CHAPTER 2
REVIEW OF LITERATURE

Although induction of mutations and polyploidy is comparatively a new branch of cytogenetics, it has already received extensive attention and a vast quantity of literature has accumulated. Since it is not possible to review this literature in its entirety, it is necessary to make a selection. The present review, therefore, does not aim at completeness. The literature mentioned here is to be taken simply as an illustration of the nature of work that is being conducted by various investigators.
2.1. INDUCTION OF MUTATIONS

*Cereals*

Saric *et al.* (1961) studied the effect of gamma rays on wheat seeds with respect to the morpho-physiological characteristics of seedlings and found that some of the investigated doses were stimulant and others inhibitory. The percentage of germination as well as height and weight of seedlings decreased with increase in dose. Reaction of the varieties tested towards the same dose was different.

Palenzona (1961) observed in wheat seedlings that the "reversal phenomenon", that is, a sharp depression of seedling growth dependent on the radiation dose and a subsequent partial recovery at very high doses, was dependent on the ploidy level of species and on the moisture level of seeds.

Borojevic and Borojevic (1969) studied stabilization of induced genetic variability in irradiated population of *vulgare* wheat. The results showed that stabilization of the characters in irradiated population began in the $M_5$ generation, reaching the mean values of the control and achieved constancy in later generations.

Kivi and Ramm-Schmidt (1969) obtained sprouting resistant mutants from Co$^{60}$ irradiated population of Finnish spring wheat variety Ruse.

Kapoor and Natarajan (1971) grew six varieties of hexaploid bread wheat (*Triticum aestivum*) under chronic exposures of gamma rays. Among varieties tested, three
varieties (N.P. 797, 798 and 836) under identical conditions responded differently with reference to characters like plant height, seed fertility, morphological abnormalities and viable mutations.

Peixoto Gomes (1972) irradiated seeds of three wheat varieties with the objective of shortening their straw without altering other important characteristics. No short straw mutants were obtained, but mutants with improved resistance to *Puccinia graminis tritici* were observed.

Singh *et al.* (1972) observed in mutation studies on bread wheat (*Triticum aestivum*), using chemical as well physical mutagens, that the treatments which had resulted in higher sterility in *M₁* gave higher mutation percentage of phenotypic detectable types irrespective of treatment, dosage effect, varietal response or geno-type treatment interaction.

Shakvarnikov *et al.* (1976) subjected different varieties of *T. aestivum* and *T. durum* to a large number of physical and chemical mutagens for induction of mutations. Different varieties responded differently to radiation treatments. Mutants possessing some good economic traits, *viz.*, heavier grains, higher glutin content, better baking qualities, etc. were scored.

Valeva (1976) studied induced mutations in wheat at various ploidy levels, that is, diploid, tetraploid and hexaploid with gamma rays and ethylene imine. Presence
of varietal response was found dependent on genotypic constitution in addition to ploidy levels. From the results it was concluded that the species from higher ploidy groups, on the whole, showed a greater degree of resistance towards mutagenic treatments with regard to parameters studied. Yet they might show higher mutability if the genotypes selected are cultivated varieties.

Puzakova et al. (1978) studied effect of gamma irradiation on winter hardiness of 'ulyanovka' winter wheat. The doses which inhibited growth promoted simultaneously the accumulation of reducing sugars and free amino acids, and in the autumn made the plants more hardy for survival.

Sharma and Gupta (1978) treated seeds of T. durum with different doses of gamma rays, ethyl methane sulphonate and hydrazine (0.50%) for different durations to demonstrate their cytogenetic effects. LD 50 was observed to lie between 6 hr and 12 hr treatment for EMS whereas it was below 6 hr treatment for hydrazine. Structural aberrations such as translocations were observed only in 10 Kr and 30 Kr gamma ray treatments.

As early as 1928, Stadler reported artificial production of mutations in barley by the use of X and gamma rays. Almost all the mutations induced were lethal and of no practical value.
Gustafsson (1947) observed the occurrence of useful induced mutations in barley for such characters as height of straw, earliness and lateness, strength of straw, chemical properties, brewing characteristics, protein content, 1,000 grain weight and tillering capacity.

In barley Gaul (1961) observed that the frequency of M_2 chlorophyll mutations decreased significantly in later formed tillers.

Heslot et al. (1961) concluded that radiomimetic substances like EMS were more effective in inducing mutations in barley than ionizing radiations.

Gaul (1965), after measuring the frequency of chlorophyll mutations, observed that the increase in mutation frequency was linear with increase in the dose. EMS appeared to be a more powerful mutagen than X-rays.

Walther (1969) considered the number of chlorophyll mutations in the M_2 generation as the basis for calculating efficiency of X-rays and thermal neutron irradiation on dormant seeds of barley. After the studies he proposed a factor of effectiveness which could give information on the number of mutations per 100 irradiated seeds.

Gaul et al. (1969) observed that micro-mutations are more important for direct use in plant breeding than macro mutations. They showed that it was relatively easy to select micro-mutations having a yield potential 10% higher than the mother variety and it was expected that the yield potential can be further raised in second, third and
later cycles of mutagenic treatment by selection. It was suggested that for the continuous improvement of newly released varieties, particularly the top varieties, the micro-mutation techniques should be used and combined with maintenance breeding.

Sharma and Bansal (1971) showed that mutation frequency in barley was higher when its EMS treated seeds were dried back in comparison to those sown in high moisture conditions.

Doll (1972), after treating the seeds of barley (var. Carlsberg II) with EMS, induced a large variation in dry matter yield but no mutant was observed with a significantly higher yield of proteins or non-protein dry matter per unit area. The non-protein yield of mutant lines was found to be reduced more than the protein yield due to which an increase in percentage of protein in most of the mutant lines was noticed.

Gustafsson et al. (1972) were able to increase short dormancy periods in barley var. Kristina by mutagenic treatments.

Hansel et al. (1972) treated seeds of a cross-bred strain of spring barley with thermal neutrons and EMS. From $M_2$ to $M_8$ positive selection for yield and kernel width was carried out under varying selection pressures. Results with selection for yield in early generations were better after neutron irradiation than after EMS treatment but in later generations the best lines of both treatments gave similar results.
Joshua et al. (1974a) observed that combined treatment of barley with fast neutrons and diethyl sulphate resulted in synergistic effects on both anaphase chromosome fragments and bridges. Storage of seeds after neutron irradiation had no significant effect on frequency of fragments and bridges.

Joshua et al. (1974b) further studied the effects of fast neutrons and gamma rays on seedling height and chromosome aberrations in barley. In response to the treatments a synergistic effect on seedling height was noted. Further, the presence of chromosome fragments and anaphase bridges showed an additive effect with combined treatments.

Thakare et al. (1974), after combined treatment of barley seeds with thermal neutrons and dES, obtained a slight synergistic effect in seedling height at lower doses and protective effect at higher doses, while combined treatment of gamma rays and dES gave synergistic effect on seedling height at all the doses tested.

Sethi (1975) treated the dormant seeds of C 164 variety of barley with EMS, gamma rays, $p^{32}$ and $s^{35}$. 147 viable mutant types were scored in $M_2$ and confirmed in $M_3$ generation. These included Dwarf, Erectoides, Stiff straw, Very early. Early, Profuse tillering, Synchronous tillering, Late leaf senescence, Long broad leaf, Erect leaf, Dark green leaf, Liguleless cum-auricleless, Thick stiff culm, Male sterile, Thick green, Double floret, Brittle
awn, Multinodosum-cum-monopodial branching, Many noded dwarf, Thick culm- dwarf and Long peduncled dwarf. Mutants obtained were meiotically normal and fully fertile.

Influence of DMSO (dimethyl sulphoxide) on the mutagenicity of EMS in barley was studied by Khalatkar (1976). Dry and soaked seeds were treated with EMS alone and in combination with DMSO. M₁ and M₂ generations indicated that DMSO was not a good carrier for EMS. With EMS + DMSO treatments a slight decrease in mutation frequency in M₂ was observed.

Li et al. (1961) utilized X-radiation to produce mutant lines in 10 varieties of rice belonging to both japonica and indica types. From six of the 10- X-irradiated varieties 37 promising lines were derived. These consisted of 20 high yielding morphologically and physiologically normal lines, 5 short-culmed, 3 erectoid (short culmed but with markedly high stiffness of the culm), 4 multibranched and 2 early types which all excelled their mother varieties in yield. In one of the X-ray treated indica variety three non-shattering mutant lines were found.

In order to induce short-culm mutation in rice variety Norin No. 22, its seeds were treated with radioactive P³² by Kauai et al. (1961). In mutant generations only those plants were selected in which yield seemed to be not notably decreased. After obtaining some required mutant types it was felt that by radiation, a long culm
variety can be changed to a short culm form without impairing its productivity.

Gopal-Ayengar et al. (1969) investigated the modification of the efficiency of diethyl sulphate (dES) on pre-soaked rice seeds. Highest mutation rates were noted after 2 hour treatment of dry rice seeds with 1.0% dES and subjecting 48 hours pre-soaked rice seeds to 0.2% dES for 2 hours. It was observed that pre-soaking sensitized the seeds to chemical treatments and removal of husk from the seeds enhanced their rate of germination and the efficiency of the chemical two-fold.

For inducing some useful mutations in rice Tanaka (1969) irradiated rice plants at the growing stage in addition to irradiating the dormant seeds. Irradiation proved effective in inducing useful mutations in both visible characters and chemical components. Mutants were found possessing useful characters like early maturity, blast resistance and high protein content.

Sharma et al. (1974) subjected the seeds of rice variety Jagannath and Rexero-R11 to EMS treatments. In treated population of var. Jagannath a high range of variation for days to heading was noted and maximum variability was obtained in 23 hr treatment. In $M_3$ and $M_5$ generations 11 early maturing mutants (5 from Jagannath and 6 from Rexero-R11) were obtained which showed higher yield than the parent varieties. From var. Jagannath one of the mutants also showed an improvement in fine grain quality.
Tsukada et al. (1976) studied mutagenic effects of some physical and chemical mutagens on rice plants. Highest frequencies of chlorophyll mutations and mutations of agronomic traits were obtained after EMS treatments and these frequencies seemed to be three times more than those from gamma rays. Regarding mutagenic effects, ethyl methane-sulphonate and nitromethyl urea seemed equivalent to gamma rays. Differences in mutation spectrum were observed between gamma rays and chemicals and among chemicals.

In order to study the frequency and spectrum of chlorophyll mutations in rice in relation to the genotype and nature of the mutagen, Bhan and Kaul (1976) subjected the seeds of three rice varieties to gamma rays and two alkylating agents (EMS and dES) alone and in combinations. They noted an enhanced chlorophyll mutation frequency with increasing dose but the doses showing 90% seedling lethality showed a drop in mutation frequency. Albina type chlorophyll mutants constituted a major class in chlorophyll mutants in M₂ in both physical and chemical treatments. EMS was responsible for inducing significantly higher proportion of albinos than did gamma rays.

Nair and Ninan (1977) studied induced seed fertility and chlorophyll mutation frequency in rice using Co60 gamma rays and EMS. A higher percentage of chlorophyll deficient mutants after EMS treatment and a higher percentage of M₁ sterility with gamma rays were observed. A dose dependent linear increase in higher
sterility classes was obtained in both the mutagens. In both mutagens the sterility classes below 50% gave the maximum frequency of chlorophyll deficient mutants; this effect also proved to be dose dependent.

Majumdar (1979) conducted studies on the response of chromosome and chlorophyll locus in rice to gamma irradiation. Different doses of gamma rays resulted in chromosomal aberrations and with the increase of radiation dose an increase in number of chlorophyll mutants was observed. The total number of chlorophyll mutants induced was higher as compared to the induced frequency of chromosomal abnormalities.

In order to examine any differences in the radiosensitivity of four inbred lines (D4, D65, N6 and Ite 701) and two hybrids of maize (D 65 x D 4 and Ite 701 x N6) Notani (1961) irradiated their dry seeds with X-rays and thermal neutron doses. Differences in radiosensitivity among inbred lines as well as among hybrids were noted. From the results it appeared that radiosensitivity was correlated with growth rate of a line evidenced from seedling height. F1 hybrids were in general more radioresistant than the parents especially at higher doses which was attributed to the general homeostatic and heterotic properties of hybrids.

Gardner (1969) subjected seeds of corn (open pollinated var. Hays Golden) to thermal neutron treatment initially and again at generation 2. It was noted that response to selection was negative in the irradiated sample until treatment was discontinued and from
generation 3 onwards a rapid linear response of 4% per generation was observed. Thermal neutron treatment increased prolificacy and thus increased additive genetic variance for both prolificacy and grain yield. Selection pressure in both control and irradiated populations resulted in higher grain yield, greater prolificacy, taller plants and later maturity; however, at generation 10, selected control and irradiated populations were equal but in case of irradiated population good future gains and a higher selection limit were predicted.

Singleton (1969) tried to induce mutations in maize with thermal neutrons utilizing the proposal that mutation can be obtained after one self-pollination in maize if the same mutated cell goes to make up both the tassel and the ear and carrying the material to the \( M_3 \) generation. The results obtained showed that 4.8% of the total progenies tested segregated for some seedling characters mostly in good monogenic ratio. Further most segregations were for albino seedling, but a few were for such characters as luteus, yellow-green, virescent and dwarf.

Jordanka (1978) studied the effects of repeated EMS and NMU treatments on the mutability in C-103 and F-7 inbred lines of maize. Following repeated NMU treatment, the mutant plant frequency and spectrum did not increase as compared to EMS. With repeated EMS treatment of seeds, hereditary variation was induced. However, repeated treatments with EMS and NMU proved of no significance in mutation breeding of maize.
Klingmuller (1961) noted a marked increase in radiation sensitivity in *Vicia faba* minor when the seeds were dried to low moisture content before irradiation.

Wellensiek (1961) irradiated dry seeds of pea cultivar 'Dominant'. In the progeny of one irradiated pea seed two mutants, namely 'early flowering' and 'very early flowering' were found which differed from the original cultivar by 13 and 28 days respectively in time of flowering.

Gottschalk (1961) obtained nearly 400 mutants in *Pisum* through X-irradiation of its seeds.

Ahund-Zade and Hvostova (1966) treated dry seeds of pea var. 'Pioneer' with various mutagens for cytogenetical analysis of the mutagenic effects of ionizing radiations and alkylating compounds. Symmetrical translocation, inversions and micronuclei were observed after meiotic studies. Reduced seed set resulted after treatment with gamma rays and fast neutrons.

Variability in quantitative characters of field been (*Vicia faba* L.) was studied by Disler (1966) under the influence of mutagenic factors. An increase in the range of spontaneous variability in plant height and number of pods and seeds per plant in mutating cultivar was observed after treatments with EI, EMS and gamma rays.
Moh (1972) induced variations in seed coat colour of some black bean (*Phaseolus vulgaris*) varieties of Latin America. Mutagenesis resulted in inducing some seed coat colour mutants which varied from white, yellow to various degrees of brown and their seed coat colour was associated with a change in hypocotyl colour from red to green. All these mutants were bearing white flowers instead of red of the parents but their morphology, growth habit and disease resistance were similar to those of the parents.

Narsinghani and Kumar (1976) subjected the seeds of coupea (*Vigna sinensis* L. Saviex Hassk.) to EMS and MMS treatments. In *M₁* and *M₂* generations reduction in survival percentage, mean pod number, seed yield per plant and average pollen fertility was observed which was less in *M₂*. A few long podded mutants, chlorophyll mutants and leaflet modifications were recorded.

Mujeeb and Greig (1976) induced mutations in French bean (*Phaseolus vulgaris*) var. "Blue Lake" by irradiation with gamma rays. Irradiation acted as a stimulant for seed germination, seedling height, and length of primary leaves. However, chlorophyll content per leaf area remained unaffected.

Prasad (1976) attempted varietal improvement of green gram (*Vigna radiata*) to isolate mutants having high yield potential and at the same time possessing tolerance to drought conditions prevailing in dry lands. Pre-soaked
seeds of green gram var. RS 4 were subjected to aqueous solutions of 0.2% and 0.3% concentrations of EMS. Ten mutants with higher number of pods than parent were scored in M₂ and tested under dry land conditions along with the parent and the highest yielding check. A mutant strain M 8 was found consistently maintaining its superiority in yield and pod number per plant as compared to the parent and highest yielding check under varying conditions of rainfall and also exhibited a combination of higher yield potential, earliness of maturity and tolerance to drought conditions.

Nerkar (1976) treated seeds from 5 varieties of Lathyrus sativus with gamma rays, EMS, NMU and combined treatments of gamma rays and NMU. After computing frequencies of chlorophyll and viable mutations on progeny basis it was found that they were dose-dependent, irrespective of the genotype, but while calculating frequencies of chlorophyll and viable mutations on the basis of M₂ population this trend was not maintained in all genotypes. Nitrosomethyl urea was found to be the most potent mutagen for the induction of mutations followed by EMS and gamma rays. The combined treatments revealed no synergistic effects.

Rao and Jana (1976) subjected the seeds of black gram (Phaseolus mungo) to X-rays and EMS treatments with the objective of obtaining some promising mutants.
The induced leaf mutants scored comprised of crinkled leaf, waxy-leaf, narrow-leaf and unifoliate mutants.

Vasileva and Mekhandzhiev (1977) treated dry seeds of two pea cultivars with 0.1 - 0.6% buffered solutions of dES and EMS and 0.01 - 0.6% solutions of El. Mutagenic effect was found dependent upon mutagen concentration and plant genotype. EMS treatments gave highest mutation frequency while dES treatments the lowest.

In Phaseolus aureus Roxb., the effect of gamma rays on dry seeds, seeds pre-soaked in distilled water and seeds pre-treated with 0.2% colchicine was studied by Raghuvanshi et al. (1978). Pre-soaking of seeds was found to affect the germination adversely. In M2 generation fringed leaf, strap leaf, advanced stigma and trisomic and male sterile mutants were isolated.

To test the effectiveness of gamma radiation on the induction of quantitative variations in 3 broad bean varieties (Vicia faba L. var. Sinjar, Egyptian and French) Kasim et al. (1978) exposed the seeds to different gamma ray doses. In M1 generation response in the three varieties was different but all the varieties exhibited earliness of flowering and increase in stem length. In all the varieties tested no relationship existed between the magnitude of irradiation and the amount of induced genetic variability.
Molkhova and Vasileva (1977) isolated three gamma ray induced mutants of pea.

Chandra and Tewari (1978) observed that in bean (*Phaseolus aureus* Roxb) var. S-8 and Pusa Baisakhi increasing doses of gamma rays and neutrons caused a gradual reduction in germination of seeds and pollen and ovule fertility. Irradiation caused the appearance of leaf abnormalities including unifoliate, bifoliate, trifoliate, tetrafoliate and pentafoliate characters.

Bhattacharya (1978) noted that in *Glycine max* L. var. Bragg a dose of 10 Kr gamma rays improved growth, yield and other characters while higher doses showed progressive inhibition.

Niknejad et al. (1978) tried to alter the mutation spectrum of a highly spontaneous mutable chickpea pure line (*Cicer arietinum* L.) by treatment with two radiomimetic substances - EMS and NaN₃ but their attempt failed in producing a significant change in mutation spectrum.

In order to demonstrate the role of DMSO in influencing the mutagenic effect of EMS Chaturvedi and Singh (1978) subjected dry seeds of mung been cv. Pusa Baisakhi to aqueous solutions of mutagen and 1% DMSO. Studies indicated that the DMSO enhanced the effectiveness of chemical mutagen which was evident from reduced germination percentage, seedling height, pollen fertility and seed fertility in *M₄* generation, and increased
frequency, spectrum of chlorophyll and viable mutations in
M\textsubscript{2} generation.

Das and Prasad (1978) studied the influence of
differential and combined treatment of gamma rays
(10–50 Kr) and 0.2% methyl methanesulphonate (MES) on
some varieties of *Lathyrus sativus* L. It was noted that
height of the plant and number of branches per plant
showed dose dependent reduction in all the varieties
at M\textsubscript{1} and both increase and decrease at M\textsubscript{2} as compared to
control.

Khan (1979) treated the dry seeds of mung bean
(*Phaseolus aureus* Roxb.) var. PS-16 with various mutagens.
Mutagenic treatments resulted in a positive shift of mean
values for all polygenic traits except for plant height
and days to flower. Treatments also induced variations for
many quantitative characters which appeared important for
the improvement of mung bean.

In Mung bean (*Phaseolus aureus* Roxb.) Khan and
Hashim (1979) studied the relative mutagenic effectiveness
of three mutagens gamma rays, \textsubscript{A} methanesulphonate (EMS)
and hydrazine hydrate (HZ). HZ proved an effective agent
followed by EMS and gamma rays when effectiveness was
measured as the frequency of mutations induced by unit dose
of mutagens.
Prasad and Prasad (1979) studied differential and combined effects of alkanesulphonates and antibiotics on quantitative characters of French bean (Phaseolus vulgaris). The pattern of effect produced by mono-functional alkylating agents in relation to mean, range variance and co-variance was similar to that of antibiotics.

Dry seeds of red gram (Cajanus cajan var. 55) were subjected to different doses of gamma rays and different concentrations of radiomimetic substances like EMS and N-nitroso-N-methyl urea by Chaturvedi and Sharma (1979). A number of mutants with good agronomic qualities was scored and some of them which bred true in M₃ and M₄ were multiplied further.

Raghuvanshi and Singh (1979) demonstrated the differences in radiosensitivity of diploids and autotetraploids in different genotypes of Trigonella foenum-graecum L at 40 Kr dose of gamma rays. Results showed that even autotetraploids of different genotypes belonging to same species may show tremendous differences in their radiosensitivity.

To enlarge the naturally occurring variations in early varieties of green gram (Vigna radiata L.) its seeds were irradiated with gamma rays by Singh et al. (1979). It was seen that a differential response to irradiation doses existed among genotypes. It was further noted that albina, xantha and chlorina types of chlorophyll...
mutations segregated in the ratio of 1 mutant : 15 normals.

Katyayani et al. (1980a) studied the mutagenic effects of maleic hydrazide (MH) and ethyl methanesulphonate (EMS) on germinating seeds of *Trigonella foenum-graecum* L. Results showed that higher concentrations of EMS (0.05-0.1%) and MH (0.1%) exercised retarding effect on seedling growth while low concentrations of both the chemicals, particularly 0.001% EMS and upto 0.05% MH resulted in its promotion. It was also observed that seed treatment with 0.001 and 0.01% MH and EMS resulted in induction of early flowering.

In *Phaseolus aureus* Roxb. var. Pusa Baisakhi radiation induced mutagenic studies were done by Katyayani et al. (1980 b) after exposing its seeds to gamma rays. Studies revealed that germination percentage showed an increase with lower doses of gamma rays (1-7 Kr), the maximum being at 4 Kr treated samples but with higher doses (8-10 Kr) a gradual decline in germination percentage was observed. The application of doses ranging from 5-7 Kr caused an increase in plant height whereas doses from 8-10 Kr induced early flowering and also increased number of pods per plant.
In order to determine the relative mutagenic effects of EMS and X-rays on induction of mutations in *Capsicum annuum* L, Zubrzycki and Von der Pahlen (1972) treated its seeds with EMS and X-rays. After analysing $M_2$ progenies it was noted that the chemical agent proved to be more efficient and effective in the induction of chlorophyll mutations while in respect of induction of morphological mutations both the agents proved equally effective. It was also noted that the chemical agent caused more damage to ovule viability than X-rays. On the basis of number of chimeras obtained, it was concluded that at the time of treatment different meristems, which give rise to fruits, existed in the seed.

To increase variability in sweet pepper (*Capsicum annuum*) Skripnikova (1976) subjected its seeds to several chemical mutagens. In $M_1$ generation mutagenic treatments resulted in decrease of germination and survival and with the increase in mutagenic treatments retardation of plant growth and development increased progressively.

Khuspe and Ugale (1977) demonstrated the effect of gamma rays and EMS on growth and fruit development of *Capsicum annuum*. In both $M_1$ and $M_2$ generations flowering got delayed to a remarkable extent after mutagenic treatments but EMS proved more effective in this respect.
The weight of 100 dry fruits increased following radiation doses but EMS was ineffective in this respect both in $M_1$ and $M_2$.

Radiocytogenetical studies in *Capsicum annuum* were done by Katiyar (1978a) after subjecting its dormant dry seeds to different doses of gamma rays. Cytogenetical studies revealed meiotic abnormalities including stickiness, clumping, altered associations, breakage, bridges, unequal segregation, laggards and abnormal microspores. Induced chromosomal abnormalities and pollen fertility were found to be dose dependent.

Katiyar (1978b) reported an induced desynaptic behaviour in a variant isolated from irradiated population of *C. annuum* following 20 Kr gamma irradiation and this phenomenon resulted in the production of meiotic anomalies such as micronuclei, polyspory and gametes with varying degrees of gametic imbalance.

Maltseva (1978) detected stimulatory action of gamma irradiation on seeds of three pepper species using a dose of 1200-1800 r. The stimulatory effect was displayed in a more rapid development of plants, earlier flowering and early ripening. The effects observed after gamma irradiation were lost after about 5 or 6 harvests.

In Colombia, *Solanum phureja* Juz. et Buk (creole potato) presented some problems to farmers because of lack of dormancy and also to geneticists and breeders
because of gametophytic self-incompatibility. In order to overcome these problems Gomez Cuervo and Estrade Ramos (1972) tried to alter both the characters by artificial induction of mutations. After seed as well as tuber irradiation phenotypical changes observed in subsequent generations proved mostly harmful for the plants. However, in the irradiated progeny one mutant was isolated whose tubers did not sprout for seven months and another gave fairly high seed set after pollination within the clone.

Boe and Demoura (1976) studied the effects of low dosage of gamma irradiation on emergence, growth, yield and sugar and protein content of potato, *Solanum tuberosum* L. var. Russel Burbank and Nampa. After exposure of seed potatoes to different doses of gamma rays it was noted that higher doses of irradiation delayed plant emergence, decreased tuber yield and tended to increase reducing sugar content of tubers. Total sugar content was variable depending upon cultivar and culture used.

An investigation was undertaken by Majid (1975) to study and compare the frequency and spectrum of mutations induced by non-ionizing radiation (UV light), an ionizing radiation (*Co*⁹⁰−gamma rays) and an alkylating agent (EMS) in two varieties of *Lycopersicon esculentum* and one variety of *L. peruvianum*. Combined treatments of physical and chemical mutagens were also tested for ascertaining the type of interaction caused by such
combination. Treatment with either physical or chemical mutagen was not as efficient in producing a wide spectrum of mutations as the combined treatments which proved quite efficacious in producing higher mutation frequency with broad spectrum of viable mutations. A good number of viable mutations affecting growth, habit, characters of leaf, flower and fruits were scored. (See also Majid, 1969).

In a mutation breeding programme undertaken by Maltseva (1977a) it was noted that the action of pre-irradiation of tomato seeds with a stimulatory dose (2Kr) of gamma rays on the growth, development flowering and fruitfulness of plants, depended on their moisture content. It was noted that seeds at moisture content of 35-40% exhibited no stimulatory effect, seeds at 11-12% moisture levels showed a slight stimulatory effect and seeds at 7-8% moisture content exhibited the greatest stimulatory effect after pre-irradiation.

In a similar experiment Maltseva (1977b) further demonstrated the dose rate dependence of stimulatory action of gamma radiation on tomato seeds. Observations revealed that radiobiological effects of the optimal dose of 2 Kr on tomato seeds depended upon the dose rate. A dose rate of 70-300 r/min was recorded to induce maximal stimulatory effect; dose rates less than 70 r/min were noted to induce a weaker stimulatory action; a dose of 1000 r/min and higher doses exhibited no stimulatory effect.
Zagoreheva and Jordanov (1977) obtained some mutants of tomato after gamma irradiation of seeds with doses of 20 and 30 Kr. In the course of study two genomic mutants (a triploid and a tetraploid form) and a chromosome aberration of the translocation type were separated. To determine the effects of pre-sowing gamma irradiation of seeds on growth, development and yield of tomatoes (var. Revermum F) Gertsuskii et al. (1977) irradiated the tomato seeds with gamma rays. Irradiation at 50–3000 r was noted responsible for accelerated growth and development and increased yield. An increase in yield by 14–16% resulted by irradiation at 50 and 250 r which also resulted in a 22–54% gain in early fruit yield.

Jordanov et al. (1977) studied induced mutagenesis in the tomato line XXIV – a, using gamma rays as mutagen. Their results showed that with 20 and 30 Kr doses the widest spectrum of mutations was produced and a dose slightly above 70 Kr proved lethal. A considerable genetic divergence in $M_2$ and $M_3$ generations was observed. Mutant forms with a high solid content, exerted stigma, short anthers which dehice on outside and plants without shoots were recorded. Among irradiated populations some forms with genomic mutations were also noted.

Yashvir (1977) induced polygenic variation in fruit length of *Abelmoschus esculentus* by the application of gamma
rays, EMS and dES. In M\textsubscript{1} generation all treatments (except 18 h EMS treatment) caused a decrease in mean fruit length. In M\textsubscript{2} generation this parameter decreased with increase in dose. In general, variation in fruit length increased at low doses and decreased at higher doses.

Effects of X-irradiation on physiological and morphological variability in \textit{Abelmoschus esculentus} were studied by Rao and Rao (1978) after exposing its seeds to gamma rays. Irradiation doses from 1-3 Kr were noted to increase germination while higher doses decreased it. A delay in germination and reduction in growth rate were noted at doses of 8 to 10 Kr.

Radiocytogenetical studies on cucurbit \textit{Luffa acutangula} were undertaken by Katiyar and Roy (1977). It was seen that with increase of irradiation dose a consistent increase in the frequency of every type of abnormality occurs. Significant differences were observed in different types of induced abnormalities between irradiated and post-irradiated stored seeds.

Dhopte and More (1978) irradiated air dried seeds of brinjal, \textit{Solanum melongena} L. var. Long White, Pusa Purple Cluster (PPC) and Manjrigota with gamma rays and \textit{R}\textsubscript{1} generation was analysed to know the change if any in quality of fruit with respect to crude protein content, vitamin C content and titrable acidity. The irradiation doses of 40, 60 and 80 Kr were lethal to the var. Long White.
and PPC, while a dose of 80 Kr was noted to be lethal for var. Manjrigota. Results indicated that gamma irradiation increased crude protein content of fruits by 0.87% in var. Manjrigota at 20 and 40 Kr doses while other doses decreased it in PPC by less than 1%. Irradiation treatments also increased vitamin C content of fruits that ranged from 8.13 to 56.91% in Long White, 7.09 to 8.62% in PPC and 10.62 to 26.77% in Manjrigota. Gamma irradiation in general also increased the titrable acidity of fruits.

Khan (1979a) treated the seeds of Solanum melongena var. Purple Beauty with gamma rays, ethyl methanesulphonate (EMS) and diethyl sulphate (dES). After EMS treatment some mutants in M1 generation produced 76-92 fruits per plant against average number of 22 fruits in control. In M2 generation from combined treatment with gamma rays and EMS some mutants showed a significant increase in number of fruits and one mutant among them produced 134 fruits, which was noted to be more than six times of average number produced by control plants. Further, some mutants were found bearing fruits in clusters while some exhibited disease resistance.

Seeds of Solanum melongena var. American Wonder were subjected to the treatments with gamma rays, EMS and dES for the induction of mutations by Khan (1979b). In M1 generation some mutants had two types of fruits differing in shape and size. Combined treatments with gamma rays
and EMS produced some mutants with fruits modified in shape and size and combined treatments with gamma rays and dES resulted in the production of some mutants with higher yields and a mutant with a creeping habit. Induced disease resistance was observed in some mutants of M$_2$ generation and a mutant produced 38 fruits against average of 18 fruits per plant in control (see also Khan, 1980, 1981, 1982a and 1982b).

**Medicinal, ornamental and other plants**

Kaul and Singh (1972) subjected dormant seeds of *Datura metel* to different doses of gamma rays to investigate their effect on its seeds, on the growth and metabolic activities of the plant and frequency and spectrum of viable mutations. Irradiation with different doses resulted in the production of chromosomal aberrations including deletions, duplications and translocations both at mitosis as well as meiosis. With increasing doses of radiations increase in seed lethality, seedling injury and production of chimeral effects such as morphological freaks were observed. In M$_1$ population an increase in the concentration of total alkaloids was noted which was more at lower dose of irradiation.

Kaul and Choudhary (1972) exposed the seeds of *Atropa belladonna* to different doses of gamma rays. Studies were aimed at assessing the variability in polygenic
characters released in $M_1$ and $M_2$ generations. A higher variability was noted in $M_2$ generation than $M_1$. After observing a greater variability for tiller number and alkaloid content than that for plant height and leaf length it was inferred that different characters may respond differently to different mutagenic treatments.

In *Mentha arvensis* Kaul and Kak (1972) were able to obtain a wide spectrum of mutations particularly with chemical mutagens though the number of mutants was not high.

Dnyansagar and Kothekar (1979), subjected the seeds of diploid and tetraploid plants of *Solanum nigrum* L. to different doses of gamma rays to study their effect on various morphological characters. On the basis of parameters studied, variable response to gamma rays was noted between diploid and tetraploid plants and the diploid *Solanum nigrum* proved more sensitive to gamma irradiation as compared to the tetraploid.

Broertjes (1976) irradiated the colchicine induced autotetraploids of three *Achimenes* cultivars with X-rays and fast neutrons. Results of the experiment in one of the cultivars were compared with the irradiation results of a diploid form and it was noted that the mutation frequency in irradiated population of the autotetraploid was 20-40 times higher than in the corresponding diploid. Mutants with some good agronomic qualities were isolated from irradiated population.
An attempt was made by Abraham and Desai (1976) to induce variability and to obtain some useful mutants of single and double type cultivars of tuberose (Polyanthes tuberosa L.). Thirteen mutants were isolated among which eleven with leaf colour variations belonged to single type and two to double. The mutants appeared more frequently with fast neutrons than with X-rays and gamma rays.

Tarar and Dnyansagar (1978, 1980) studied the comparative mutagenic effects of EMS and gamma rays in Turnera ulmifolia Linn. var. anqustifolia Willd. They recorded varying degrees of meiotic irregularities after treatments with the mutagens. An increase in their frequencies was observed with the higher exposure to gamma rays and higher concentration and duration of EMS treatments. It was further noted that frequency of meiotic abnormalities was less in second generation whereas in third generation they were noticed only occasionally. Plants raised from irradiated or EMS treated seeds exhibited earliness or delay in flowering, reduction in the size and number of flowers, and variations in floral parts. However, floral abnormalities were more pronounced in the plants raised from EMS treated seeds and appeared predominantly in the M₄ generation but rarely in subsequent generations.

Prasad and Singh (1978) irradiated dry seeds of safflower var. I.C. 11842 with 45 Kr gamma rays from
a Co$^{60}$ source. One mutant gave a 63.8\% increased seed yield per plant over the parent variety.

Behera and Patnaik (1979) exposed dormant seeds of *Amaranthus hypochondriacus* L. to different doses of gamma rays and chemical mutagens (EMS and dES). A number of viable mutations affecting the leaves and inflorescence was noted in $M_1$ and $M_2$ generations among which fasciation of floral axis resulting in different patterns was common.

In an attempt to obtain some disease resistant mutants in *Musa sapientum* L. var. "Gros Michel" Valez Fortuno and Cedeno Maldonado (1972) irradiated its rhizomes with 2.5 - 40 Kr gamma rays. In $M_2$ generation two mutants were scored, one with drastic leaf deformations and the other with intensive pigmentation and small morphological differences, but they were comparable to the control in respect of height and fruit characters.

In order to enlarge the variability for branching in diploid and tetraploid toria to increase the oil yield of the crops Gupta and Singh (1974) subjected seeds of T-12 strain of toria (*Brassica campestris*) and its autotetraploid to gamma rays. Observations on yield of control and treatment elites revealed that all the treatment populations gave higher yields than control. A significant difference was noted between diploid and tetraploid treatment elites.
Rai and Das (1975) irradiated dry seeds of *Linum usitatissimum* L. var. Hira, Mukta and Neelam with gamma rays to induce mutations. Irradiation resulted in different types of mutations in different varieties. With an increase in the dose of irradiation an overall increase in mutation frequency was noted. A considerable increase was observed in all the mutants in their days to flowering, days to maturity, number of non-bearing tillers per plant and number of leaves per cm on the main tiller while a drastic reduction was noted in their plant height, number of capsules per plant and number of seeds per capsule.

In a gamma irradiated population of peanuts (*Arachis hypogaea*) a suppressed branched mutant was isolated by Mouli and Patil (1976). The mutant had larger leaves, altered flowering pattern, reduced shelling, smaller kernel and branch length being only 20% and 50% of normal in the autumn and spring growing seasons respectively.

Seetharam and Srinivasachar (1976) subjected the seeds of two linseed varieties (*Linum usitatissimum*) to gamma irradiation of varying doses. In *M₁* generation irradiation hampered growth and survival, the deleterious effects being proportional to the dosage. Irradiation also resulted in the appearance of morphological abnormalities and delayed flowering in *M₁*. In the *M₂* generation the 60 Kr dose gave maximum frequency of chlorophyll and viable mutations. Among the chlorophyll mutations scored,
viridis occurred more frequently. The visible mutants scored included change in flower and seed colour, change in petal arrangement and male and female sterile types.

In the selection of apple trees with good agronomic traits Kolontaev and Kolentaev (1977) used radiation mutagenesis. Grafts of Anatonovka apple trees were X-irradiated and the three groups of morphological mutants scored included slow, average and rapidly growing plants. It was noted that after a dose of 6 Kr weak-growing mutants appeared frequently while early growing ones appeared after a 2 Kr dose. Each group of mutants differed in early and late fruiting, type of fruiting and yield.

With the objective of obtaining some dwarf apple mutants Kopan and Kopan (1977) subjected apple seeds to gamma rays and chemical mutagens. Some treatments were found to be responsible for variability of hybrid seedlings in relation to growth vigour and viability.

Chopra and Singh (1979) studied the morphological responses of *Guizotia abyssinica* an oil seed crop of economic importance, to three different concentrations of 2, 4-D, 4 acute doses of gamma rays and varying combinations of 2, 4-D concentrations and gamma ray doses given at the seed stage. Results indicated that combined treatments exercised a greater deleterious effect on germination as compared to individual treatments. Further it was noted
that growth of the plants was inversely proportional
to the increasing gamma ray doses and 2,4-D concentrations
but greater retardation was recorded in combined treatments.
Treatments also induced a variety of morphological
anomalies in leaves.

Variability in the growth of apple tree grafts after
spring treatment of scions with Co$^{60}$ gamma irradiation was
studied by Potapov and Kanashina (1979). Acute irradiation
resulted in the production of forms with reduced growth
characteristics. Irradiation also resulted in increased bud
awakening and spur formation. Irradiation of grafts with
1.5 to 4.5 Kr resulted in grafts with maximum spur formation.

2.2. INDUCTION OF POLYPLOIDY

Das and Krishnaswami (1964) subjected the mulberry
seeds (varieties SRS -1 and Bush Malda ) to different
concentrations of colchicine solution to induce polyploidy.
It was observed that percentage of germination was higher
in treated seeds than in control but higher concentrations
proved lethal to the seedlings of both the varieties.
Immediate effects of treatment were the arrested growth of
seedlings, thickened cotyledons and swollen hypocotyls.

With the aim of producing tetraploids of mulberry
with higher yield, for silkworm feeding and for serving as
a source of breeding material for the production of triploid
varieties, Das et al. (1970) obtained tetraploids by the treatment of young mulberry seedlings with 0.4 and 0.6% colchicine for different durations. Maximum number of tetraploids was recorded with 0.4% colchicine solution with a treatment time of 9 hours. A 4 hour treatment of buds with 0.2% colchicine solution also induced tetraploidy. In induced tetraploids gigantism was observed in leaf, floral parts, pollen and stomata; leaves were dark-green, succulent and more pubescent; pollen fertility and seed setting were lower.

Singh and Kaul (1967) were successful in inducing polyploidy in *Datura innoxia* by treating its seeds with 5% ethyl alcohol at 35°C for 45 minutes. The polyploids thus obtained, possessed vigorous growth, increased alkaloid content and larger number of seeds per plant as compared to the control.

Ghosh (1967) was successful in inducing polyploidy in two varieties of rice 'Ashkata' and 'Dular', by employing shoot immersion method under partial vacuum. The treated seedlings possessed comparatively shorter height and thicker, stouter and darker-green leaves. Results obtained showed that colchicine treatment resulted in the formation of mixoploids instead of true colchiploids, the formation being attributed to the structural characteristics of apical meristem of rice. Investigations also revealed that in rice there occurs diminution in vigour with polyploidy.
Dnyansagar and Mhaske (1974) subjected seeds of *Sida rhombifolia* to 0.4% and 0.5% aqueous solutions of colchicine for 12 and 18 hours respectively, and obtained tetraploid plants. Induced tetraploids exhibited the usual gigas characters associated with autotetraploidy like larger stomata, flowers, pollen and larger seeds and sturdier plants. Meiotic studies displayed univalents, bivalents, occasionally trivalents and quadrivalents at diakinesis and metaphase I. Fibre studies revealed that fibre of the induced tetraploids was stronger than that of the diploids and its strength reached the value of that of jute.

With the objective of producing tetraploids of some species of *Zinnia* which would prove of better ornamental value Gupta and Koak (1976) treated the seeds of *Z. elegans* with different concentrations of colchicine. Effective concentrations exercised adverse effect on survival of the plants. Polyploids were, therefore, available only in classes having low survival values.

Mosashvili and Chankotadze (1977) treated grape seeds with colchicine under different conditions of exposure at 3 developmental stages. 0.1%, 0.2% and 0.3% concentrations of colchicine proved effective as indicated by the highest percentage of polyploid changes in root meristems. Also three tetraploids were isolated from the seedlings as a result of colchicine treatment.

For the induction of tetraploidy in *Crotalaria brownii*
and C. sericea Gupta and Gupta (1977) treated their shoot apices with 0.2% colchicine solution. Induced tetraploids in general were found inferior to their corresponding diploids.

Uanjari and Phadnis (1977) subjected the seeds of Momordica charantia L. to different concentrations of colchicine to induce polyploidy. Induced tetraploids were devoid of vigorous growth and exhibited delayed flowering. However, their foliar and floral size was bigger than that of diploids.

Indira and Abraham (1977) reported radiation induced tetraploid in Capsicum annuum L. The tetraploid was characterised by stunted growth, presence of thicker and larger leaves with larger stomata and an increase in size and number of floral organs. Induced polyploid was completely sterile with extremely poor fruiting, the fruits being devoid of seeds.

Raut and Thombre (1977) were successful in inducing tetraploidy in Impatiens balsamina L. by soaking its seeds in 0.05% and 0.1% colchicine. In colchicine treated population, plants showing arrested growth, height retardation, abnormal plumules and leaf shape were observed. Autotetraploids possessed bigger flower size and longer blooming period.
Semeniuk (1978) induced polyploidy in the summer flowering pot plant *Exacum affine* Balt. Tetraploids were not horticulturally superior to original varieties.

Colchicine induced polyploids in *Apluda mutica* L. were reported by Murty and Satyavathi (1978). Induced tetraploids exhibited robust stature but the induced dekaploid was reduced than its parent.

Bakulin (1978) induced polyploidy in different *Populus* species by subjecting their seedlings to colchicine treatments. Induced polyploids exhibited some distinctive morphological peculiarities and had larger stomatal cells and greater number of chloroplasts than diploids.

Roy and Mishra (1979) while inducing tetraploidy in *Phaseolus aconitifolius* noted that only the colchicine treatment to apical buds proved successful. The autotetraploids thus obtained exhibited gigantism only in vegetative parts. Cytological observations revealed various chromosomal associations such as univalents, bivalents, trivalents and quadrivalents. In tetraploids normal pollen fertility was followed by normal fruit and seed set. By raising the plants from these seeds, a reversal of tetraploids to diploids was observed.

In an attempt to produce new forms of *Nemesia strumosa* with large flowers and of a shorter height, Gospodarek and
Hulewicz (1979) tried to obtain polyploids by doubling its chromosome number using colchicine. The results obtained showed that though colchicine treatment did not result in chromosome doubling in the cultivars used, their morphological characters got changed, namely, the plants were shorter and their flowers were larger which were thought to be the consequences of gene mutations.

Dy's et al. (1979) treated apical meristems of *Portulaca grandiflora* with colchicine and were successful in inducing polyploidy. Most of the treated plants showed restricted growth, dark-green and thicker leaves and morphological changes in the flower structure. During studies, some plants after treatment produced no flowers, especially those which had very thick leaves and were thought to be high polyploids. It was further noted that gigantism was much more pronounced in leaves than in flowers. In induced polyploids male fertility did not differ from that of diploids, but seed set was three times lower due to a very small number of ovules.