weight of fruit for the different treatments. Statistical analysis revealed significant difference among the treatments for mean weight of fruit.

Among the inbreds, KC recorded the highest mean value (21.49 g) for the weight of fruit and PS recorded the minimum mean value (15.57 g). Both PS and Co-1 showed significantly lower mean values compared to KC.

The mean weight of fruits in M_4 generation ranged from 17.24 g in PS to 19.27 g in KC. KC recorded an insignificant increase in the mean weight of fruit over PS and Co-1. Gamma rays did not create any significant difference in the three inbreds for weight of fruits, though an insignificant increase in mean values was noticed in PS and Co-1.

The mean weight of fruit in F_4 population ranged from 16.73 g in Co-1 x KC to 21.74 g in KC x PS. Among all the crosses involving PS, KC x PS recorded significantly higher mean fruit weight compared to PS whereas PS x Co-1 and PS x KC showed only an insignificant increase. When KC x Co-1 recorded a significant increase in mean value over Co-1, Co-1 x KC recorded only an insignificant increase.

In the F_4M_4, the mean fruit weight ranged from 16.39 g (PS x Co-1) to 24.13 g (Co-1 x KC). PS x Co-1 recorded a mean value which was insignificantly lower than that of the M_4 generation of its parents. Both PS x KC and its reciprocal cross, KC x PS showed significantly higher fruit weight when compared to irradiated PS but with regards to treated KC,

Table 27. Mean fruit weight and frequency distribution of variants (percentage) in the fourth generation.

Treatments		Fruit weight (g)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	15.57	-	100	-
	Kilichundan (KC)	21.49	-	100	-
	Co-1	16.38	-	100	-
M_4	PS	17.24	34.13	24.00	41.87
	KC	19.27	26.32	19.78	53.90
	Co-1	18.01	13.03	21.95	65.02
F_4	PS x Co-1	17.43	25.30	27.31	47.39
	PS x KC	17.54	20.69	37.41	41.90
	KC x PS	21.74	6.90	20.75	72.35
	KC x Co-1	18.87	15.03	30.95	54.02
	Co-1 x KC	16.73	35.32	24.65	40.04
F_4M_4	PS x Co-1	16.39	33.03	23.14	43.83
	PS x KC	21.29	7.50	22.35	70.15
	Co-1 x PS	20.69	10.33	15.90	73.77
	KC x PS	21.28	2.68	15.71	81.61
	KC x Co-1	20.15	7.97	20.16	71.87
	Co-1 x KC	24.13	0	7.67	92.33

			F value	CD value
F value	10.44*	Between treatments (T)	0.35	-
CD value	2.25	Between phenotypic classes (P)	198.83*	31.19
		T x P interaction	7.24*	11.93

* Significant at 5% level.

they showed only an insignificant increase. The mean value recorded by Co-1 x KC was significantly higher to the exposed parents.

PS x KC and Co-1 x KC registered significant increase in fruit weight due to the effect of gamma rays, whereas KC x Co-1,KC x PS and PS x Co-1 showed no significant difference.

5.7. Number of fruits per plant

The mean number of fruits produced per plant in the fourth generation by the different treatments is given in table 28. Statistical analysis showed significant difference among the different treatments.

The mean number of fruits produced by the inbreds was in the order of 4.56 in Co-1 to 10.64 in KC. KC exhibited a significant increase in the mean value over PS and Co-1.

The mean number of fruits in M_4 generation ranged from 4.74 in Co-1 to 7.96 in KC. Here also, KC was superior to PS and Co-1 with regard to the number of fruits. When PS x Co-1 recorded an insignificant increase in the mean value, KC showed a significant reduction.

Table 28. Mean number of fruits per plant and frequency distribution of variants (percentage) in the fourth generation.

	Treatments	Number of fruits/ plant	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Con-trol	Pusa Sawani (PS)	4.65	-	100	-
	Kilichundan (KC)	10.64	-	100	-
	Co-1	4.56	-	100	-
M_4	PS	4.94	27.59	48.71	23.70
	KC	7.96	4.40	35.59	60.01
	Co-1	4.74	19.58	56.61	23.81
F_4	PS x Co-1	5.34	9.81	64.12	26.07
	PS x KC	5.55	23.25	59.48	17.27
	KC x PS	6.84	8.41	47.77	43.82
	KC x Co-1	6.36	3.15	60.30	36.55
	Co-1 x KC	6.73	3.98	51.61	44.41
F_4M_4	PS x Co-1	5.37	9.42	70.24	20.34
	PS x KC	5.18	9.27	53.01	37.72
	Co-1 x PS	8.47	4.94	35.30	59.76
	KC x PS	5.07	6.66	62.88	30.46
	KC x Co-1	6.74	6.58	42.64	50.78
	Co-1 x KC	7.58	2.00	38.00	60.00

F value 12.39*
CD value 1.41

	F value	CD value
Between treatments (T)	0.12	-
Between phenotypic classes (P)	163.18*	3.37
T x P interaction	4.68*	12.62

* Significant at 5% level.

In the F_4 generation, the range of the mean number of fruits was 5.34 in PS x Co-1 to 6.84 in KC x PS. When compared to KC, all the crosses involving it produced significantly lesser number of fruits. Both Co-1 x KC (6.73) and K^C x Co-1 (6.36) recorded mean values which were significantly higher than that of Co-1. All the crosses of PS except KC x PS showed no significant difference in the mean number of fruits compared to PS.

The mean number of fruits ranged from 5.07 (KC x PS) to 8.47 (Co-1 x PS) in the F_4M_4 generation. Co-1 x PS registered a significantly higher mean value, with respect to the M_4 population of the parents, whereas PS x Co-1 showed only an insignificant increase. In crosses involving PS and KC the mean values observed were significantly lower than KC, but insignificantly higher than PS. But in KC x Co-1 and Co-1 x KC, the mean value was significantly higher to Co-1, but insignificantly lower to KC.

Gamma ray was effective in creating an insignificant increase in fruit number in crosses PS x Co-1, KC x Co-1 and Co-1 x KC. But in KC x PS the mean value decreased due to the effect of gamma rays whereas no significant change was observed in PS x KC.

5.8. Yield per plant

The mean yield per plant for the different treatments in the fourth generation is given in table 29. There was significant difference in the mean yield among the different treatments. The mean yield per plant ranged from 72.30 g to 228.80 g in PS and KC respectively. KC recorded a significant increase in mean yield over PS and Co-1.

In M_4, the mean yield ranged from 84.83 g in PS to 153.47 g in KC. Here also, KC was significantly superior to PS and Co-1. When KC recorded a significant reduction in the mean yield due to the effect of gamma rays, PS and Co-1 showed an insignificant increase.

In the F_4 population, the range was 93.18 g in PS x Co-1 to 148.68 g in KC x PS. A significant reduction in the mean yield was noticed in all the crosses of KC, when compared to KC. In PS x Co-1, an insignificant increase in the yield was recorded over the parents.

In the F_4M_4, a range of 87.86 g in PS x Co-1 to 182.94 g in Co-1 x KC was observed. Co-1 x PS recorded a significantly higher yield over the M_4 generation of parents. PS x Co-1 failed to show any significant difference from the parents. PS x KC and its reciprocal cross exhibited

Table 29. Mean fruit yield per plant and the frequency distribution of variants (percentage) in the fourth generation.

Treatments		Fruit yield/ plant (g)	Frequency distribution of variants		
			Negative variants	Control group	Positive variants
Control	Pusa Sawani (PS)	72.30	-	100	-
	Kilichundan (KC)	228.80	-	100	-
	Co-1	74.73	-	100	-
M_4	PS	84.83	23.40	36.23	40.37
	KC	153.47	3.42	19.00	77.58
	Co-1	85.38	6.19	45.15	48.66
F_4	PS x Co-1	93.18	10.10	36.04	53.86
	PS x KC	97.07	24.43	49.21	26.36
	KC x PS	148.68	0	8.45	91.55
	KC x Co-1	119.55	0.71	19.22	80.07
	Co-1 x KC	112.47	2.00	30.12	67.88
F_4M_4	PS x Co-1	87.86	9.42	58.26	32.32
	PS x KC	110.19	8.48	24.41	67.12
	Co-1 x PS	177.17	5.72	10.27	89.02
	KC x PS	107.71	7.18	25.19	67.63
	KC x Co-1	136.25	4.76	9.18	86.06
	Co-1 x KC	182.94	0.67	1.33	98.00

			F value	CD value
F value	11.33*	Between treatments (T)	0.31	-
CD value	38.93	Between phenotypic classes (P)	305.68*	3.50
		T x P interaction	10.75*	13.09

* Significant at 5% level.

significant reduction in the mean value from irradiated KC, but an insignificant increase over exposed PS. KC x Co-1 recorded a mean value of 136.25 g which was significantly higher than that of treated Co-1, but insignificantly lower than that of irradiated KC. But Co-1 x KC showed a significant increase over exposed Co-1 and an insignificant increase over treated KC.

When KC x PS registered a significant reduction in the mean yield due to the effect of gamma rays, Co-1 x KC recorded a significant increase. All the other crosses failed to exhibit any significant variation due to gamma irradiation.

6. Phenotypic Frequency distribution of variants in the fourth generation

6.1. Plant height

The frequency distribution of plant height variants (in percentage) for the different treatments are presented in table 22. Statistical analysis showed no significant difference among the treatments. But there was significant variation among the three phenotypic classes and the treatment x phenotypic class interaction.

The frequency of negative variants in the F_4 generation ranged from 0% in Co-1 x KC and KC x Co-1 to 13.05% in PS x KC. The frequency ranged from 0% (KC) to 6.41% (PS) in the M_4 generation. In the F_4M_4, maximum negative variants was noticed in PS x KC (11.87%) and the minimum in Co-1 x KC and KC x Co-1 (0%). PS x Co-1 and Co-1 x PS in F_4M_4 showed comparatively lower percentage of negative variants. The frequency of negative variants increased in PS x Co-1 and KC x PS due to the effect of gamma rays.

The frequency of positive variants in the F_4 was maximum in KC x Co-1 (90.02%) followed by Co-1 x KC (87.28%). The frequency was minimum in PS x KC (19.28%). Among the M_4 population, the frequency or positive variants was maximum in KC (79.03%) and minimum in Co-1 (19.57%). In F_4M_4, the percentage of positive variants ranged from 26.09 in PS x KC to 88.15 in KC x Co-1. F_4M_4 of Co-1 x PS and Co-1 x KC had comparatively higher frequency of positive variants. The frequency of positive variants increased in PS x KC and KC x PS due to the effect of gamma rays. But the trend was reverse in PS x Co-1, Co-1 x KC and KC x Co-1.

In the F_4 generation, the frequency of individuals coming under the control group ranged from 9.98% in KC x Co-1 to 67.67% in PS x KC. In M_4, the range was 20.97% (KC) to 75.24% (Co-1). In F_4M_4, PS x KC (62.04%) had the maximum frequency in the control group and KC x Co-1 (11.85%) the minimum.

Compared to the frequency of negative variants, a significant increase in the positive variants was observed in all the treatments in the fourth generation.

6.2. Days to flowering

The frequency distribution of variants for number of days to flowering in the different treatments are given in table 23. Statistical analysis showed no significant difference among the treatments. But the variation among the three phenotypic classes and the interaction was found to be significant.

The frequency of negative variants in F_4 ranged from 36.79% in KC x PS to 88.54% in KC x Co-1. A comparatively higher range of frequencies (56.65% (Co-1) to 75.35% (KC)) was noted in M_4. In F_4M_4 maximum frequency of negative variants was observed in Co-1 x KC (85.86%) followed by KC x Co-1 (81.34%) and the minimum in PS x KC (15.34%). Frequency of negative variants shown by PS x Co-1 and Co-1 x PS in F_4M_4 was comparatively higher. Due to the effect of gamma rays the frequency of negative variants decreased in PS x Co-1, KC x Co-1, PS x KC and KC x PS.

The frequency of positive variants in F_4 was maximum in KC x PS (33.52%) and minimum in KC x Co-1 (4.68%). PS x Co-1 and Co-1 x KC had lower frequency of positive variants. In M_4, the range of positive variants was 3.40% (KC) to 16.55% (PS). The frequency of positive variants was maximum in PS x KC (48.08%), followed by KC x PS (41.31%) and minimum in Co-1 x KC (2%). PS x Co-1 [illegible] and KC x Co-1 also had comparatively lower frequency of positive variants. Gamma rays were effective in increasing the frequency of positive variants in KC x Co-1, PS x KC and KC x PS. But in PS x Co-1 and Co-1 x KC, the percentage of positive variants decreased due to the effect of gamma rays.

The frequency of phenotypes coming under the control group ranged from 6.78% (KC x Co-1) to 29.69% (KC x PS) in F_4. In M_4 the frequency was maximum in Co-1 (28.74%) and minimum in KC (11.25%). In the case of F_4M_4, frequency coming under the control group ranged from 12.14% (Co-1 x KC) to 41.09% (KC x PS).

In all the treatments, there was a significant reduction in the frequency of positive variants when compared to negative variants.

6.3. Number of leaves per plant

Table 24 gives the frequency distribution of leaf number variants in the fourth generation for the different treatments. There was no significant difference among the treatments. But, there was significant variation among the three phenotypic classes and the treatment x phenotypic class interaction.

In the F_4 generation, the frequency of negative variants ranged from 1.08% (KC x PS) to 11.74% (PS x Co-1). KC x Co-1 and PS x KC had comparatively higher percentage of negative variants. The frequency of negative variants in M_4 was maximum in Co-1 (24.70%) and minimum in KC (4.40%). In F_4M_4, the negative variants ranged from 0.67% in Co-1 x KC to 18.27% in PS x Co-1. Co-1 x PS, KC x Co-1 and KC x Co-1 and KC x PS showed comparatively lower percentage of negative variants. Due to the effect of gamma rays, the frequency of negative variants increasedin PS x Co-1 PS x KC and KC x PS.

The frequency of positive variants ranged from 30.24% (PS x Co-1) to 68.53% (KC x PS) in F_4. In M_4 the frequency of positive variants ranged from 22.45% in Co-1 to 52.24% in PS. In F_4M_4, KC x PS had the maximum frequency of 78.93% and PS x Co-1 had the minimum of 23.33%. Co-1 x PS, Co-1 x KC and KC x Co-1 showed comparatively higher frequency of positive variants. In Co-1 x KC, KC x Co-1, PS x KC and KC x PS, a gamma ray induced increase in the frequency of positive variants was observed. But in PS x Co-1, there was a reduction in the frequency of positive variants, due to the effect of gamma rays.

In the control group, the frequency ranged from 30.39% (KC x PS) to 63.61% (Co-1 x KC) in F_4. The frequency was maximum in Co-1 (52.85%) and minimum in PS (43.13%) in the M_4 generation. In F_4M_4, the frequency in the control group ranged from 23.66% (Co-1 x PS) to 58.40% (PS x Co-1).

To the exclusion of Co-1, all the other treatments had significantly higher percentage of positive variants compared to the frequency of negative variants.

6.4. Length of fruit

The frequency distribution of fruit length variants (in percentage) for the different treatments in the fourth generation is presented in table 26. Statistical analysis revealed no significant difference among the treatments. But, there was significant variation among the three phenotypic classes and treatment x phenotypic class interaction.

With regards to the negative variants, the frequency ranged from 1.93% (PS x KC) to 17.63% (Co-1 x KC) in the F_4 generation. Comparatively lower frequency of negative variants was noted in PS x Co-1, KC x Co-1 and KC x PS. In the M_4 generation, the frequency ranged from 1.38% in Co-1 to 9.07% in PS. In the F_4M_4, maximum frequency of negative variants was noted in PS x Co-1 (11.80%) followed by KC x PS (9.08%) and the minimum in Co-1 x KC (0%). Co-1 x PS and KC x Co-1 showed comparatively lower frequency of negative variants. In PS x Co-1, PS x KC and KC x PS there was an increase in the number of negative variants, due to the effect of gamma rays. On the other hand, gamma rays reduced the frequency of negative variants in Co-1 x KC and KC x Co-1.

In F_4, the frequency of positive variants was maximum in KC x PS (64.89%) and minimum in Co-1 x KC (33.25%). PS x Co-1, KC x Co-1 and PS x KC recorded comparatively higher frequency of positive variants. In M_4, the frequency ranged from 57.92% (PS) to 76.91% (Co-1). The frequency of positive variants in F_4M_4 was maximum in Co-1 x KC (96.55%) and minimum in PS x Co-1 (49.95%). Co-1 x PS and KC x PS also had comparatively higher percentage of positive variants. In all the crosses except PS x Co-1, there was an increase in the frequency of positive variants due to the effect of gamma rays.

In the control group, the frequency ranged from 28.51% (KC x PS) to 49.21% (Co-1 x KC) in F_4. In M_4, the range was 21.71% (Co-1) to 32.96% (PS). The frequency under the control group ranged from 3.45% (Co-1 x KC) to 38.25% (PS x Co-1) in F_4M_4.

When compared to the frequency of negative variants there was a significant increase in the frequency of positive variants in all the treatments.

6.5 Weight of fruit

Table 27 represents the frequency distribution of fruit weight variants for the different treatments in the fourth generation. Statistical analysis showed no significant difference among the treatments. The variation among the three phenotypic classes and the treatment x phenotypic class interactions were found to be significant.

The frequency of negative variants in the F_4 generation ranged from 6.90% in KC x PS to 35.32% in Co-1 x KC. The range of negative variants was 13.03% (Co-1) to 34.13% (PS) in M_4. In F_4M_4 maximum negative variants was observed in PS x Co-1 (33.03%) followed by Co-1 x PS (10.33%) and the minimum in Co-1 x KC (0%). Due to the effect of gamma rays the frequency of negative variants decreased in Co-1 x KC, KC x Co-1, PS x KC and KC x PS, but in PS x Co-1, an increase in frequency was noticed.

With regards to positive variants, the frequency was maximum in KC x PS (72.35%) and minimum in Co-1 x KC (40.04) in the F_4 generation. In M_4, the frequency ranged from 41.87% in PS to 65.02% in Co-1. In F_4M_4, the range was 43.83% (PS x Co-1) to 92.33% (Co-1 x KC). Comparatively higher frequency of positive variants was observed in the F_4M_4 of Co-1, KC x Co-1, PS x KC and KC x PS. Gamma rays created an increase in the frequency of positive variants in Co-1 x KC, KC x Co-1, PS x KC and KC x PS. But a reverse trend was noted in PS x Co-1.

In the control group, the frequency ranged from 20.75% (KC x PS) to 37.41% (PS x KC) in the F_4 generation. In M_4, the maximum frequency of individuals coming under the control group was observed in PS (24%) and the minimum in KC (19.78%). In F_4M_4, the frequency ranged from 7.67% in Co-1 x KC to 23.14% in PS x Co-1.

A significant increase in the frequency of positive variants compared to negative variants was noted in all the treatments.

6.6. Number of fruits per plant

The frequency distribution of fruit number variants for the different treatments in the fourth generation is presented in table 28. Statistical analysis showed no significant difference among the treatments. There was significant variation among the three phenotypic classes and the treatment x phenotypic class interaction.

Among the various treatments in the F_4 generation, maximum frequency of negative variants was observed in PS x KC (23.25%) and the minimum in KC x Co-1 (3.15%). Co-1 x KC, PS x Co-1 and KC x PS also had lower frequency of negative variants. In M_4, the frequency ranged from 4.40% (KC) to 27.59% (PS). Co-1 (19.58%) had comparatively higher percentage of negative variants. In F_4M_4, the frequency of negative variants ranged from 2% (Co-1 x KC) to 9.42% (PS x Co-1). To the exclusion of KC x Co-1, all the other crosses recorded a reduction in the frequency of negative variants, due to the effect of gamma rays.

The frequency of positive variants in the F_4 ranged from 17.27% in PS x KC to 44.41% in Co-1 x KC. The range of positive variants in M_4 was 23.70% (PS) to 60.01% (KC). In F_4M_4, maximum positive variants was observed in Co-1 x KC (60.00%) followed by Co-1 x PS (59.76%) and the minimum in PS x Co-1 (20.34%). KC x Co-1 recorded a comparatively higher percentage of positive variants. A gamma ray induced reduction in the frequency of positive variants was noticed in PS x Co-1 and KC x PS. On the other hand, in Co-1 x KC, KC x Co-1 and PS x KC, the frequency of positive variants increased due to the effect of gamma rays.

The frequency of individuals coming under the control group ranged from 47.77% (KC x PS) to 64.12% (PS x Co-1) in the F_4. In M_4, the frequency was in the order of 35.59% in KC to 56.61% in Co-1. The frequency of control groups in F_4M_4 was maximum in PS x Co-1 (70.24%) and minimum in Co-1 x PS (35.30%).

All the treatments except the M_4 of PS and F_4 of PS x KC showed a significant increase in the frequency of positive variants compared to that of negative variants.

6.7. Yield per plant

The frequency distribution of yield variants for the different treatments in the fourth generation is given in table 29. Statistical analysis showed no significant difference among the treatments. The variations among the three phenotypic classes and the treatment x phenotypic class interaction were found to be significant.

In F_4 generation, the frequency of negative variants ranged from 0% (KC x PS) to 24.43% (PS x KC). Comparatively lower frequency of negative variants was recorded by Co-1 x KC and KC x Co-1. In M_4 generation, the range was 3.42%

in KC to 23.40% in PS, Co-1 showed a lower frequency of 6.19%. The frequency of negative variants ranged from 0.67% (Co-1 x KC) to 9.42% (PS x Co-1) in the F_4M_4 generation. Due to the effect of gamma rays, an increase in the frequency of negative variants was noticed in KC x Co-1 and KC x PS. But a reverse trend was observed in PS x Co-1, Co-1 x KC and PS x KC.

The frequency of positive variants ranged from 26.36% (PS x KC) to 91.55% (KC x PS) in the F_4 generation. KC x Co-1 and Co-1 x KC recorded a comparatively higher value for positive variants. In M_4, positive variants ranged from 40.37% in PS to 77.58% in KC. In F_4M_4, maximum frequency of positive variants was observed in Co-1 x KC (98%) and the minimum in PS x Co-1 (32.32%). Co-1 x PS and KC x Co-1 showed higher frequency of positive variants. When an increase in the frequency of positive variants due to the effect of gamma rays was noted in Co-1 x KC, KC x Co-1 and PS x KC, a reduction was observed in PS x Co-1 and KC x PS.

The frequency of individuals coming under the control group ranged from 8.45% (KC x PS) to 49.21% (PS x KC) in F_4. In M_4 generation, the frequency was highest in Co-1 (45.15%) followed by PS (36.23%) and KC (19.00%). In the F_4M_4, the frequency ranged from 1.33% in Co-1 x KC to 58.26% in PS x Co-1.

DISCUSSION

DISCUSSION

Genetic variability created in quantitative / polygenic characters using both physical and chemical agents has become a most potent line of approach to tailor better varieties of crop plants to suit almost all stress conditions. Many dedicated research workers including Gregory (1955) in groundnut, Oka et al. (1958) in rice and Rawlings et al. (1958) in soybean have analysed the effect of mutagen on polygenic systems. A general conclusion drawn from earlier studies clearly demonstrate that mutagens can create genetic variation in quantitative characters in any direction. But still, it is a matter of debate whether irradiation induced mutations in polygenes occurs towards negative and positive direction or towards either of the two. The problem is of great importance from the stand point of practical utilization of radiation energy for the improvement of economically important characters of crop plants. The present study is an attempt to have a comparative evaluation of pure breds and cross bred in yielding both negative and positive variants in bhindi by using ^{60}Co-gamma rays in M_3 and M_4 generations. Comparison is also made between conventional breeding technique (hybridization) and induced mutation for creating variabilities in polygenic systems. The results eminated during the course of study is discussed below.

<u>Mean character expressions and frequency of variants in segregating generations</u>

Table 30 shows the direction of shift in mean plant height and range in frequency of variants in M_3 and M_4 generations. In the third generation, gamma rays induced a negative shift in plant height in all the three pure breds. Similar effect was noticed in F_3 and F_3M_3 of PS x Co-1 and its reciprocal cross. But in all the other crosses, a positive shift in mean plant height was observed in both F_3 and F_3M_3.

In M_4 generatior, Kilichundan and Co-1 exhibited a positive shift in mean plant height, but Pusa Sawani showed a negative shift. An insignificant negative shift was noticed in PS x KC in both F_4 and F_4M_4. KC x PS and crosses involving Co-1 and KC showed a positive shift in mean value.

A reduction in mean plant height as a result of mutagen treatment has been reported by several workers. Mutants showing dwarfness with short stems were reported by Tedin and Hagberg (1952) in M_3 of *Lupinus luteum*, Hackbarth (1955) in M_2 of irradiated *Lupinus albus*, Korah (1959) in M_1 and M_2 of *Oryza* and Shasthry and Nandhachery (1965) in M_4 of irradiated rice. Sakai and Suzuki (1964), after X-irradiation in rice, reported that mutation of polygenes

Table 30. Shift in mean plant height and range in frequency of variants in M_3 and M_4 generations.

Pure breds	M_3	M_4	Combinations.	Cross breds: In comparison with female parent				Cross breds: In comparison with male parent			
				F_3	F_4	F_3M_3	F_4M_4	F_3	F_4	F_3M_3	F_4M_4
Pusa Sawani	-	-	PS x Co-1	-	+	-	+	-*	-	-	-*
			Co-1 x PS	-*		-*	+	-		-	+*
Kilichundan	-	+*	PS xKC	+	-	+*	-	+*	-	+*	-
			KC x PS	+*	+	+*	+	+*	+	+*	+
Co-1	-	-*	Co-1 x KC	+*	+	+	+	+*	+*	+*	+*
			KC x Co-1	+*	+*	+*	+*	+*	+	+*	+*

Range in frequency of variants

Generation	Negative variants: Irradiated Pure breds	Negative variants: Irradiated Cross breds	Negative variants: Cross breds	Positive variants: Irradiated Pure breds	Positive variants: Irradiated Cross breds	Positive variants: Cross breds
Third	14.84- 27.60 (KC) (Co-1)	5.00 -18.02 (KCxPS) (Co-1xPS)	9.09 - 20.33 (KCxCo-1) (PSX Co-1)	28.58-42.42 (Co-1) (KC)	31.95- 54.34 (Co-1xPS) (KCXPS)	23.84 - 54.45 (PSXCo-1) (KC xCo-1)
Fourth	0 — 6.41 (KC) (PS)	0 — 11.87 (KCxCo-1) (Co-1xKC) (PSxKC)	0 — 13.05 (KCxCo-1) (Co-1xKC) (PSxKC)	19.57-79.03 (Co-1) (KC)	26.09- 88.15 (PSxKC) (KCxCo-1)	19.28 - 90.02 (PSxKC) (KCxCo-1)

* Significant at 5% level.

responsible for quantitative characters like plant height occurs in most cases unidirectionally in minus direction. Increased genetic variance for characters like height, ear length etc. was found in the M_3 progenies of irradiated maize by Sutka and Bulint (1971). Sree Rangasamy et al. (1973) observed that the green gram plants treated with gamma rays were shorter than the parents. 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.

An increase in mean plant height as a result of mutagen treatment, as noted in certain cases in the present study, has also been reported by several workers. A positive shift in plant height was observed by Goud et al. (1971) in ragi, after EMS treatment. Increased plant height in M_2 and later generations in comparison to the unirradiated plants was observed by Kumar and Das (1977) in Brassica. They suggested that this may be related to the effect of selection applied in M_2 and later generation. Increased plant height after mutagen treatment was also reported by Kamannavar (1985) in chilli.

The negative shift in the mean plant height noticed in some of the treatments may be due to the higher range of negative phenotypes created by gamma rays. But in certain other treatments like Pusa Sawani in M_4 generation, in spite of the lower percentage of negative phenotypic variants, a negative shift in mean plant height was observed. This can be attributed to a higher frequency of negative variants in the extreme direction. The frequency of positive variants created was higher in majority of the crosses (both irradiated and non-irradiated) in the third and fourth generation and hence a positive shift in mean value was observed.

The range in frequency of variants varied widely with respect to the genotype and the generations. In the third generation irradiated pure breds recorded a higher range of negative plant height variants. Both F_3 and F_3M_3 showed a wider range of negative variants. The range of positive variants was highest in irradiated cross breds compared to pure breds. In the fourth generation, no negative variants was created in Kilichundan and in crosses involving Kilichundan and Co-1. But in these cases, the frequency of positive variants was higher. Compared to the third generation, the frequency of negative variants was lower in M_4 which added for a higher frequency of positive variants on increased mean plant height. So selection for tall plants will be effective in the fourth generation.

In the case of Bhindi, tallness associated with shorter internodal length, which induces flower production potentiality, is an attribute contributing to the yield and hence tall plants are preferred. Hybridization and hybridization together with irradiation gave better results compared to irradiation of pure breds; of which cross breds are more desirable.

Number of days taken to flowering

Table 31 shows the shift in mean number of days taken to flowering and range in frequency of variants in M_3 and M_4 generations. There was a negative shift in the mean number of days taken to flowering in Kilichundan and Co-1 in the third generation. But in Pusa Sawani, there was a positive shift. In Crosses PS x Co-1 and PS x KC, there was a positive shift in the mean value in both F_3 and F_3M_3 compared to the female parent. Compared to Pusa Sawani, all the crosses involving it showed a positive shift in the mean number of days to flowering in both F_3 and F_3M_3. Co-1 x KC took lesser number of days to flower in F_3 and F_3M_3 whereas, KC x PS took comparatively more number of days.

Pusa Sawani and Kilichundan in the fourth generation showed a negative shift in the number of days taken to flowering, but Co-1 showed a positive shift. To the exclusion of crosses involving Pusa Sawani and Kilichundan, all the others recorded a negative shift in the mean value in F_4 and F_4M_4. The scope for selecting early flowering types are more from

Table 31. Shift in mean number of days taken to flowering and range in frequency of variants in M_3 and M_4 generations.

Pure breds	M_3	M_4	Combinations	Cross breds: In comparison with female parent F_3	F_4	F_3M_3	F_4M_4	In comparison with male parent F_3	F_4	F_3M_3	F_4M_4
Pusa Sawani	+	-	PS x Co-1	+	-*	+	-	-*	-*	-*	-
			Co-1 x PS	-	Not selected	-	-	+		+	-
Kilichundan	-	-*	PS x KC	+	+*	+*	+*	-	+	+	+*
			KC x PS	+	+	+	+*	+*	+*	+	+*
Co-1	-	+	Co-1x KC	-	-	-	-*	+	-*	-	-*
			KC x Co-1	-	-*	-	-*	-	-*	-	-

Range in frequency of variants

Generations	Negative variants: Irradiated Pure bred	Irradiated Cross breds	Cross breds	Postive variants: Irradiated Pure breds	Irradiated Cross breds	Cross breds
Third	18.87-34.76 (KC) (PS)	13.97 - 46.44 (KCxPS) (PSxCo-1)	14.06 - 26.16 (PSxKC) (Co-1xPS)	29.57- 50.22 (PS) (KC)	16.80 - 65.16 (PSxCo-1) (KCxPS)	31.11 - 46.21 (PSxCo-1) (KCxCo-1)
Fourth	56.65-85.35 (Co-1) (KC)	15.34 - 85.86 (PSxKC) (Co-1xKC)	36.79 - 88.54 (KCxPS) (KCxCo-1)	3.40- 16.55 (KC) (PS)	2.00 - 48.08 (Co-1xKC) (PSxKC)	4.68 - 33.52 (KCxCo-1) (KCxPS)

* Significant at 5% level.

crosses PS x Co-1, Co-1 x KC and its reciprocals compared to PS x KC and its reciprocal. Selection for early flowering types could be more effectively done in the fourth generation rather than in the third generation since higher frequency of negative variants are created in the later generation.

A genotype dependent variation in the range in frequency distribution was observed in both M_3 and M_4 generations. A wider range of negative variants was seen in irradiated cross breds in both generations, but higher range was noticed in pure breeds in both cases. Hence, irradiation of pure breds offer much scope for selection for early flowering types. Higher sensitivity of inbreds to irradiation than hybrids was reported by Boyle (1968) in Agropyron. On the other hand, Joshva et al. (1967) observed the hybrids of Norin-6 x PTB-10 to be more effective than the parents to gamma irradiation.

Plants with varying flowering habits such as early, intermediate and late flowering lines were obtained by Abrams and Velez- Fortcino (1962) in M_3 and M_4 generations of irradiated pigeon peas. Works on several crops had clearly shown that earliness in flowering was induced by irradiation. Tedin (1954) obtained ten early flowering mutants in Lupinus luteus. Matsumara and Fuji (1955) noted in

Nicotiana tabacum and *Nicotiana sylvestris* that gamma ray has induced earliness in flowering by fifteen days in a mutant than its parents. Earliness in flowering by seventeen days in mutant forms of M_3 of *Sesamum* was observed by Rai and Jacob (1956). Similar results were reported by Gladstones (1958) in *Lupinus digitalis* and Gottschalk (1960) in *Pisum sativum* treated with X-rays. Daly (1960) observed that in the third generation of gamma ray treated population of *Arabidopsis thaliana,* among the lines selected for early flowering, 20-50% were significantly earlier than the non-irradiated selected population. On the other hand, Rudraswamy (1984) observed delayed flowering at higher doses of gamma ray in Horse gram.

3. Number of leaves produced per plant

Shift in mean number of leaves per plant and range in frequency of variants in M_3 and M_4 generations are given in the table 32. In the third generation, Pusa Sawani and Co-1 recorded a negative shift in mean value, while Kilichundan showed a positive shift. The hybrids exhibited insignificant variation in the mean value either towards positive or negative direction, depending on the genic status. Compared to Pusa Sawani, all the crosses involving it (except KC x PS) had lesser number of leaves in F_3 and F_3M_3. But majority

Table 32. Shift in mean number of leaves per plant and range in frequency of variants in M_3 and M_4 generation.

Pure breds	M_3	M_4	Combinations	Cross breds: In comparison with female parent				Cross breds: In comparison with male parent			
				F_3	F_4	F_3M_3	F_4M_4	F_3	F_4	F_3M_3	F_4M_4
Pusa Sawani	-	+	PS x Co-1	-	-	-	+	-	+	-	-
			Co-1 x PS	-		+	+*	-		-	+*
Kilichundan	+	-	PS x KC	-	+	-	+	+	-*	+	-*
			KC x PS	+	+	+	+	+	+*	+	+*
Co-1	-	-	Co-1 x KC	+	+	-	+*	+	-	+	+
			KC x Co-1	+	-	+	-	+	+*	+	+*

Range in frequency of variants

Generations	Negative variants: Irradiated Pure breds	Negative variants: Irradiated Cross breds	Negative variants: Cross breds	Positive variants: Irradiated Pure breds	Positive variants: Irradiated Cross breds	Positive variants: Cross breds
Third	9.17 - 13.08 (Co-1) (KC)	5.92 - 16.01 (KCxPS) (Co-1xPS)	14.06 - 23.46 (KCxPS) (Co-1xPS)	22.37 - 32.76 (KC) (Co-1)	28.78 - 43.33 (PSxCo-1) (Co-1xKC)	25.77 - 44.84 (Co-1xPS) (KCxPS)
Fourth	4.40 - 24.70 (KC) (Co-1)	0.67 - 18.27 (Co-1xKC) (PSxCo-1)	1.08 - 11.74 (KCxPS) (PSxCo-1)	22.45 - 52.24 (Co-1) (PS)	23.33 - 78.93 (PSxCo-1) (KCxPS)	30.24 - 68.53 (PSxCo-1) (KCxPS)

* Significant at 5% level.

of the crosses involving Kilichundan exhibited an insignificant positive shift in the mean number of leaves in F_3 and F_3M_3. The positive shift observed in these crosses may be related to the positive shift in mean plant height.

In the fourth generation, Co-1 and Kilichundan showed only a negative shift in the number of leaves, whereas Pusa Sawani recorded a positive shift. Significant increase in the number of leaves was observed in the irradiated population of Co-1 x P^5 and Co-1 x KC. Cross breds in the fourth generation exhibited higher number of leaves, compared to those in the third generation.

The range in frequency of positive variants in the third generation was higher in cross breds compared to pure breds. Similar is the case in the fourth generation also. From this, it is evident that hybridization alone or together with irradiation is more effective than irradiation of pure breds in increasing the number of leaves, which in turn will increase the yield by enhancing the photosynthetic efficiency as well as the number of productive nodes. Compared to M_3 generation, the range of positive variants was higher in M_4 generation.

An insignificant reduction in the mean number of leaves noted in some of the treatments in the present study was in line with the reports of Mareen (1985) in the M_2 generation of gamma ray irradiated bhindi. The absence of significant variation in mean value in F_3M_3 from the control population can be attributed to the production of polygenic mutations with positive and negative effects in equal frequency. The symmetrical augmentation of phenotypic variation may be the character of mutation in polygenes for a quantitative character as reported by Oka et al. (1958).

Number of branches per plant

Table 33 shows the shift in mean number of branches per plant in M_3 and M_4 generations. In M_3 generation, a positive shift in the mean number of branches was noticed in Pusa Sawani and Co-1. But in Kilichundan, a negative shift was observed. A complete negative shift in the mean value was seen in crosses of Co-1 and Kilichundan in both F_3 and F_3M_3. When PS x KC showed a negative shift in mean value in F_3M_3, its reciprocal cross showed a positive shift. A predominating negative shift in the mean number of branches was noticed in F_3 of all crosses.

Table 33. Shift in mean number of branches per plant in M_3 and M_4 generations

Pure breds	M_3	M_4	Combinations	Cross breds							
				In comparison with female parent				In comparison with male parent			
				F_3	F_4	F_3M_3	F_4M_4	F_3	F_4	F_3M_3	F_4M_4
Pusa Sawani	+	+*	PS x Co-1	-	+	+	+	-	+	-	+
			Co-1 x PS	-		+	+*	+		+	+*
Kilichundan	-	-*	PS X KC	-	-	-	+	-	-*	-	-*
			KC x PS	-	-*	+	-*	+	+	+	-
Co-1	+	+	Co-1 x KC	-	+	-	+*	-	-*	-	+
			KC x Co-1	-	-*	-	-*	-	+*	-	+*

* Significant at 5% level.

In M_4 generation, a similar effect as seen in M_3 was observed. But in F_4 and F_4M_4 comparatively more number of treatments exhibited positive shift in the mean number of branches per plant.

Sakai and Suzuki (1964) noted decreased number of tillers in rice and suggested that X-ray irradiation resulted in a decrease in polygenic characters like number of tillers. Similar result was reported by Ehrenberg *et al.* (1964) in rice in the M_4 generation. Gamma ray and EMS treatments in rice has led to a significant reduction in mean number of tillers in M_2 and M_3 generation (Nayar, 1976). Coud (1967a) in hexaploid wheat observed a shift in mean value towards negative direction for tiller number. On the other hand, Bateman (1959) observed that the mean value of tillers per plant in rice increased after irradiation and suggested that the overall effect of polygenic mutation in rice was unidirectional. Toriyama and Futsuhara (1962) obtained a mutant 'Fu.54' in rice which had higher number of tillers than its parents. The mean number of branches in M_2 and later generations was found to be increased due to treatment with gamma rays and thermal neutrons as was reported by Kumar and Das (1977) in *Brassica*.

<u>Length of fruits</u>

The shift in mean fruit length and range in frequency of variants in M_3 and M_4 generation is depicted in table 34. Depending on the genic status, the mean value for fruit length exhibited both positive and negative shift. In M_3 generation, Pusa Sawani and Co-1 showed positive shift compared to their respective controls. But Kilichundan showed a reverse trend. PS x Co-1 recorded an insignificant positive shift compared to the parents in both F_3 and F_3M_3. PS x KC and its reciprocal cross showed positive shift in the mean length of fruits in F_3 and F_3M_3, compared to Pusa Sawani. In the case of crosses involving Co-1 and Kilichundan, a positive shift was noticed in F_3M_3, but in F_3, there was a negative shift in the mean value compared to Kilichundan.

In M_4 generation also, Pusa Sawani and Co-1 produced longer fruits, but Kilichundan produced only shorter fruits compared to control. The effects noticed in F_4 and F_4M_4 were comparable to that observed in F_3 and F_3M_3. In general, majority of irradiated cross breds exhibited positive shift in fruit length, rather than in non-irradiated cross breds. This may be due to a higher production of gamma ray induced positive variants in these treatments.

Table 34. Shift in mean fruit length and range in frequency of variants in M_3 and M_4 generations.

Pure breds	M_3	M_4	Combi-nations	Cross breds: In comparison with female parent F_3	F_4	F_3M_3	F_4M_4	In comparison with male parent F_3	F_4	F_3M_3	F_4M_4
Pusa Sawani	+	+	PS x Co-1	+	+	+	+	+	+*	+	+*
			Co-1 x PS	-		+	+*	+		+	+*
Kilichundan	-	-*	PS x KC	+*	+	+*	+	-	-*	+	-*
			KC x PS	+	-*	-	-*	+*	+*	+*	+
Co-1	+	+*	Co-1 x KC	+	+	+*	+*	-*	-*	+	-
			KC x Co-1	-	-*	+	-*	+*	+*	+*	+*

Range in frequency of variants

Genera-tions	Negative variants: Pure breds	Negative variants: Cross breds	Cross breds	Positive variants: Pure breds	Positive variants: Cross breds	Cross breds
Third	10.64 - 18.37 (KC) (PS)	10.78 - 13.49 (Co-1xPS) (PSxCo-1)	10.11 - 30.41 (KCxCo-1) (PSxKC)	31.80 - 50.31 (Co-1) (KC)	36.05 - 57.53 (PSxCo-1) (KCxPS)	23.02 - 58.73 (Co-1xKC) (KCxPS)
Fourth	1.38 - 9.07 (Co-1) (PS)	0 - 11.80 (Co-1xKC) (PSxCo-1)	1.93 - 17.63 (PSxKC) (Co-1xKC)	57.97 - 76.91 (PS) (Co-1)	49.95 - 96.55 (PSxCo-1) (Co-1xKC)	33.25 -64.89 (Co-1xKC) (KCxPS)

* Significant at 5% level.

Significant differences in the mean values of panicle length among treated and between treated and controls were observed by Matsuo et al. (1964) in M_6 generation of rice. A negative shift in mean paniclo length following x irradiation has been reported in rice by Sakai and Suzuki (1964). Nayar (1976) has also reported similar reduction in mean panicle length in rice. On the contrary, increased frequency of mutants in M_3 with respect to panicle length was reported by Siddiqui and Swaminathan (1968) in EMS treated rice.

The range of negative variants created in F_3M_3 was lower compared to that in M_3 and F_3. But the range of positivo variants created were comparable in M_3, F_3 and F_3M_3. The positive shift in the mean value seen in certain genotypes are due to the production of lesser number of negative variants and more number of positive variants. In the M_4 generation, the range of negative variants was still lower. Highest range of positive variants was observed in irradiated cross breds in the fourth generation. Hence selection for longer fruits will be more effective from the fourth generation of irradiated cross breds.

Weight of fruits

Table 35 gives the shift in mean fruit weight and range in frequency of variants in the M_3 and M_4 generations. Mutagen treatment led to a general increase in mean fruit weight in all the three pure breds. The cross breds also recorded a positive shift in the mean value in majority of cases in F_3 and F_3M_3. There was significant positive shift in F_3M_3 in crosses, PS x KC, Co-1 x KC and their reciprocals. In the crosses involving Pusa Sawani and Co-1 only an insignificant positive shift was noticed.

In M_4 generation, Kilichundan recorded only a negative shift in mean fruit weight. But in Pusa Sawani and Co-1, there was an insignificant positive shift. Compared to Kilichundan, KC x Co-1 and PS x KC recorded a negative shift in F_4 and F_4M_4, but KC x PS showed a negative shift only in F_4M_4. All the other crosses showed variation in fruit weight in the positive direction in the fourth generation.

Increase in mean fruit weight in majority of the crosses can be attributed to the fact that the number of positive variants created was higher than that of the negative variants. The range of negative variants was lower compared to that of positive variants in both third and

Table 35. Shift in mean fruit weight and range in frequency of variants in the M_3 and M_4 generations.

Pure breds	M_3	M_4	Combinations	Cross breds: In comparison with female parent F_3	F_4	F_3M_3	F_4M_4	In comparison with male parent F_3	F_4	F_3M_3	F_4M_4
Pusa Sawani	+	+	PS x Co-1	+	+	-	+	+	+	+	+
			Co-1 x PS	+		+	+*	+		+	+*
Kilichundan	+	-	PS x KC	+*	+	+*	+*	+	-*	+*	-
			KC x PS	+*	+	+*	-	+*	+*	+*	+*
Co-1	+	+	Co-1xKC	+*	+	+*	+*	+	-*	+*	+*
			KC x Co-1	+	-*	+*	-	+*	+ *	+*	+*

Range in frequency of variants

Generation.	Negative variants: Irradiated Pure breds	Negative variants: Irradiated Cross breds	Negative variants: Cross breds	Positive variants: Irradiated Pure breds	Positive variants: Irradiated Cross breds	Positive variants: Cross breds
Third	12.28 - 18.63 (KC) (Co-1)	9.29 - 14.77 (Co-1xPS) (PSxCo-1)	15.72 - 20.27 (PSxCo-1) (Co-1x PS)	50.20 - 60.66 (PS) (KC)	45.73 - 68.29 (PSxCo-1) (Co-1xPS)	46.54 - 63.17 (KCx Co-1) (KCxPS)
Fourth	13.03 - 34.13 (Co-1) (PS)	0 - 33.03 (Co-1xKC) (PSxCo-1)	6.09 - 35.32 (KCxPS) (Co-1 x KC)	41.87 - 65.02 (PS) (Co-1)	43.83 - 92.33 (PSx Co-1) (Co-1x KC)	40.04 - 72.35 (Co-1xKC) (KCxPS)

* Significant at 5% level.

fourth generations. Compared to the third generation, a wider range of negative and positive variants was observed in the fourth generation, ie. the variability created in the M_4 generation is higher than that in the M_3 generation. This was in agreement with the result obtained by Sakai and Suzuki (1964) in X rayed paddy. Patel and Swaminathan (1961) reported wide range of variability in M_2, M_3 and M_4 generations of irradiated tobacco.

As is noted in the present study, Rawlings et al. (1958) reported that seed weight in soybean increased after irradiation. On the contrary, 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. Similar result was obtained by Lekha Rani (1985) in chilli in M_2 generation. Rao and Siddiq (1977), after analysing induced variation for yield and its components in rice, suggested that the changes in the mean value and skewness of the frequency distribution in mutagen treated population varied with the variety, character, mutagen and the generation.

Number of fruits

Shift in mean number of fruits per plant and range in frequency of variants in M_3 and M_4 generations are given in table 36. Depending on the genic status, the treatments

showed a negative or positive shift in mean value.
In the M_3 generation, Pusa Sawani exhibited an insignificant positive shift in the mean value. But in Kilichundan and Co-1 an insignificant negative shift was noticed. A general negative shift was observed in F_3 and F_3M_3 of crosses involving Pusa Sawani and Co-1. In all the other crosses, ie. PS x KC, Co-1 x KC and their reciprocals, the mean fruit number shifted in the positive direction in both F_3 and F_3M_3. The increase in mean value was significant in majority of the cases.

In M_4 generation, both Pusa Sawani and Co-1 recorded positive shift in the mean number of fruits. But Kilichundan showed a significant reduction. Compared to Kilichundan, all the crosses involving it exhibited a significant negative shift in F_4 and F_4M_4. In general, irradiation of cross breds was found to be more effective in creating significant increase in fruit number, rather than irradiation of pure breds. This can be due to higher sesnitivity of hybrids to gamma rays than that of the parents as observed by Joshva et al. (1967) in rice.

Sakai and Suzuki (1964) reported a decrease in mean expression of polygenic characters like number of panicles after X irradiation in rice. On the other hand,

Table 36. Shift in mean number of fruits per plant and range in frequency of variants in M_3 and M_4 generations

Pure breds	M_3	M_4	Combinations	Cross breds: In comparison with female parent F_3	F_4	F_3M_3	F_4M_4	In comparison with male parent F_3	F_4	F_3M_3	F_4M_4
Pusa Sawani	+	+	PS x Co-1	+	+	-	+	-	+	-	+
			Co-1 x PS	-		-	+*	-		-	+*
Kilichundan	-	-*	PS x KC	+*	+	+*	+	+	-*	+*	-*
			KC x PS	+*	-*	+*	-*	+	+*	+*	+
Co-1	-	+	Co-1 xKC	+*	+*	+*	+*	+*	-*	+	-*
			KC x Co-1	+	-*	+*	-*	+	+*	+*	+*

Range in frequency of variants

Generations	Negative variants: Irradiated Pure breds	Irradiated Cross breds	Cross breds	Positive variants: Irradiated Pure breds	Irradiated Cross breds	Cross breds
Third	10.84–12.89 (Co-1) (KC)	6.39 – 21.87 (KCxPS) (PSxCo-1)	16.26 – 30.98 (KCxCo-1) (PSxCo-1)	27.23– 36.21 (KC) (Co-1)	25.52– 43.52 (PSxCo-1) (Co-1x KC)	21.75 – 38.08 (Co-1x PS) (Co-1x KC)
Fourth	4.40–27.59 (KC) (PS)	2.00 – 9.42 (Co-1xKC) (PSxCo-1)	3.15 – 23.25 (KCxCo-1) (PSxKC)	23.70– 60.01 (PS) (KC)	20.34– 60.00 (PSxCo-1) (Co-1x KC)	17.27 – 44.41 (PSxKC) (Co-1x KC)

* Significant at 5% level.

Berezoskil et al. (1981) obtained increased fruit number per plant in third generation by chemical mutagen treatment in tomato. Similar result was reported by Kamannavar (1985) in chilli by gamma irradiation. Lekha Rani (1985) reported that 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 polygenic traits occurred symmetrically in positive and negative directions following gamma irradiation.

The negative shift in the mean value observed in crosses involving Pusa Sawani and Co-1 in the third generation was due to the production of more number of negative variants compared to positive variants. Comparatively higher positive variants produced was responsible for positive shift in mean value in all the other crosses. The range of positive variants was wider in fourth generation compared to third generation.

Fruit yield per plant

Table 37 gives the shift in mean fruit yield per plant and range in frequency of variants in the M_3 and M_4

generations. An insignificant positive shift for mean fruit yield in the M_3 generation of pure breds was noticed. Compared to Co-1, its crosses with Pusa Sawani showed insignificant positive shift in F_3 and F_3M_3. In PS x KC, Co-1 x KC and their reciprocals, significant positive shift compared to both parents was observed in F_3M_3. In F_3 of PS x KC and Co-1 x KC only an insignificant positive shift was noted compared to Kilichundan.

Kilichundan in M_4 recorded a significant negative shift, while Pusa Sawani and Co-1 showed insignificant positive shift. Compared to Kilichundan, all the crosses involving it exhibited significant negative shift in F_4 and F_4M_4. In crosses involving Pusa Sawani and Co-1 a positive shift was noted in the fourth generation.

Significant positive shift in the mean yield exhibited by crosses involving Kilichundan in the third generation may be due to the higher percentage of positive variants created by the effect of gamma rays. Higher yield is contributed by increased length, weight and number of fruits. In irradiated population of cross breds a wider variability is created in both M_3 and M_4 generation, compared to irradiated pure breds and non-irradiated cross breds. The range of positive variants in the fourth generation was higher than that in the third generation.

Table 37. Shift in mean fruit yield per plant and range in frequency of variants in the M_3 and M_4 generations.

Pure breds	M_3	M_4	Combinations	Cross breds: In comparison with female parent F_3	F_4	F_3M_3	F_4M_4	Cross breds: In comparison with male parent F_3	F_4	F_3M_3	F_4M_4
Pusa sawani	+	+	PS x Co-1	+	+	-	+	+	+	+	+
			Co-1 x PS	+		+	+*	+		+	+*
Kilichundan	+	-*	PS x KC	+*	+	+*	+	+	-*	+*	-*
			KC x PS	+*	-*	+*	-*	+*	+*	+*	+
Co-1	+	+	Co-1x KC	+*	+	+*	+*	+	-*	+*	-*
			KC x Co-1	+	-*	+*	-*	+*	+*	+*	+*

Range in frequency of variants

Generation.	Negative variants: Irradiated Pure breds	Negative variants: Irradiated Cross breds	Negative variants: Cross breds	Positive variants: Irradiated Pure breds	Positive variants: Irradiated Cross breds	Positive variants: Cross breds
Third	13.01-20.04 (KC) (PS)	13.45 - 37.25 (KCxPS) (PSxCo-1)	9.14 - 31.16 (KCxPS) (PSxCo-1)	39.37- 56.34 (KC) (PS)	24.70 - 60.00 (PSxCo-1) (KCxPS)	26.61 - 59.09 (Co-1xPS) (KCxCo-1)
Fourth	3.42-23.40 (KC) (PS)	0.67 - 9.42 (Co-1xKC) (PSx Co-1)	0 - 24.43 (KCxPS) (PSxKC)	40.37- 77.58 (PS) (KC)	32.32 - 98.00 (PSxCo-1) (Co-1xKC)	26.36 - 91.55 (PSxKC) (KCxPS)

* Significant at 5% level.

Increase in yield as a result of irradiation was reported by many workers including Gelin (1954) in *Pisum sativum*, Gregory (1956) in M_6 of *Arachis hypogaea*, Van Embden and Jaaraverslag (1959) in M_6 of soybean, Li *et al.* (1960) in rice , Svejda (1961) in M_3 and M_4 of *Pisum* and Abrams and Velez-Forticino (1962) in M_3 and M_4 of pigeon pea. Nandpuri *et al.* (1971) reported that Okra plants treated with 30 kR gamma rays gave significantly higher yield. Vasudevan *et al.* (1984) studied the yield performance in M_3 and M_4 generations of *Vigna unguiculata*. Though the errect mutants obtained showed reduction in plant height, the grain yield per plant was higher due to more branching.

Mutants showing lower yield than their parental forms were also observed by some workers like Gottschalk (1960) in *Pisum sativum*, Johnston (1961) in M_4 and M_5 of oats, Sakai and Suzuki (1964) in M_4 of rice and Kotvics (1981) in M_3 and M_4 of soybean. Griffith and Johnston (1962) showed that in oats, seed irradiation caused mutations with regard to yield only in the minus direction. Matsuo *et al.* (1964) who observed significant differences between M_6 mutants and control with respect to weight of panicle, reported that mutation in polygenes could occur in positive as well as negative direction. Increase in yield by combining hybridization and induced mutation, as observed in the present study, is in agreement with the result obtained by Savov (1980) in wheat.

In majority of the polygenic traits studied, it was seen that irradiation of cross breds gave better result than irradiation of pure breds. A wider variability is created by cross bred irradiation. This result is in confirmuty with the conclusions made by Joshva et al. (1967) in rice, Siddiqui (1971) and Milkovski et al. (1976) in cotton. Siddiqui (1971) attributed the increased variability to enhanced recombination frequency and the release of hidden genetic variability. Mareen (1985) also reported that hybrid materials of bhindi were more sensitive to mutagen compared to pure breds. This may be due to the fact that the crop used for the present study was a polyploid. Normally polyploids are more resistant to mutagen treatment compared to diploids. The present study clearly reveal that to have mutation breeding in polyploids like bhindi, irradiation of cross breds would be more reliable to get wider variability than hybridization or irradiation of pure seeds.

M_1 sterility and character expressions in M_3

Table 38 gives the distribution of maximum and minimum mean values for the different quantitative characters

Table 38. The maximum and minimum mean values among the three M_1 sterility classes

Treatments	Plant height		Days to flowering		No. of leaves		No. of branches		Fruit length		Fruit weight		No.of fruits		Yield	
	Maximum	Minimum	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Pusa Sawani	H	M	H	L	M	L	M	L	M	L	L	H	M	H	M	H
Kilichundan	L	M	L	H	M	H	H	L	M	L	L	H	L	H	L	H
Co-1	L	H	M	L	L	H	L	H	L	M	L	H	M	M	M	H
PS x Co-1	M	H	H	L	L	H	L	M	L	M	L	M	L	M	L	M
Co-1 x PS	M	L	M	H	L	M	H	M	M	H	M	L	H	L	M	L
PS x KC	M	L	H	L	M	L	H	L	M	L	M	L	H	L	H	L
KC x PS	M	H	M	H	M	L	M	L	M	H	M	L	H	L	M	L
Co-1 x KC	M	L	M	L	H	L	H	M	L	M	L	M	H	L	L	M
KC x Co-1	M	H	H	L	M	L	L	H	M	H	M	H	M	L	M	L

L - Low M_1 sterility group

M - Medium M_1 sterility group

H - High M_1 sterility group.

among the three M_1 sterility classes, in the third generation. The maximum and minimum phenotypic distribution of negative and positive mutants induced by gamma rays among the three M_1 sterility classes is given in the tables 39 and 40.

In Kilichundan and Co-1, the maximum plant height was observed in the low sterility class, whereas in Pusa Sawani, the high sterility group recorded the maximum mean value. In all the cross breds, the medium sterility group recorded the highest mean plant height. Dwarf types are seen in the medium sterility group in Pusa Sawani and Kilichundan. In Co-1 x PS, PS x KC and Co-1 x KC, the low sterility group showed the lowest mean value. In Co-1, PS x Co-1, KC x PS and KC x Co-1, the high sterility group recorded the minimum value.

Early flowering types were observed in the low sterility group in Pusa Sawani, Co-1 ,: PS x Co-1, PS x KC, Co-1 x KC and KC x Co-1. In Kilichundan, Co-1 x PS and KC x PS, high sterility group yielded the early flowering types. Number of leaves were maximum in the medium sterility group in Pusa Sawani, Kilichundan and their crosses. But Co-1 and its hybrids with Pusa Sawani had maximum number of leaves in the low sterility group. Maximum number of branches per plant was observed in the medium sterility group in Pusa Sawani and KC x PS. The low sterility group recorded the maximum number of branches in Co-1, PS x Co-1 and KC x Co-1.

Table 39. Maximum and minimum phenotypic distribution of negative and positive mutants induced by gamma rays among the three M_1 sterility groups in third generation.

Treatments	Plant height				Days to flowering				Number of leaves				Length of fruits			
	Negative variants		Positive variants		Negative variants		Positive variants		Negative variants		Positive variants		Negative variants		Positive variants	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Pusa Savani	M	H	H	M	L	M	L	H	L	M	H	L	L	H	H	M
Kilichundan	L	M	M	H	M	H	L	H	H	L	L	H	H	M	M	H
Co-1	H	L	L	M	L	M	H	L	H	M	M	L	H	L	L	H
PS x Co-1	L	M	M	H	L	H	H	L	H	L	L	H	M	L	M	H
Co-1 x PS	H	M	M	L	L	M	M	L	H	M	H	M	L	H	L	M
PS x KC	L	H	M	L	L	M	L	H	L	H	H	L	L	H	H	L
KC x PS	L	H	L	H	M	L	M	H	L	H	H	M	H	L	M	H
Co-1 x KC	L	H	H	M	H	M	L	H	L	H	H	M	M	H	H	M
KC x Co-1	M	H	M	H	H	M	M	H	M	H	L	H	H	M	M	H

Table 40. The maximum and minimum phenotypic distribution of negative and positive mutants induced by gamma rays among the three M_1 sterility groups.

Treatments	Fruit weight				Number of fruits				Fruit yield			
	Negative variants		Positive variants		Negative variants		Positive variants		Negative variants		Positive variants	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Pusa Sawani	H	M	L	M	H	L	H	L	H	L	L	H
Kilichundan	L	H	M	H	H	L	L	H	H	L	L	H
Co-1	H	H	M	H	H	M	M	H	H	M	M	H
PS x Co-1	H	L	L	H	M	L	L	M	M	L	L	M
Co-1 x PS	L	M	M	L	H	M	M	H	H	L	M	L
PS x KC	M	H	M	L	M	L	H	L	L	M	M	L
KC x PS	L	M	M	L	L	H	M	L	M	H	H	M
Co-1 x KC	M	L	L	M	L	H	H	M	L	M	L	M
KC x Co-1	H	L	M	L	H	L	M	H	L	H	M	L

As regards the fruit length, majority of the treatments recorded maximum value in the medium sterility group. Fruit weight is also maximum in the medium sterility group in Co-1 x PS, PS x KC, KC x PS and KC x Co-1. All the other treatments recorded maximum fruit weight in the low sterility group. The mean value for the number of fruits also varied among the three M_1 sterility classes depending on the genic status. In Pusa Sawani, Co-1 and KC x Co-1, the maximum mean value was observed in medium sterility group. But in crosses such as Co-1 x PS, PS x KC, KC x PS and Co-1 x KC, the high sterility group recorded the maximum mean value. Medium sterility group represented the highest yielders in Pusa Sawani, Co-1, Co-1 x PS, KC x PS and KC x Co-1. But in Kilichundan, PS x Co-1 and Co-1 x KC, the low sterility group gave the maximum yield.

The variation in the mean value among the different sterility classes is due to the production of varying frequencies of negative and positive variants, which in turn is dependent on the character and genic status. In majority of treatments it has been observed that individuals with desirable attributes such as tallness, early flowering, more number of leaves and branches, higher yield etc. were obtained from either low or medium sterility classes.

Gaul (1958) studying the effect of X rays on mutation frequency in Spikes having different sterility, suggested that selection of more fertile spikes which do not possess severe chromosomal aberrations will be a good approach towards maximization of mutation frequency. Similar results were obtained by Bekendam (1961) in rice and by Hildering and Van Der Veen (1966) in tomatoes. Ehrenberg _et al._ (1961) demonstrated that spikes belonging to different sterility classes showed different mutation rates. Kivi (1965) studying the effect of gamma rays in barley, obtained the maximum mutations in spikes having medium fertility (31-70%). This is supported by the work of Sharma and Bensal (1970) in barley. They obtained the highest mutation frequency at 50% fertility after gamma irradiation.

SUMMARY

SUMMARY

The mutagenic effect of ^{60}Co gamma rays on different genotypes of Bhindi (three pure breds and their cross combinations) have been studied in detail in M_3 and M_4 generations. The experiment was conducted during 1983-85 at the Department of Agricultural Botany, College of Agriculture, Vellayani, with the main objective of assessing the extent of induced polygenic variability in the segregating generations of irradiated pure breds and hybrids. The seeds of treated hybrid materials, their control, parental varieties and 30 kR exposed parental types were collected from the second generation and carried forward to the third and fourth generations. Data on plant height, number of days to flowering, number of leaves per plant, number of branches per plant, length of fruit, weight of fruit, number of fruits per plant and fruit yield per plant were collected.

The tabulated data were analysed statistically following Fischer (1935). Percentage frequencies were transformed by the angular as proposed by Snedecor (1956). The following conclusions were made from the experiment.

1. The mean value in polygenic traits varied depending on the genotype, generations and character under study.

2. All the genotypes created both negative and positive variants in all the characters due to the effect of gamma rays.

3. The frequency distribution of positive and negative variants varied widely with respect to the genotype and the generation.

4. In the M_3 generation, there was a negative shift in plant height in all the pure breds due to gamma ray exposure. But in majority of the crosses, a positive shift was observed in F_3 and F_3M_3. The range of positive variants created was highest in the irradiated cross breds. The frequency of negative variants was lower and that of positive variants was higher in the fourth generation, compared to the third generation and hence selection for tall plants could be done effectively from cross breds in the fourth generation.

5. Early flowering types were observed with a higher frequency in crosses involving Co-1. Selection for early flowering types could be more effectively done in the fourth generation ratner tnan in the third generation due to the occurrence of higher frequency of negative variants. Compared to cross breds, irradiated pure breds gave higher frequency of negative variants.

6. Cross breds in the fourth generation exhibited higher number of leaves, compared to those in the third genera-

tion. It was found that hybridization alone or together with irradiation was more effective than irradiation of pure breds in increasing the number of leaves.

7. A genotype dependent insignificant variation in the mean number of branches was observed in both third and fourth generations. Comparatively more number of treatments exhibited positive shift in mean number of branches in F_4 and F_4M_4.

8. As regards the length of fruit, majority of irradiated cross breds exhibited positive shift rather than non-irradiated cross breds. The range of negative variants created in F_3M_3 was lower than that in M_3 and F_3. Highest range of positive variants was seen in the fourth generation of irradiated cross breds.

9. Mutagen treatment led to a general increase in mean fruit weight. Compared to the third generation a wider range of negative and positive variants was observed in the fourth generation.

10. In the case of number of fruits also, the shift in mean value varied depending on the genotype and the generation. Irradiation of cross breds was found to be more effective in creating significant increase in fruit number. The range in positive variants was wider in the fourth generation compared to the third generation.

11. A significant positive shift in mean fruit yield was noticed in F_3M_3 involving Kilichundan. But in F_4M_4 they exhibited a negative shift. In the cross bred irradiated population a wider variability was created, compared to pure breds and non-irradiated cross breds. The range of positive variants in the fourth generation was higher than that in the third generation.

12. M_1 sterility influenced mean character variations were noted in majority of the characters. Majority of treatments had higher frequency of desirable phenotypes in the low or medium sterility class.

13. In majority of the characters studied, desirable variation was observed in the gamma ray irradiated cross breds. The fourth generation exhibited more variability compared to third generation which offered scope for a positive selection response.

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* Originals not seen.

PLATES

Plate 1. A general view of the experiment - Segregating population (Third generation).

Plate 1

Plate 2. Segregants showing plant height variations in M_3 generation.

Plate 3. A profusely branching mutant in M_3 generation.

Plate 2

Plate 3

Plate 4. Leaf size and shape variations in the segregating population (M_3 generation).

Plate 5. Leaf size and shape variations in the segregating population (M_3 generation)

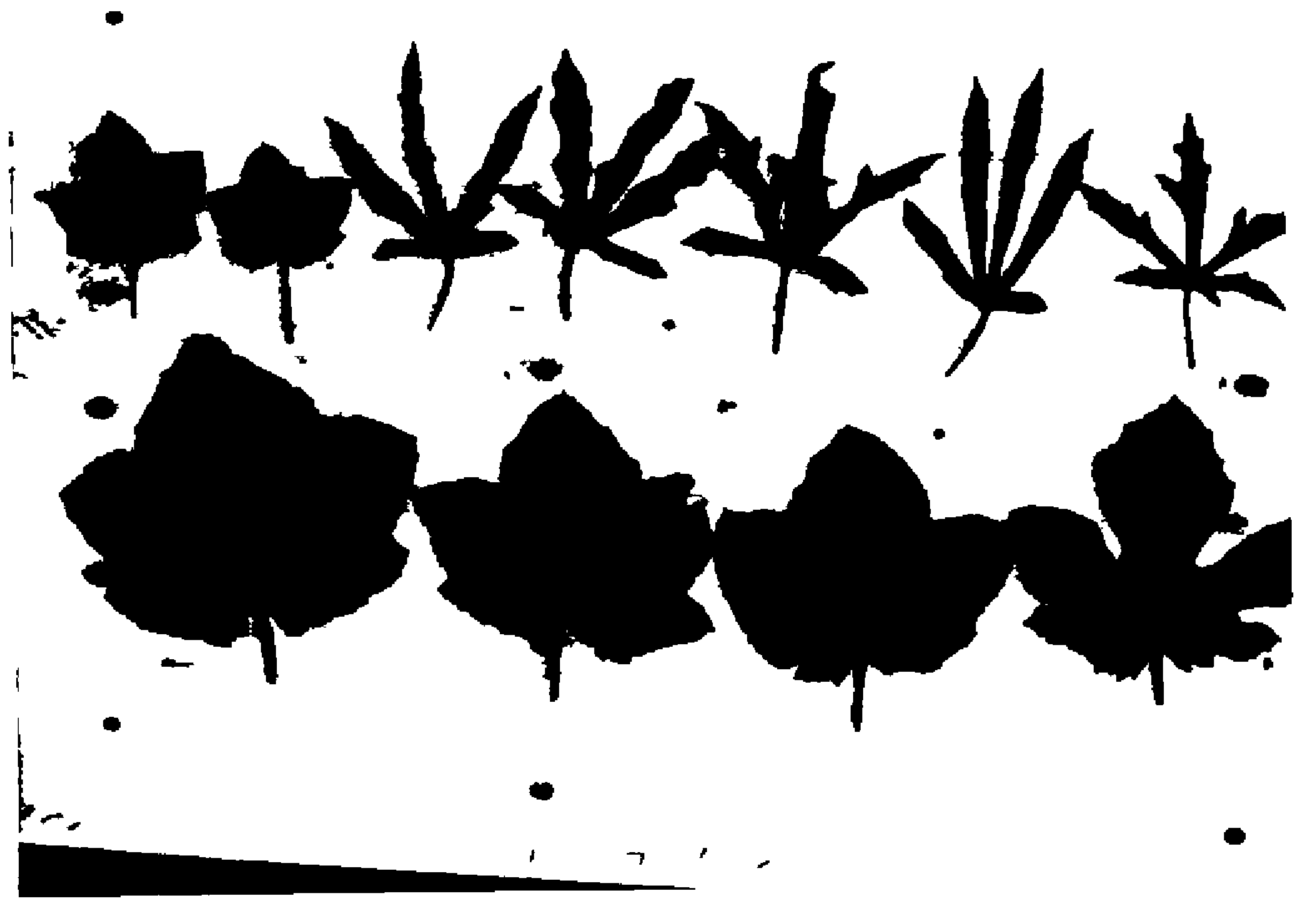

Plate 4

Plate 5

Plate 6. A broad leaved dwarf plant.

Plate 7. A broad leaved tall plant.

Plate 6

Plate 7

Plate 8. A narrow leaved dwarf plant.

Plate 9. A narrow leaved tall plant.

Plate 8

Plate 9

Plate 10. Fruit size variations in the segregating generation.

Plate 11. Fruit colour variations in the segregating generation.

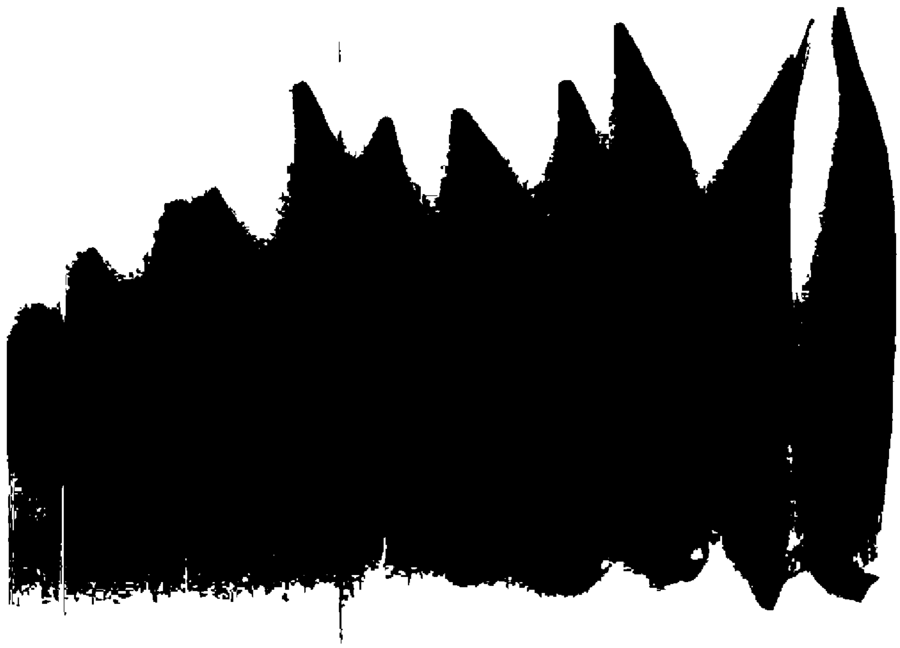

Plate 10

Plate 11

Plates 12 and 13. Plants showing twin fruits in M_3 generation.

Plate 12

Plate 13

GAMMA RAY INDUCED POLYGENIC VARIABILITY IN BHINDI

BY

AHMED REGINA B.Sc.(Ag.)

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement
for the degree of
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
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DEPARTMENT OF AGRICULTURAL BOTANY
COLLEGE OF AGRICULTURE
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ABSTRACT

The present investigation on 'Gamma ray induced polygenic variability in Bhindi' was carried out in the Department of Agricultural Botany, College of Agriculture, Vellayani during 1983- '85. This study was taken up as a continuation of the Post-graduate project for the year 1981-83 entitled 'Genic status in relation to radiosensitivity, mutation frequency and spectrum in Bhindi'. Three pure bred varieties (Pusa Sawani, Kilichundan and Co-1) and their crosses in all possible combinations were used for the study. The extent of variability created by 30 kR ^{60}Co gamma rays in quantitative characters was assessed in the segregating generations of M_3 and M_4 of the pure breds and the hybrids along with the respective controls. The experiment was laid out in RBD with two replications. Data were collected on (1) Plant height (2) number of days to flowering (3) number of leaves per plant (4) number of branches per plant (5) length of fruit (6) weight of fruit (7) number of fruits per plant and (8) fruit yield per plant. In the third generation, the mean value shift and the frequency of negative and positive variants compared to the control was studied. The variation in mean value and frequency distribution with respect to different M_1 sterility classes were also assessed in the third generation. Based on the

yield performance in M_3, selection was made and carried forward to the fourth generation to assess variability in polygenic characters. The tabulated data were analysed statistically.

All the characters analysed showed difference in expression depending on the genotype and the generation. Both positive and negative variants were created in all the genotypes for all the characters. Desirable variation was observed in gamma ray irradiated cross breds in majority of the characters studied. The variability created was higher in the fourth generation, compared to the third generation. Tallness was induced in majority of the cross breds in the third generation. The frequency of negative variants for plant height was lower and that of positive variants was higher in the fourth generation. Early flowering character was induced with a higher frequency in irradiated pure breds compared to cross breds. The experiment clearly showed that selection for early flowering types could be more effectively done in the fourth generation due to the occurrence of higher frequency of negative variants. Comparatively more number of treatments exhibited higher number of leaves and branches in the fourth generation. Fruit characters such as length, weight and number were found to be enhanced by the irradiation of cross breds. A Wider range of variability was observed in the fourth generation with respect to these characters. All the genotypes involving Kilichundan showed increased fruit yield due to gamma ray exposure. Compared to pure breds and non-irradiated cross breds, a wider variability was created in irradiated cross breds. Depending on the M_1 sterility class, the phenotypes were found to be distributed both in negative and positive directions in all the characters analysed. Higher frequency of desirable phenotypes were observed in the low or medium sterility class, compared to the high sterility class, in majority of the treatments.

The increased variability created by gamma rays for different quantitative characters in the segregating generations helped to select out few plant types with desirable character combinations. Follow up work involving preliminary and comparative yield trials can help in selecting out one or two cultures which can outyield all the high yielding varieties available at present in this particular crop.