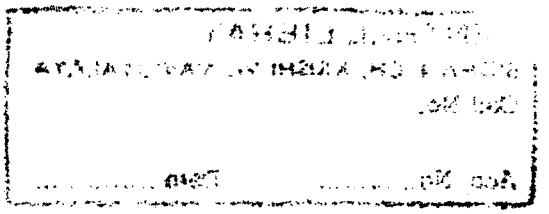
INDUCTION OF VARIABILITY FOR PRODUCTIVITY AND NODULATION IN BLACK GRAM (*Vigna mungo* L. Hepper)

A Thesis
Submitted to the
Bidhan Chandra Krishi Viswavidyalaya
for the award of the Degree of Doctor of Philosophy
in
GENETICS AND PLANT BREEDING

BY
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1988



Dedicated to my elder sister

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CERTIFICATE

It is certified that Sri P. K. Biswas is a bonafide research worker who conducted his research project on "Induction of variability for productivity and nodulation in black gram (Vigna mungo L. Hepper)" under my supervision for the Degree of Doctor of Philosophy in the Department of Genetics and Plant Breeding, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya. No part of his thesis has been submitted for any other degree.

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Prodip Kumar Biswas

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INTRODUCTION

Quantitatively, grain legumes are important next to cereals as the source of calories and protein (Aykroyd and Doughty, 1964). Qualitatively, however, grain legumes are more important, as they are the main sources for certain important aminoacids, such as lysine and threonine. Animal protein are out of reach for a large majority of the low-income groups of populations. The grain legumes or pulses occupy a unique position in Indian Agriculture. Because, they provide the only high-protein component of the average diet. It has increasingly recognized in recent years that pulses offer perhaps the only, and certainly the most practical means of solving the protein-malnutrition problem in India at present stage, as it may take many years to bring about a major advance in the production of high-protein foods of animal origin. Pulses contain 20-30 per cent protein on a dry basis, which is nearly three times the value found in cereals. No other country in the world has so much area under these crops as does India and she is the largest producer of grain legumes in the world producing 11.9 million metric tons in 1970 (Production year book, Vol. 24, FAO, Rome, 1970). The consumption of grain legumes in India varies from 14-114 g./capita/day (Patwardhan, V. N. 1962. Amer. J. Clin. Nutr. 11:2). The per-capita consumption of legumes varies in different states within India (Patwardhan, 1962). The consumption in the State of Tamil Nadu is as low as 16 g./capita, whereas in Madhya Pradesh it is as high as 55 g. and

in West Bengal it is 30 g. (Gopalan et al., 1971). Thus, greater availability of pulses can make a significant contribution to the nations physical and mental health .

Black gram (Vigna mungo (L.) Hepper), commonly known as 'urd' is a major grain legume of South-East Asia particularly in India. It is widely cultivated in different States of India including West Bengal. Black gram is a nutritious pulse crop and its seed protein content is also high (24%) .

After cooking or puffing, black gram is widely consumed as a part of daily diet in many traditional food preparations of India. The whole grain or splited grains are used for the preparation of 'dhal' which is consumed alongwith cereal preparation or as soup. Some of the common savory preparations containing split black gram seeds are idli, papad and adai. Idli is a common break fast dish prepared in many parts of India by steaming fermented mixed dough of ground rice and black gram dhal. Papads or papadams are paste goods prepared from black gram, green gram, and other varieties of dhals and produced both on a home and commercial scale throughout India.

The importance of black gram lies not only in their food value to human beings but also to the fact that they supply the proteinaceous fodder for tropical live stock. All parts of 'urd' plants are rich in nitrogeneous materials. In addition to this

the plant is important as replinishers of soil nitrogen. Over the past hundreds of years, pulses including black gram have been an important way to restore the fertility of Indian soils in the absence of adequate manuring. Black gram produces nodules on roots, on which bacterial colonies live in symbiosis with plants. The bacterial species have the ability to utilize atmospheric nitrogen and fixing it in some form or another. When soil nitrate supplies are limited the black gram plants are able to use this fixed nitrogen, and in return the bacterial colonies are supplied with carbohydrates.

Many of the lateritic soils of wetter parts of tropics, as well as the more alkaline soils of the arid tropics are deficient in nitrogen and black gram can play an important role for the maintenance of fertility in any permanent agricultural system. Black gram increases soil aeration and percolation to a considerable extent. It can be used as a green manure. The black grams also derive their importance from their relatively low water requirement; because of this characteristic, they offer a most important means of increasing agricultural production and farmers' income in India's dry lands, which constitute more than 75% of the total cropped area in the country .

Compared to cereals, the average national yields of pulses have been very low. Black gram is a very poor yielder of seeds which is around 400 kg/ha (Indian Agril. in brief, 1985). A factor

responsible for the poor yield is that this crop generally has been grown in lands of marginal productivity without the benefit of such inputs as fertilizers and pesticides. One result of this low level management has been that those genotypes have been selected which have the capacity to do well under adverse conditions and can not take advantage of more favourable factors of crop growth. Another important factor responsible for the low production is that many of the available varieties of these crops take a long time to mature, with the result that their growing season overlaps that of the cereals.

The earlier attempts are directed to improve this crop largely through simple procedures of selection from local collections. It is well known that selection can not be effective in populations without variability and progress in breeding is dependent upon the extent of genetic variability. The existing genetic variability in black gram is very limited. Recently, emphasis has been laid on a major reconstruction of the plant type in pulses including black gram. The genetic reconstruction of plant type in terms of improved harvest index is often difficult to achieve without changing the physiological structure, more particularly the photosensitivity. Thus, a major breeding objective in recent years for crop like black gram has been to cut down its excessive vegetative growth, improve the harvest index, and reduce their maturity duration. This last attribute is important, as it helps to increase the per day productivity of this crop and makes it possible to fit into more intensive cropping patterns.

In black gram, most of the economic characters are quantitative in nature and are characterised by continuous distribution which is due to the influence of many genetic factors as well as environmental fluctuations. The creation of variation for such characters for the selection to act upon is very important in crop improvement and this has long been accomplished through hybridization. As the genetic variability in blackgram is very limited it was felt appropriate to induce variability using physical as well as chemical mutagens in different quantitative characters influencing productivity directly and indirectly including seed yield. Induced mutation can play an important role in restructuring of the plant type leading to yield improvement together with shortening of the growth period for this important grain legume. Though the desirable mutations do not arise in large number in well adapted and genetically stable varieties, the occurrence of even a few desirable mutations in high yielding idiotypes has the great advantage of becoming homozygous and expressing its superiority within a couple of generations after induction. Mutations of crop plants, appearing inferior to cultivated types, sometimes, prove to be very important source of germ plasm when transferred to favourable idiotypes. Again, a mutation that is inferior to the original line in a particular area of cultivation, may become distinctly superior in other climatic or environmental conditions (Ganguli and Bhaduri, 1982).

Yield is a complex quantitative character which depends upon a number of other characters and their interactions. It is strongly influenced by environmental factors. Moreover, undesirable linkages involving yield components are known to exist in crop plants (Webb et al., 1968). Association of characters, the expression of which is governed by the closely linked genes in the parent material, has been reported to be altered in certain cases due to mutagenic treatments. Induced mutations could therefore, be used as a valuable tool in breaking, the linkage of undesirable traits with useful productive traits.

It is well known that, biological fixation of nitrogen through root nodule development influences seed yield and its protein content. Thus, it was also considered to be useful to examine the variation if any in nodule development following mutagenic treatments.

Information regarding the induction of polygenic variability in black gram is very scanty. An attempt was therefore, made to study the radio- as well as chemosensitivity of the two varieties of (T-9 and B-76) black gram in M_1 generation and also to study the relative quantum and nature of induced phenotypic and genotypic variability, the heritable portion of the induced genetic variability and its response to selection for grain yield and its components in the M_2 and M_3 generations following mutagenesis with X-rays, gamma rays and ethyl methane sulphonate (EMS). Association of some important characters were studied in M_3 generation. Variability for nodule development was assessed for some selected mutants in M_3 generations.

REVIEW OF LITERATURE

The phenotype of a living organism is the ultimate result of interaction of genes with each other and also with the surrounding environment throughout the developmental process of the organism. Treatment of germinating or dry seeds or any other plant part or parts with physical or chemical mutagens result in genotypic changes leading to altered character expression. sensitivity to mutagens is influenced by a series of factors of which the type of mutagens, does, moisture content, pH, genotype of the biological system are some of the more important (Ehrenberg, 1955; Konzak, Nilan, Harle and Heiner, 1961 and Sparrow and Evans, 1961). Mutagenic experiments with both ionizing and non-ionizing mutagens on a number of economic plants have been conducted by different workers, which helped in getting many valuable information about the genetic variants as well as the mechanism of genetic changes.

Chlorophyll mutations and some other macro mutations, although are not useful for pland breeding purposes, have been used as one of the measures of dose effect for different mutagenic treatments. The role of induced micromutations have been studied by a number of workers in several crop plants including cereals and pulses. It is now proven that, polygenic mutations result in the release of considerable variability in irradiated populations, but the opinion seems to differ regarding the direction of maximum

mutations. However, FAO/IAEA (1987) published a list of important varieties of a number of crop species produced by mutagenesis. In each case details are given of place and date of release or approval, the type and date of mutagenic treatment and the main characteristics which have been improved. The species listed are Arachis hypogaea (1 variety), Citrus sp. (1), Curcuma domestica (C. longa) (2), Dolichos lablab (Lablab perpureus) (1), Gossypium sp. (1), Hordeum vulgare (3), Lycopersicon esculentum (1). Oryza sativa (20), Ribes nigrum (1), Sesamum orientale (S. indicum) (1), Setaria sp. (2), Sorghum bicolor (1), Triticum turgidum (T. durum) (1), Vicia faba (1), Vigna unguiculata (1), Vigna mungo (1) and Vigna radiata (3) .

The literatures reviewed are being presented under the following heads : early history of mutation research; mutagens and their mode of actions; mutagenic sensitivity; efficiency and effectiveness of mutagens; mutation research in different crops; mutation research in grain legumes; and role of mutation on nodulation and nitrogen fixation .

Early History of Mutation Research .

Hugo de Vries is the first worker who studied mutation comprehensively in the evening primerose (Oenothera), the highly variable organism (and also in 1901, to coin the word itself). Most Oenothera populations maintain high frequencies of balanced

translocations, sometimes involving the entire chromosome complement. Instead of producing point mutations in high frequency, chromosomal mutations were produced in high frequencies.

In the unifoliate mutant all leaves were simple instead of normal trifoliate condition. Such deviation has been observed both in nature as well as following irradiation in Phaseolus vulgaris by Blackeslee (1919).

Various workers have reported that pigment formation in chlorophyll mutants appeared to be greatly conditioned by light and temperature. Akerman (1922) and Sirks (1929) showed that strong light destroys the pigments of the mutants. Hallqvist (1923) and Collins (1927) noted that low temperature aggravates chlorophyll deficiencies.

The importance of micromutations in evolution was first recognised and stressed by Baur (1924). Muller 1927 initiated the art of artificial mutagnesis in Drosophila melanogaster and demonstrated the induction of sex-linked recessive lethal mutations. Actually he for the first time reported the usefulness of ionizing radiation (X-ray) in producing point mutation or gene mutation in living organisms.

In the case of crop plants, Stadler (1928), successfully produced some mutants of maize and barley with the help of X-rays and gamma-rays. McClintock in a series of papers (1931, 1933 and

and 1944) presented the behaviour of chromosomal aberrations including deficiencies or deletions, translocations (reciprocal and non-reciprocal) and inversions in Zea mays. Stadler (1933) described the genetic nature of induced mutations in plants while working with maize. Stubbe (1934) studied some micro-mutations in Antirrhinum.

In the unifoliate mutant of broad bean all leaves are simple unlike pea (Lamprecht, 1935), where some of the leaves have been found to be unifoliate and few others normal bifoliate. The mutants were of spontaneous origin.

In wheat, Anthony (1940) has reported partial transformation of anthers into carpel like structures. The change of habit is a common occurrence after irradiation and has been observed in bean (Genter and Brown, 1941) and many other crops. Stubbe and Wettstein (1941) discussed the role of micro-and macro-mutations in evolution.

Auerbach in a series of papers (1943, 1944 and 1945) studied chromosomal re-arrangements and reported about some new mutants in Drosophila. In 1943, she used chemical as mutagens. Gustafsson (1944) studied the resistance of dormant seeds to X-rays. He (1947) also reported a chlorophyll mutant in barley which under different environmental conditions with longer day length gave about 35% more yield. Stadler and Roman (1948) studied the effect of X-rays upon mutation of gene A in maize.

Mutagens and their mode of actions.

The pathways of mutation induction by physical and chemical mutagens are different.

Physical mutagens.

Gamma and X-rays are electro-magnetic radiations having lowest wave lengths in the electromagnetic spectrum. By virtue of their lowest wave lengths these high energy radiations possesses the very high penetrating power. The radiation energy is observed by the body in quantum. Photons or radiation energy absorbed in quantum excites the impinged atoms and molecules. When an excited atom is raised to ionisation potential by further absorption of photons, an electron is rejected out to produce an ion pair. Due to this property these radiations are called ionising radiations. While the excited atom brings about the more directed way of tearing up of chemical bonds, the excitation of external electrons appears as an indirect method of inducing chemical changes. The electron originally ejected carries away much of the energy received; the rest comes out in the form of X-rays or as kinetic energy of auger electrons. The atom originally affected remains single or multiply ionised and it much goes strong activation, but most of the energy is carried away by new secondary ionising radiations. These secondary electrons constitute a new changed corpuscular radiation which dissipates its energy through the process of "Cascade shower". Secondary electrons where energy no longer suffice for "gloveing collisions" is thereby

transferred directly to intermolecular forces, until the electron itself becomes degraded to the thermal range. Eventually, the secondary electron is captured by some atom or molecule with the formation of a negative ion unless it is recombined with a positive ion which originally liberated it .

In biological systems the radiation events lead into inhibition of mitosis, production of chromosomal aberrations, point mutations, and miscellaneous effects like oxidation of double bonds, sulphide groups, rupture of aromatic cyclic structures, enzymic inhibition and in some cases induce molecular polymerisation. Two theories have been propounded to explain direct and indirect effects of radiations in biological systems. According to the "hit theory" or "target theory" a definite biological effect results whenever an ionisation occurs with a "sensitive volume" which coincides with genetic material. The indirect action theory, on the other hand, conceives the whole cellular environment as target. For example radiolysis of water milieu in the cell produces reaction radicals of high oxidising potential which in turn trigyres off a series of biochemical events, some of them affecting the genetic molecule .

Neutrons belonging to the family of corpuscular radiations are uncharged high energy particles. Neutrons traversing a meterial transfers the energy through elastic collisions almost exclusively with the target atomic nuclei. After a series of such collisions the incident particle becomes incorporated into the nucleus to form a

new "compound nucleus" of an excited stationary state. The compound nucleus disperses off its excitation energy by nuclear disintegration through the production of secondary radiations which may include charged corpuscular radiations, gamma-rays and neutrons of lower energy than the incident one. These primary and secondary events lead to dense ionisation in the target area. The manifest biological effects are explained on the basis of direct and indirect action theories of radiations.

The direct effects of ionising radiations on the DNA are .

1. Rupturing of H-bond linking the bases.
2. Induction of breaks in one or both of the DNA chains.
3. Formation of thymine dimers.
4. Cross linking of DNA strands inter or intra types.

Pollard (1969) has made a hypothesis for the mode of action of ionising radiations on the genetic material as follows :

i) An ionising event occurs in a part of the transcription apparatus and changes the structural conformation of one or more components. This stops the normal process of temporary separation of the DNA strands and the use of one strand to make massenger RNA. This blocks both DNA replication and RNA synthesis.

ii) This may cause DNA to become detached from the transcription apparatus or even to break, so that it no longer moves smoothly through its combination of transcription and synthetic stages.

iii) Such DNA may not be normal and is destroyed by cell mechanisms for destruction of foreign DNA.

iv) Cell becomes full of degradation products and incomplete transcription components.

v) Base insertions are not accurately made from the template and mutation occur.

The indirect effects of radiations result from the fact that by and large the living tissues contain 75% water and is the most abundant single target available for ionisation. Ionization of water and subsequent radiolysis lead to the formation of five radicals in the following way. Subsequently these free radicals induce mutations.

1. Ion pairs are first produced in water.

$$H_2O \xrightarrow{\text{Radiation}} H_2O^+ \text{ (ion)} + e^-$$

2. The free electron reacts with normal water molecule form the H_2O ion.

3. H_2O^+ and H_2O^- react further with water molecules to form ions and free radicals which are chemically highly reactive.

$$H_2O^+ + H_2O \longrightarrow H^+ + OH^o$$

$$H_2O^- + H_2O \longrightarrow OH^- + H^o$$

The H^+ and OH^- ions are not energetic and recombine to form water. The free radicals OH° and H° however, react with other molecules in several ways and these are usually referred to as indirect effects. They are as follows :

$$OH^\circ + H \longrightarrow H_2O$$

$$H^\circ + H^\circ \longrightarrow H_2$$

$$OH^\circ + OH^\circ \longrightarrow H_2O_2$$

The last reaction is of consequence to the biological system, since hydrogen peroxide is an effective oxidising agent and exists at surprisingly high concentrations in the near vicinity of an ionizing event. In the presence of oxygen, normally the reaction $H^\circ + O_2 \longrightarrow H_2^\circ O$ leads to the formation of peroxyl radical which has relatively long life, so that it can migrate to the surface of large molecules and cause chemical reactions, generally detrimental to cell function. The OH° radical is also an oxidizing radical like peroxide and the next result of the indirect effect of radiation is oxidation i.e. removal of electrons from other molecules. General reactions, normally cited are :

$$RH + OH^\circ \longrightarrow R^\circ + H_2O$$

$$R\text{-}NH_2 + H_2^\circ O \longrightarrow R\text{-}NH_2 + OH^+$$

$$RH + H_2O \longrightarrow RO^\circ + H_2O$$

Such active radicals produced by indirect effect of radiations may cause alternations in the DNA molecules, leading to mutation .

Chemical mutagens.

Chemical mutagens are classified into four groups : base analogues and related compounds, antibiotics, alkalyting agents, and miscellaneous chemicals like hydroxyl amine, nitrous acid and acridine dyes.

Alkylating agents are by far the most potent groups of mutagenic chemicals for mutation induction in cultivated plants. These are compounds which bear one or more alkyl groups capable of being transferred to other molecules at position where electron density is sufficiently high. All these chemicals react with DNA by alkalyting the phosphate group as well as the purine and pyrimidine bases. The triesters formed by the alkylation of phosphate groups are unstable and tend to lose the alkyl group. However, it can also lead to breakage of the phosphodiester bond. The most frequent event regarding bases is the formation of alkyl guanine. The possible consequence of alkylation of guanine is believed to be the lose of a base pair (deletion) or replacement of alkylated base by suitable purine or pyrimidine base. The latter situation may lead to kinds of mutations called transition or transversion (Freese, 1963). An important element for an alkylating molecule is its number of functional groups. Thus they are recognised as mono-, bi-, and tri-functional alkylating agents. The biological toxicity caused by poly-functional

alkylating agents is greater than that produced by the mono-functional ones. The former is believed to form crose links between DNA duplex and thus preventing chain separation prior to their self-duplication and culminating in cell death .

Heslot (1965), while reviewing the mode of action of alkylating agents concludes that they appear to be capable of inducing preferentially transitions GC on AT and also micro or macrolesions by loss of a purine nucleotide or fragments of greater lengths. Ethyl methane sulphonate (EMS) $C_2H_5OSO_2CH_3$:

This chemical has been shown to react particularly with the base guanine for a long time (Freese, 1963). Krieg (1963) has shown that the reactivity of EMS with three of the four bases decreases in the order : Guanine, Adenine, Cytosine. Like other alkylating agents, EMS reacts with both phosphate group of nucleic acids and purine bases especially the guanine of the DNA molecule (Freese, 1963). The action of guanine base i.e., alkylation of N_7 is inferred to be important pathway in mutation and chromosome breakage . The alkylation of purine in 7th position gives rise to quaternary nitrogens which are unstable. Either the alkyl groups itself hydrolyses away from the purine or else the alkylated purine separates from the deoxyribose leaving it depurinated. The liberation of ethylated and methylated purines from DNA base has been observed (Lett et al., 1962). The gap might interfere with DNA duplication or cause the incorporation of a wrong base. Bautz and Freese (1960) suggest the removal of guanine to be the main cause of mutations induced by EMS .

N-Nitroso-N-methyl Urea (NMU) $CH_3N(NO).CO.NH_2$.

It is a monofunctional alkylating agent in the sense that it has only one alkyl group. Although DNA seems to be main target, the inactivation of repair enzymes may play an important role in modifying primary lesions in the DNA. It reacts primarily with phosphate groups in the DNA. Alkylation occurs readily with guanine at position N_7 followed by adenine at N_3 and cytosine. Alkylation of bases may occasionally lead to rearrangement of configuration so that the base-deoxiribose bond is broken rather than alkyl base bond. The depurinated DNA is labile and the sugar-phosphate bond can break at the depurinated site .

Hydroxylamine ($NH_2OH.HCl$) .

Hydroxylamine (HA) reacts specifically with cytosine in DNA molecule (Freese et al., 1961). The main mutagenic effect of HA is apparently caused by its reaction with cytosin. The attachment of HA to cytosine opens the resonance structure of pyrimidine ring and destroys the normal pyrimidine absorption spectrum. The HA reacted cytosine is not able to pair with guanine since the 5'-position hydrogen interferes strictly with the hydrogen atom on guanine. However, this compound can make atleast one hydrogen bond with adenine and this causes its incorporation in place of guanine. This event leads to a base pair transition .

C ——— T
G A

Mutagenic sensitivity •

1. Dose effects•

According to Gustafsson (1944), the "critical dose" is that which gives a maximum number of mutations and structural rearrangements, but still allowing survival of a sufficiently large number of populations• Most of the workers used LD_{50} value as the critical dose• While Gaul (1963) has suggested as high a dose which results 5% survival for increasing the efficiency of mutation production •

There has been two different views on the effective dose of radiation i•e•, 30 KR or higher doses should be used so that as large genetic variation as possible might be induced (Gaul, 1964)• The second view propounds that low or medium doses (i•e• 10 to 20 KR) should be preferred since frequency of practically desirable mutants is not necessarily increased with high radiation doses (Yamagata and Syakudo, 1960). Micke (1970) has recommended a dose which enables the frequency of multiple mutations with unfavourable linkages to be considerably reduced •

Dose effect on germination, growth and survival has been demonstrated by Patil and Bohra (1963) in pea nuts, Santos (1965) in Phaseolus aureus • Dose depending of germination decline in peas was reported after treatment with X-rays (Blixt el al, 1963) and EMS (Heringa, 1964)• Seedling growth declines in peas with the increase in the dose of gamma rays (Blixt et al., 1963) and EMS

(Speekman, 1964). Blixt (1967) observed a positive correlation between seedling injury and reduction in survival in Pisum following treatment with different mutagens.

Woynarowska (1970) irradiated flowering plants and seeds with varying moisture contents with a range of doses. The limit of tolerance for germinating seeds was 4 KR but for others it varied and could be even as high as 25 KR or more. No yield increase resulted from doses as low as 4 KR. Certain valuable mutants induced included forms capable of germinating at reduced temperatures; the greatest number of these resulted from irradiation of flowering plants and germinating seedlings with 4 KR and dry seeds with 10-30 KR.

Gerasimenko et al. (1971) found that, seeds of two varieties with contrasting features proved highly sensitive to gamma-ray doses of 2, 4 and 6 KR, ethyl eneimire (EI) doses of 0.2 and 0.4% and an ethyl methane sulphonate (EMS) dose of 0.2%.

Jana et al. (1974) irradiated dry seeds of lentil with 1, 5, 10 and 15 KR X-rays and the effects of radiation were measured from the yield of induced chromosome aberrations observed in roots. The yield of X-ray induced aberrations increased linearly with the exposure. When seeds were presoaked before irradiation there was a remarkable increase in yield of total aberrations still increasing at the longer presoaking time.

Treatment of dry and 6 hour presoaked seeds with HA (0.1%/2 hr.) resulted in chromosome breakage not restricted to the heterochromatic regions and influenced by the pH. Post treatments of 1 and 5 KR X-irradiated seeds (presoaked) with HA (0.1% /2hr.) showed that the yield of aberrations in combined treatment was more than additive, the synergistic effect was depending on the dose of X-rays.

Gupta and Yashvir (1976) observed increase in mutation frequency with the increase of dose in Setaria italica. Frequency also increased with the duration of mutagen treatment and were much higher in combined treatments (EMS and DES) of chemical and physical mutagen (gamma-ray) than the individual treatments. A synergistic effect was observed between the two groups of mutagens in culture MU-1. The mutation spectrum was also wider in culture MU-1 .

Germination shoot as well as primary root length of all the pigeon pea varieties decreased with increase in concentration of EMS. None of the varieties showed 50% reduction in germination indicating L.D. 50 for germination lay above 2% EMS solution, the highest concentration used. Root and shoot inhibition due to EMS treatment suggest that the varieties studied fall into two distinct groups : (a) NP-69 and NP (WR)-15 group (more than 50% inhibition) and (b) AS-3 and AS-5 group (less than 50% inhibition). Genetic divergence is suggested to be responsible for differential varietal response to EMS treatments (Das and Tickoo, 1977) .

Ganguli and Bhaduri (1979) in green gram showed that the survival percentage declines after 30,000 r and L.D. 50 lies somewhere around 60,000 r of X-rays. Out of the three doses of thermal neutrons applied to green gram, the sublethal effect was produced at such a high dose as 8×10^{12} n.p./cm^2. Work with black gram (Jana, 1963) which is very similar to green gram conforms the above conclusion where 50% survival has also been recorded at 60,000 r.

Bandyopadhyay and Bose (1980) treated dry seeds of black gram with 0.1% and 0.2% aqueous solutions of ehyl emimine (EI) and hydroxyl amine (HA) for 4 hours at room temperature. Cytological studies revealed that the percentage of chromosomal aberrations induced was the highest in 0.2% HA. Percentages of pollen sterility were 12.92 in 0.1% EI, 14.01 in 0.2% EI, 12.39 in 0.1% HA, 13.77 in 0.2% HA and 2.24 in control. In M_2 generation, percentage of germination which was the lowest in 0.2% EI was 60% as compared to 90% in control. Percentage of seedling mutants was maximum in 0.2% EI.

Nallathambi and Raja (1983) treated grains of Oryza sativa cv. Co 37 with gamma radiation or EMS or both. In M_1, germination and survival fell progressively as dosage increased. The maximum reduction in germination (10.86%) was caused by combined treatment. Reduction in seedling survival was greater from gamma radiation and combined treatments than from EMS alone.

Combined treatments had additive effects on germination and survival, as well as pollen grain fertility in the M_1. Pollen and grain fertility in the M_1 was reduced more by gamma radiation than by EMS.

Grains of barley cultivar Joti were soaked in 3, 6, 9 and 12 mM solutions of sodium bisulphite for 16 h. before planting in the field. In the M_1, seedling injury increased from 13.1-21.1% and spike sterility increased from 11.6 to 18.3% as the concentration of sodium bisulphite increased from 3 to 12 mM. In the M_2 the frequency of chlorophyll deficient seedlings almost doubled (1.61 - 3.06 per 100 seedlings) with the same rise in bisulphite concentration (Singh, 1983).

Natarajan et al. (1985) subjected seeds of two varieties of Cajanus cajan (L.) Mill. to 1-40 KR gamma rays or 3-15 mM diethyl sulphate. Low doses of the mutagens slightly increased M_1 plant height on 30th day, but higher doses reduced height. Diethyl sulphate reduced pollen fertility more than did gamma rays in SAI, but reverse was true in CD 2. Diethyl sulphate reduced M_1 seed germination more than gamma radiation in both varieties.

Seeds of two cultivars, each of 'macrosperma' and 'microsperma' varietal groups of lentil were mutagenised with gamma-rays and NMU to determine their mutagen sensitivity and mutability. The increasing doses of gamma rays and NMU decreased

germination, root and shoot length, pollen fertility and plant survival, but increased the occurrence of leaf spots. The root system was found to be more sensitive to both mutagens than the shoot (Sharma and Sharma, 1986).

2. Genotypic effect.

The differential mutagenic sensitivity of different genotypes was reported as early as 1955 by Gregory in pea nuts, Blixt et al. (1960) in peas and Siddiq and Swaminathan (1968) in rice.

Preliminary test of the gametocidal effects of chemicals in sesame was studied by Mazzani et al. (1971). They reported that certain differences were noted in the reaction of two cultivars to dichloroisobutyric acid and other compounds tested. The quantity of pollen produced was reduced by 2.2, dichloropropionic and trichlorobenzoic acids, the effect of the former, being more drastic than the latter. These compounds also reduced anther dehiscence.

Sinha and Godward (1972) compared the radiosensitivity of microsperma and macrosperma lentils and observed that the germination and survival percentage at 2 leaf stage was low in macrosperma than in microsperma.

Sahai (1974) studied the mutagenic sensitivity of two varieties each of Phaseolus aureus and Phaseolus mungo. It was observed that LD 50 dose for the Phaseolus aureus varieties were

higher (indicating greater radio resistance) than Phaseolus mungo varieties. In moong, the early maturing variety Pusa Baisakhi was more sensitive than the late maturing S-9. Thus, within a species, differential mutagenic sensitivity was observed.

Rukmanski (1974) studied four cultivars of fresh bean and observed varietal differences in natural water absorption, which in all cases took over 24 h. Processor absorbed the most water and Zagorets the least. The latter also had the slowest water intake. Absorption rate increased if the seeds were given preliminary soaking and then dried. After this treatment Zagorates completed absorption in 7 h. and the other varieties in 6 h. Preliminary soaking is therefore, recommended for expediting treatment with mutagenic solutions.

Hussain and Disouki (1976) studied the effects of EMS and gamma rays on Phaseolus vulgaris L. and observed differential mutagenic sensitivity in different varieties.

The mutation frequency showed linear relationship with the increasing dose of mutagens. At biologically comparable doses of NMU and gamma-rays, the frequency and spectrum of mutations induced with NMU was higher than with gamma-rays. The mutagen resistant variety L-259 yielded lower frequency and narrower spectrum of mutations than the mutagen sensitive varieties L-235 and L-258. These two mutagen sensitive varieties yielded similar frequency

and comparable spectrum of mutations. Induced mutability is governed by the genetic architecture of the material used and by the nature of the mutagen employed. A wide range of the spectra of different types of viable mutations induced with NMU and gamma-rays showed that there is much scope for the mutation method in the breeding of lentil (Sharma and Sharma, 1979).

Reddy and Reddy (1984) treated sixteen varieties of rice with ethyl methane sulphonate (EMS), diethyl sulphate, hydrazine or gamma-rays. Five mutants of Tellakattera are dwarfs with the gene d_6 to d_{10} ; these genes are nonallelic to each other or to the gene in DGWG. Various mutants with changed plant, panicle and grain traits were obtained. Of 124 grain mutants obtained from 2 of the cultivars, those from MR 5 show variability for protein content (11.5 - 13.7) and many of these have fine grains. Among the grains mutants IR 8 FG 26 and IR 8 FG 33 have a deeper distribution of protein within the endosperm than does IR 8 . A semidwarf mutant of HR 47 has a height of 89.8 cm., an increased panicle number and, compared with HR 47, a higher protein content and 15-20% higher yield. The IR 8 mutant FG 19 has translucent grains with a length : width ratio of 2.91 vs. 2.52 in IR 8.

Kowyama et al. (1985) subjected three varieties of rice differing in radiosensitivity to 5-40 KR doses of X-rays. M_2 chlorophyll (particularly albino) mutation frequency increased with dose. There were no varietal differences in chlorophyll

mutation frequency. Over 50% of mutants detected in M_2 were sterile, most having chromosome aberrations. Short culm, dwarf and long awned mutants were also detected.

Sharma and Sharma (1986) mutagenised seeds of two cultivars of lentil each of 'macrosperma' and 'microsperma' varieties groups with gamma-rays and NMU to determine their mutagen sensitivity and mutability. The 'macrosperma' varietal group was more sensitive to both the mutagens than 'microsperma' group. In 'microsperma' group, variety 'Pusa-1' was more sensitive to both the mutagens than 'L-259', while in the 'macrosperma' group 'L-1491' showed more sensitivity to the mutagens than 'L-1492'. Radio-sensitivity corresponded positively with chemo-sensitivity in both varietal groups. There was a positive relationship between radio- and chemo-sensitivity of the genotypes and their mutability. The results also revealed the existence of a parallelism between radio-mutability and chemo-mutability. Due to saturation in the mutational events and vigour of both diplontic and haplontic selection in the biological material, the mutation frequency either decreased or remained constant at higher doses of the doses of the mutagens.

3. Locus specificity.

Some chemicals are quite specific in reacting with particular bases of DNA molecules (Freese, 1963). Thus, the reactivity

of hydroxylamine with cytosine at a particular pH is 30 times greater than that with commonly occurring DNA bases (Freese et al., 1961; Brown and Schell, 1961; Malling, 1966). Hydeazine, on the other hand, reacts specifically with thymine under particular experimental conditions (Freese et al., 1961 b).

Auerbach (1965) has pointed out that the response of particular genes to base specific mutagens cannot always be attributed to the reaction between mutagen and DNA. She has considered several other possible explanations, including one based on the protection of DNA by accessing substances such as the repressor material.

Several of the genes which are sensitive to hydrazine are located on chromosome 2 which has received considerable attention because it accounts for nearly 16% of the mapped genes in tomato (Clayberg et al., 1966).

Hydrazine, hydroxylamine and ethyl methane salphonate have been tested for their mutagenic effect on the tomato plant (Jain et al., 1968). A number of genus are particularly sensitive to hydrazine. Homozygous mutants for a number of these genes were consistently obtained in the M_1 generation following treatment of seeds with this chemical. These genes were little affected by other chemical mutagens, which did, however, induce mutations at some other loci. Several of the hydrazine-sensitive genes, like 16% of the 150 genes mapped in tomato, are in chromosome 2.

Mutagenic Effectiveness and Efficiency.

Effectiveness usually pertains to rate of mutation as related to dose while efficiency is reffered to the mutation rate in relation to damage .

Evidence on comparative effects of X-rays and thermal neutrons, indicate that in case of neutron treated seeds, the effect is more uniform as reflected by uniform damage of seedlings and survival of a large number of low fertility M_1 plants. While the effects of X-rays, in barley, is reported to be more of extrachromosomal or physiological nature, the neutron effects, on the other hand, is primarily genic (Caldecott et al., 1952; 1954; Ehrenberg and Nybom, 1954).

Ethyl methane sulphonate (EMS) and ethyl imine (EI) have been reported to be the most potent among the chemical mutagens used in rice (Kawai and Sato, 1965). N-methyl-N'-nitroso-guanidine (NG) has also been reported to be a potent mutagen both in microorganism (Mandell and Greenberg, 1960 and Eisenstark et al., 1965) and Aratidepsis thaliana (Muller and Gichner, 1964).

Prasad et al. (1967) reported NG to be as potent as EMS in barley.

Monti (1968) reported in peas that the effectiveness of DES was 3 to 4 times higher than that of X-rays, when either chlorophyll or morphological mutations or both together are considered .

Varughese and Swaminathan (1968) compared the spectrum and frequency of mutation induced by gamma-rays and ethyl methane sulphonate in wheat. It was found that, EMS is capable of inducing a wide range of mutations with a higher frequency. It was suggested that, in polyploid crops, chemical mutagens like EMS may prove more advantageous than physical mutagens for the induction of qualitative changes. Siddiq and Swaminathan (1968), working with rice found that gamma radiation is as efficient as EMS in inducing mutations. Further they observed that, NMU had the highest mutagenic effectiveness, measured by the method suggested by Konzak, Nilan, Wagner and Foster (1964).

Chauhan and Singh (1971) induced male sterility in sesame by maleic hydrazite, FW_{450} (2,3-dichloroisobutyrate) and Dalapon (2, 2-dichloropropionic acid) and showed that FW_{450} induced complete male sterility with less inhibitory effects on growth than the other chemicals. Sterility level of 77.15% and 81.5% were obtained with 1% maleic hydrazide and 0.5% Dalapon respectively.

Prasad (1972) compared the mutagenic effectiveness and efficiency of gamma rays, NMU, and NMG using Triticum durum and reported that NMU was the most effective and reasonably efficient mutagen. Higher mutagenic effectiveness and efficiency of NMU than NG and NEU was reported by Sree Ramulu (1972) in Sorghum subglabrescens.

Uhlik (1972) conducted a comparison study of mutational activity of ethyl methane sulphonate (EMS) and gamma irradiation in Lens esculenta (Moench.). The highest proportions of segregating M_2 progeny, comprising chlorophyll mutants and chimeric plants, were 29.7 and 20% for EMS and gamma-radiation respectively. EMS was more efficient than gamma-rays, producing higher percentage of mutants and more types of mutants per progeny.

Ilieva-Staneva (1973) taken dry seeds of Phaseolus vulgaris var. subcompressus and (1) irradiated with 175-1575 rad fast neutrons and (2) soaked in 0.6 or 0.37% ethyl methane sulphonate (EMS) for six hours or in 0.15 or 0.075% EMS for 24 h. The higher doses of EMS had greater depressive effects on the M_1 than the fast neutrons. Mutation frequency was higher from treatments with EMS than those with fast neutrons. Mutation spectra from treatments with either mutagen were narrow.

Kasprzyk (1975) treated field broad bean with different mutagens and found highest incidence of non-lethal micro mutations when gamma rays were used in conjunction with either ethyl eneimine or N-nitroso-N-methylurea or these chemicals were used together. In these cases this incidence exceeded the sum of the effects of the separate use of the same mutagens by from 20% to 49%. Useful changes in the variability of quantitative characters were obtained. For a given incidence of mutation, the use of these combinations of mutagens provoked a less profound reduction in the vitality of M_1 plants than did their separate use.

Vasileva and Mehandjiev (1976) treated dry seeds of Sofia 135 and Auralia with various concentrations of diethyl sulphate (DES), ethyl eneimine (EI) and ethyl methane sulphonate (EMS). A study was made of the frequency and range of chlorophyll and morphological mutations in the $M-M_3$. The highest mutation frequency was obtained using EMS and the lowest with DES. The greatest range of mutations was obtained using low concentrations of EMS and EI. The more mutable variety was Auralia .

Nerkar (1977) studied the response of five varieties of Lathyrus to different mutagens and found that while mutagen effectiveness was in the order : NMU > EMS > gamma-rays, the mutagen efficiency was gamma-rays > EMS > NMU. Both mutagenic effectiveness and efficiency was higher in lower dose.

Jagtap and Das (1976) studied the mutagenic efficiency and effectiveness of four monofunctional alkylating agents, EMS, dES, MES and EI in relation to the role of differential alkyl groups, concentration of the mutagen, pH value and duration of treatment in barley var. K 12. Efficiency was calculated as per methods suggested by Konzak et al. (1965) and Walther (1969). Effectiveness was estimated as the factor of effectiveness (F.E.), proposed by Walther (1969), dES was more efficient than MES, EMS and EI, in relation to lethality only, while MES was the most efficient in relation to sterility as well as in producing high frequency of mutants per mutation. This suggests higher specificity of EMS with

regard to certain loci. On the other hand, the factor of effectiveness i.e. mutations per 100 treated seeds was highest in EI. Contrary to earlier reports MES has been found to be more effective and efficient than ethylating agents due to particular treatment regime.

In green gram Neutron have been considered more efficient than X-rays since a more uniform effect is produced regardless of the physiological conditions of the seeds. The selective action of neutrons have been explained due to the absence of secondary physiological effects associated with their action, and their relative effectiveness for induction of chromosomal aberrations. Thermal neutrons produced a higher rate of mutation and a higher frequency of highly fertile plants in the M_2. X-ray, however, yielded a wider range of mutation spectrum than thermal neutrons (Ganguli and Bhaduri, 1979).

Sichkar (1979) treated seeds of five varieties of soyabean with gamma-rays, N-nitroso-N'-ethylurea (NEU), N-nitroso-N'-methylurea (NMU), ethyl eneimine (EI), dimethyl sulphate (DMS). N-nitroso-N'-dimethylurea (NDMU) and ethylene oxide (EO). Judging by percentage of chlorophyll mutations induced, the mutagens fell into the following descending order of efficacy : NMU > NEU > EI > gamma-rays > EO > NDMU > DMS. Depending on the mutagen and concentration used, 1.58 - 19.04% of chlorophyll mutations were obtained. The optimum concentrations were 0.125% NMU, 0.025% NEU, 0.03% EI, 0.05% EO, 0.00625% NDMU and 0.02% DMS. No correlation

between dose and mutation frequency was found with gamma-rays. UN II MK 9186 and Lanka had the highest mutation rate. The mutagens giving the highest mutation frequency also gave the broadest mutation spectrum. In all, 16 types of chlorophyl mutation were induced, of which the most frequent were Xantha, lutescens and Xanthoterminalis.

Leshchenko et al. (1979) presented the results of a study of the effect of chemical mutagens and gamma radiation on soyabean. The most effective mutagens were N-nitroso-N-methyl-urea, N-nitroso-N-ethylurea and ethyl eneimine and most mutable varieties VN II MK 9186 and Lanka (Link).

Sharma and Sharma (1979) studied mutagenic effectiveness and efficiency of NMU and gamma rays with three varieties of Lens culinaris. NMU was almost three times more effective than gamma rays. NMU can be a useful mutagen at low concentrations. Both mutagenic effectiveness and efficiency were higher at lower dose of NMU in all the varieties. However, effectiveness and efficiency were higher at the lower dose of gamma rays in the variety L-258, but less in the varieties L-235 and L-259. In spite of a general decline in mutagenic efficiency and effectiveness with increasing dose, the highest mutation rates were recorded in the higher doses of gamma rays as well as NMU.

Carroll et al. (1986), treated seeds of soyabeans, cv. Bragg with EMS, gamma-rays or sodium azide, of which EMS was the most effective in generating chlorophyll deficient variants in the M_2.

Dixit and Dubey (1986) treated dry seeds of lentil with EMS (0.05 - 0.25%), nitroso methylurea (NMU, 0.025 - 0.1%) and diethyl sulphate (DES, 0.25 - 0.75%) and observed a range of meiotic chromosome aberrations in PMCs of plants grown from treated seeds. A characteristic feature was the presence of a high frequency of chromosome translocations, resulting in the occurrence of multivalents. The effects of the mutagens decreased in the order NMU > EMS > DES .

Mutation Research in Different Crops.

As classified by Gaul (1961), macro-mutations are large and can be recognised on a single plant basis. These are of two types : transpecific and intraspecific. Further, it is also classified into chlorophyll mutations and viable mutations. On the other hand, micro-mutations are mutations with small effects and can be recognised only when a group of mutant plants are compared with a normal one. Micro-mutations differ from normals only quantitatively and mutations with larger and smaller grains or higher yield are the examples of micro-mutations.

Macro-mutations.

Cereals.

Singh (1971) irradiated hulled and unhulled seeds of indica and japonica rice varieties with 20 and 30 KR of gamma-rays. The influence of husk on radiosensitivity was measured

using different biological parameters like rate of germination and survival, shoot growth inhibition, pollen and spikelet sterility etc. The results suggest that there is no considerable increase in radiosensitivity of varieties with the hulled treatments. The differential radiosensitivity of *indica* and *japonica* sub-species appears to be due to differences in the physical and chemical nature of husk in addition to genetic factors.

Grains of rice varieties Tellahamsa and IR 24 were subjected to gamma irradiation (10, 15, 20 or 25 KR) or treated with methyl methane sulphonate (MMS; 0.1 or 0.2%), N-nitroso-N-methyl urea (NMU; 0.02 or 0.03%) or hydroxylamine (0.75 or 1%). Chlorophyll mutations were scored on an M_1 plant progeny, M_1 panicle progeny and M_2 population basis. Mutants per mutation (on M_1 panicle progeny basis) and mutagenic efficiency (rate of mutation/lethality), effectiveness (rate of mutations/(dose or concentration x duration)) and factor of effectiveness ((number of mutations/number of treated grains) x 100) were also calculated. Marked varietal differences in response to the different treatments were observed; gamma irradiation produced a higher frequency of mutations than chemical mutagens in IR 24 but not in Tellahamsa. In terms of mutagenic efficiency, considered the most useful measure for plant breeders, chemical mutagens were superior to gamma irradiation. The most efficient chemical mutagen was 0.03% NMU in Tellahamsa and 0.1% MMS in IR 24. Expression of mutation frequency on an M_2 plant population basis is recommended (Rao and Rao, 1983).

When grains of variety Co 37 were treated with gamma radiation or ethyl methane sulphonate (EMS) or both, viable mutants were obtained from all treatments. Combined treatments gave a higher mutation frequency than individual treatments. The two mutagens appeared to have an antagonistic effect on mutation frequency/100 M_1 spikes and additive effect on mutation frequency of / 100 M_2 plants. Combined treatments produced a broader spectrum of mutants than individual treatments, and gamma radiation produced a broader spectrum than EMS (Nallathambi and Raja, 1983).

In rice, Lin et al. (1984) observed chlorophyll mutants increased to 14-73% in the M_2 following irradiation of grains from ten crosses with 20 KR gamma-rays. Of these mutants, 77% were albino, compared with upto 9% in the control. Heading was advanced by 1-3 days. Coefficient of variation of plant height was 10-13% compared with 7-13% in the control.

Logrinenko et al. (1981) studied genetic effects of treating spring duram wheat with pesticides. Of seven pesticides tested, Granosan and TITD had an appreciable mutagenic effect, while no mutational changes were induced by 2,4-D and its amine and sodium salts.

Paladi (1982) presented information on mutation in winter wheat varieties and F_1 - F_3 hybrids after treatment of the grain with various chemical mutagens. The hybrids generally exceeded their parental varieties in frequency and range of mutation. The

most effective mutagens in inducing mutations were N-nitroso-N-methylurea and N-nitroso-N-dimethylurea. Repeated treatment with the mutagens generally increased the frequency of mutations.

An extensive study of segregation pattern of a number of induced chlorophyll mutations in barley (Moh and Smith, 1951) showed that usually a single recessive factor is involved. In the same plant, Moh and Nilan (1953) have been reported partial transformation of anthers into carpel like structures after Bikini atomic explosion. Goodspeed (1950) in Nicotiana, and Bhatia and Swaminathan (1963) in wheat, after X-irradiation, also obtained mutants with partial transformation of stamens into pistils.

Minocha and Saini (1971) treated barley seeds with ethylmethane sulphonate and gamma irradiation followed by soaking in distilled water on 1000 ppm. gibberellic acid for two hours to study the effect of the post-treatments on the chlorophyll mutation frequencies. Post-soaking in water resulted in reduction in mutation frequencies. Mutation frequencies following mutagen plus G.A. treatments were slightly more as compared to mutagen plus water treatments. Maximum mutation frequencies, however, were obtained when no post-treatment was given.

Numerous reports on the frequency of chlorophyll mutants induced by different mutagens on different crop plants are available. In barley, where extensive work has been done, high frequency of albino and lower frequency of viridis have been found to have induced through X-rays and gamma-rays (Nilan, 1972).

Schwartz (1951) reported in cron that when male sterile plants were outcrossed to different unrelated lines, the F_1 and F_2 generations were normal. He explained that the character was due to interaction between gene and cytoplasm.

Babayan (1983) studied mutagenic effect of ethyl eneimine and hydroxyl amine on germinating grains of barley. Air dried grains of one winter and one spring variety were soaked for 20-24 h. or treated in filter paper rolls for 4-7 days, provided that, optimum conditions were available for germination and early growth (filter paer rolls), gave a low mutation frequency (2-3% chlorophyll mutations and 0.5-1.5% morphological mutations with 0.02% ethyl eneimine treatment; 0.2 - 0.5% and 0.3 - 0.7% respectively after 0.02% hydroxyl amine treatment) compared with that obtained with direct soaking for 24 h. (10-18% chlorophyll and 5-10% morphological mutations with 0.02% ethyl eneimine; 2-3% and 1.0 - 1.5% respectively with 0.02% hydroxyl amine).

Oil seeds .

Pleiotropic genes affecting morphology of both leaf and flower has been reported in sweet clover by Kirk et al. (1934).

In groundnut, Patil and Bora (1961) noted after X-irradiation partial or complete failure of cytokinesis leading to the

formation of monads, dyads, triads and bigger pollen grains as well as twin pollen grains. The seeds from pollen mutant has given rise to a wide range of plants showing different meiotic behaviour. A varied proportion of dyads and triads has been observed in some of the plants where a meiotic division is normal in some others.

Bora (1963) showed the occurrence of xantha and vinescent mutants after x-irradiation in groundnut. Chlorina was observed from a cross between x-ray induced virescent mutant and spontaneous krinkle leaf mutant (Patil, 1973). Individual treatments of gamma rays and EMS were known to induce xantha, albina and virescent mutants in groundnut (Ashri and Levy, 1974). Three major genes were reported to control chlorophyll development in groundnut (Patil, 1973).

Ramanathan and Rathinam (1983) induced qualitative mutations in two groundnut cultivars, TMV 9 and Ah 7911. Qualitative mutations in M_2 consisted of chlorophyll and viable mutants. The spectrum of chlorophyll mutations showed differential response of the two varieties to mutagenic treatments. Combination treatment in TMV 9 and higher dose of gamma rays in Ah 7911 resulted in less than additive values for chlorophyll mutation. induced viable mutations included mutations for dwarfism, kernel size, testa colour and growth habit. Mutations for testa colour, consisted of brown, purple red, white, variegated and purple

lining around micropyle as against rose testa in the control. Two mutants having semispreading growth habit possessed desirable features of short nature, higher pod and kernel yield, bold kernels and increased shelling per cent compared to that of control.

/ Sesamum orientale (var. T_{10}) seeds subjected to X-ray irradiation (Nayar, 1969) mostly produced deleterious mutations involving the main stem, branches and flowers. Some of the isolates in the M_2 population were late flowering.

X-ray treatments on Sesamum indicum seeds have produced true breeding mutants with clustered capsule (Nair et al., 1975), multicoloured and "Large Capsules" (Murthy, 1979), and changed phyllotaxy (also with Beta and Gamma-ray treatments) in three varieties (Kobayshi, 1978). While, gamma-ray treatments have affected survivability and pollen fertility and produced chlorophyll mutations at doses higher than 30 KR (Ramachandran and Gopinathan, 1977).

Ashri (1977) isolated mutant types showing capsule indehiscence in M-2 generation of seeds of two varieties of sesame treated with ethyl methane sulphonate or ethidium bromide .

Nayar (1977) described a few new varieties of sesame directly selected from matured population or from hybridization of mutants followed by selection. These are :

(a) TM 6 (yellow seeds) - derived from X-ray induced mutants TM_1 .

(b) TM_7 (large silique and large black seeds) - derived from gamma-ray induced variety Vemma .

(c) TM_{12} (large pale yellow seeds) - derived from crosses of TM_1 and TM_9 followed by selection .

Nair and Nair (1978) observed dwarf mutants to be most frequent followed in lower frequencies by a series of undesirable mutations of the stem and leaf when the cultivated sesame variety Kayamkulam-1 was treated with different doses of gamma irradiation. He obtained a few early flowering mutants also .

Ornamental plants .

Gupta and Shukla (1970) reported somatic mutations for flower colour and shape in Montezuma rose after gamma irradiation and found 5 KR to be the best dose. They also observed somatic mutations for flower colour in rose varieties Bettina, Lady Florence Strange, McGredy's Sunset and President Poincare with 4 KR gamma-ray treatment (Gupta and Shukla, 1971a). In roses, Kaicker and Swarup (1972) found 5 KR and 7.5 KR gamma rays and 0.2% NMU more effective in bringing about changes in flower colour, giving 10-20% recovery of mutations in the gamma-ray treatments and 2% with the chemical mutagen (NMU). Das and Ghosh (1972), however, reported 1.0 - 2.5 KR to be the optimum dose for roses. At IRRI, India, the varieties developed through

this method are Abhisarika (from Kiss of Fire), Pusa Christina (from Christian Dior) and Madhosh (from Gulzar). The gamma-ray induced mutant of Montezuma, which was very vigorous, compact and profuse blooming with darker reddish coloured flowers, was released as Angara (Gupta, 1979).

In annual chrysanthemum Jain and Mazumdar (1957) and Jain et al. (1961) observed changes in flowers from single to double of various types and from nontubular to tubular corolla. The dose for obtaining mutants in chrysanthemum ranged from 1-30 KR (Gupta, 1966; Gupta and Shukla, 1971b; Gupta and Jugran, 1978). The mutants isolated in pure form and released as new cultivars from these studies are Anamika, Himani, Kapish, Lohita, Gairik, Tamara, Asha, Shukla, Basant, Pingal, Kansya, Aruna, Ashankit, Jhalar, Kanak, Kunchita, Nirbhaya, Nirbhik, Shefali, Svarnim and Shreta (Gupta, 1979). Rana (1964) in Chrysanthemum carinatum after treatment with ionizing radiations, observed an induced chlorophyll chimera which was shown to be of chromosomal origin. Das and Ghosh (1972) observed three distinct changes (yellow, orange, brown) from the original pink colour in variety Pride of Madford.

Gupta and Shukla (1974) found bougainvilleas, in general, to be sensitive to radiation. Abraham and Desai (1977) suggested administering recurring low doses of radiation to increase surviving populations and induce mutations. The bougainvillea

varieties developed in India through induced mutations are Arjuna (from Partha), Jaya and Jayalaxmi Variegata (from Jayalaxmi). Lady Hudson of Ceylon Variegata (from Lady Hudson of Ceylon) and Silver Top (from Versi colour) (Gupta, 1979; Gupta and Nath, 1977; Nath et al., 1983).

Misra (1977, 1978) reported (2-5 KR dose of gamma rays to be optimum for inducing mutants in gladiolus and obtained some promising colour mutants in the varieties Oscar, Jawagenaar and Picardy.

Gupta (1979) reported development of two gamma-ray induced mutants in tuberose (Polianthes tuberosa). Rajat Rekha, a mutant induced in single flowered tuberose after exposure to 2 KR gamma rays has leaves with silvery white streaks along the middle line of the lamina which makes it more ornamental even when not in flower. The mutant induced in double flowered tuberose after exposure to 2 KR gamma rays has leaves with golden yellow streaks along their margins and has been named Svarna Rekha. Six carmine coloured radiomutants of perennial portulaca (Portulaca grandiflora) were isolated and released by Gupta (1979).

In Tithonia, Kaicker et al. (1971) induced mutations through irradiation of seeds, giving rise to qualitative variations of desirable nature, viz., change in colour from orange red to yellow and striped types. Rana et al. (1963) raised X-irradiation mutants in Cosmos bipinnalus for forms of flower.

Other plants :

In Lupin Tendin (1954) have obtained a mutant similar in nature, in which the petals are reduced, greenish in colour and the flowers never open .

Bishop (1954, 1957) observed colour and russetting of skin of fruits in apple when subjected to ionizing radiations (X-rays and Thermal neutrons).

Sagawn and Mehlquist (1957, 59) induced by X-rays, single flowered, red, pink and white mutants in carnation .

Seeds of jute (var. T. M.) were treated with different concentrations of ethylene imine (0.5% and 0.03%) and also with different doses of X-rays (18,000 r and 12,000 r) and their subsequent effects on growth and morphology were studied. It was found that there was a close similarity in effect between X-ray and ethylene-imine treatments. Thus, both the chemical and X-ray treatments induced such leaf abnormalities as forked leaves, pitcher-shaped leaves (epinocidia), and various changes in the shape of the lamina in the affected plants. Stem abnormalities were also observed. Most of these types of stem and leaf abnormalities are known to be induced after X-ray treatment and have been reported from time to time by various authors. Such similarity of actions suggests that ethylimine affects auxin synthesis in much the same way as X-ray are known to do (Bose and De, 1964).

Basak (1966) estimated amounts of cross pollination in X-irradiated and non-irradiated segregating (F_2) populations of jute for a monogenic factor using red as a seedling marker character. Cross pollination has been found to be greater in the irradiated than in the non-irradiated population. The reason for the increase in cross pollination is presumably due to radiation induced pollen sterility. This method of promoting cross pollination can be utilized more effectively where artificial crossing is difficult. Complications arising in selection of mutants in mutation breeding have been discussed.

A slow growing male sterile mutant, "Ribbon", was first observed in the M_2 progenesis of 70,000 R treatment of the dry seeds of Corchorus capsularis L.. Generally, normal leaf trait was found to be dominant over 'Ribbon' trait and male fertility over sterility. The leaf variation is controlled by one factor pair and similar is the case with male sterility. The trend of fluctuation of pollen sterility in F_2 population indicates the probability of the presence of two closely linked genes controlling the two traits (Rakshit, 1967).

Micromutations.

Induced micronutations for quantitative characters which are controlled by polygenes have been studied by a number of workers in a number of crop plants. Many workers have emphasized that the variance is increased in the treated populations giving scope for effective selections.

Gregory (1955) assumed that the shifting in the mean in an irradiated population is in the magnitude of individual changes. Konzak (1956) and MacKey (1956) pointed out that, it is more difficult to induce an improvement in the direction in which the breeding is already being performed. Bateman (1959) for the first time, came out with the hypothesis that, induced polygenic mutations follow a particular direction which is always opposite to that of the direction of the previous selection. This hypothesis has been supported and extended by Brock (1965) and Goud (1967, 1968).

Gaul (1965) and Aastveit (1966) formulated a new hypothesis stating that, "By random mutation a change in the mean value of almost any quantitative character of interest in plant breeding is to be expected in a direction associated with reduced vitality and the alternation of the mean is largely independent of the genotype and for the mutagenic treatment".

Gregory (1960) found that, quantitative characters which show greater variability in genetic background before the treatment offer better opportunities for obtaining positive mutations after the treatment. Later (1968), he presented data which suggest that "The number of minus and plus mutations in the polygene system are nearly equal and that it is the magnitude of the phenotypic effect of a mutation which gives 'minus' effects and not its unidirectional character". He also showed that the number of such changes becomes large if their magnitude becomes small. Consequently, in these changes the alternation of the mean could be largely independent

of the genotype. Thus the increase of genetic variability permits selection in either direction.

Goud (1968) has clearly pointed out, in wheat, how the previous selection affects the direction of maximum mutations and he also pointed out that, selection has to be applied simultaneously for all economic characters as one is likely to lose one character in trying to improve the other. He clearly indicated that the characters which are not subjected to selection previously, the induced mutations do not follow a particular trend but would be at random.

Quantitative studies on variation of heading date on irradiated materials show that, the induced variation in many instances were towards earliness or lateness in equal frequencies or in other cases more towards lateness (Abrams and Vilez-Fortuno, 1962; Abrams and Frey, 1964; Gonzalez and Frey, 1965). Several other characters were changed in early maturing mutants.

Cereals.

Substantial increase of genetic variance for days to heading, panicle length, and plant height of rice through X-ray irradiation was reported by Kao et al. (1960).

In rice, Castillo Munoz (1983) studied eight yield characters in segregating M_2 sub populations resulting from the treatment of Caribe with ethyl methane sulphonate, sodium

azide and gamma-rays. It was apparent that all these mutagenic agents were efficient in inducing genetic variability. Heritability values for number of spikelets/panicle and panicle weight suggested that these traits will respond to selection.

Wang and Pang (1984) induced micronutations in rice through gamma irradiation. Hybrid rice grains were more sensitive to radiation than were the parental grains and their subsequent development showed increases in range of variation, mutation frequency, variation coefficients and heritability.

Sun et al. (1984) in a study of 222 mutants induced from 23 cultivars, mutants showing variation in 1, 2-3, 4-5, and 6 agronomic characters represented, respectively, 6.5%, 42%, 48.7% and 13.1% of total. Some variations occurred simultaneously in the same mutant. seventy two dwarfs were 10-35 cm. shorter, 105 mutants were 5-35 days earlier and 11 mutants were 1.7-5.4% higher in protein than their respective parent. The range of variation for resistant to Pyricularia oryzae and Xanthomonas oryzae was increased but the frequency of variation was low.

Several useful mutants with short stems and short growth periods were selected by Alionte et al. (1985) from the M_2 or M_3 of Krasnodar 424 and Ariana treated with gamma rays or X-rays. Several of the mutants also had higher yields and increased grain protein contents. Test cross of mutant 52a with the parent Krasnodar 424 showed that the short stem of former was controlled by a single recessive gene .

Brief information is given on the parentage and characteristics of 35 mutants recorded in the catalogue of upland rice cultivars of the Institut de Recherches Agronomiques Tropicals. Four mutants derived from 63-88 (not entered in the catalogue) showing useful characters, including strong tillering, semidwarf habit and good panicle exsertion, are briefly described. The semidwarf habit of the cultivar IRAT 13 and the line M 312 A was controlled in each case by a single recessive gene; some example of linkage are reported (Jacquot, 1986).

Several mutants which matured 4-27 days earlier than the parent varieties were derived by gamma irradiation of the semidwarf varieties BR-IRGA 409, BR-IRGA 410, CICA 8 and CICA 9. All the mutants showed alterations in other characters, such as height and grain shape. The mutant 410 MU 30 matured 10 days earlier than its parent BT-IRGA 410, but equalled it in yield. CICA 8 MU 53 matured 17 days earlier than its parent CICA 8 and shared its resistance to Pyricularia oryzae (Carmona, 1986).

The mutants UPRM 500 and Basmati 370-A-132-3-9 were induced in the varieties Hansraj and Basmati 370, respectively, by treatment with ethyl methane sulphonate. None of the mutants out-yielded the variety Ratna but Basmati 370 A-132-3-9 out yielded the control varieties Type 3 and Hansraj. Both mutants have higher hulling, milling, and head rice recovery than Basmati 370 in quality. Basmati 370-A-132-3-9 is moderately resistant to Xanthomonas campestris pv. Oryzae (Mani et al., 1986).

Mallick et al. (1986) studied ethyl methane sulphonate (EMS) induced micromutation in a tall indica rice. When grains of the tall indica variety Dahar Nagra were soaked in an aqueous solution of 1% EMS for 4, 6 or 8 h., tiller number per plant, filled grains number/panicle and yield/plant were reduced and weight of 1000 filled grains (1000 w) was increased in the M_2 and M_3. Treatment induced genetic variability and advance in the five traits; the longer the treatment the greater was the estimated parameter. For example, for 1000 w genetic advance was increased from 0.14% with the 4 h. treatment from 3 to 7.8% for the same treatments, the respective figures for yield/plant was 2.81 ——— 6.46% and 13.6 ——— 22.3% . It is concluded that EMS treatment could be used to select improved plant types on the basis of induced polygenic variability, particularly in the M_3 .

High phenotypic variability for the characters of plant height and number of productive tillers per plant in wheat following X-irradiation was reported by Bhatia and Swaminathan (1963).

Bahl et al. (1968) treated dry seeds of wheat varieties namely, N.P. 823 and N.P. 860 with X-rays (20 KR and 30 KR). Mean of different characters in the irradiated treatments were not appreciably influenced except for plant height in M_2 generation. However, the higher doses of irradiation increased correspondingly the spectrum of variability in all the characters particularly in the case of ear length and plant height. In the study of M_2 population, there was no particular advantage in selecting bulks of M_1

from the main shoot versus side tillers. Similarly for M_3 generation, bulk originating from such of the M_2 plants whose mean were higher than the mean of the control did not show any advantage over the bulks from all the plants irrespective of their individual yield level.

Borojevic and Borojevic (1968) studied the response of different genotypes of Triticum aestivum ssp. vulgare to metagenic treatments. For the study of the response of different genotypes to irradiation they have chosen several varieties of T. aestivum ssp. vulgare. The analysis through generations was performed on seven varieties representing entirely different genotypes and divided in three experiments according to year and type of treatment. The results show that irradiation by Thermal neutrons, X-rays and gamma-rays results in a decrease in the mean value of quantitative characters in the M_1 generation. The mean values increase sharply in M_2 compared to M_1 but are still below those of control. In M_3 a slight decrease was observed, in the M_4 a stagnation and in the M_5 the mean values are around those of control in all genotypes. If the individual genotypes are considered in which the mean has reached or exceeded the mean of the control in the M_4 and M_5. It was very difficult to see the response of different genotypes. In general, all genotypes react in the same way. The specific response to mutagenic treatments was not found in the studies of the quantitative characters of the seven high selected varieties of Triticum aestivum vulgare in later generations.

Buneeva and Shevtsova (1981) studied mutability of winter bread wheat after treatment with chemical mutagens. Useful mutant lines produced by treating grains of Bezostaya 1 with ethyl eneimine and N-nitrose-N-methyl urea included some lines (381 and 171) which outyielded the control by 20.5%.

Yanev (1982) treated grains of 5 varieties with gamma-rays, fast neutrons, ethyleneimine, ethyl methane sulphonate and other chemicals mutagens. The salient characters of some of the mutant lines obtained are described. These includes forms with a high content of gluten and protein and forms with reduced height. Particularly promising were mutants obtained by treating F_1 hybrid grains with gamma rays (5-10 KR); these mutants were short, lodging resistant, high yielding and resistant to cold and drought.

Molotkov (1982) studied chemical mutagenesis and yield in winter wheat plants. Information is presented on the behaviour of chemically induced mutants in several generations and when intercrossed. Selected mutants showed themselves supperior to the varieties from which they were derived in a number of characters, notably lodging and disease resistance, ear compactness and protein and gluten content.

Gaul (1964) pointed out that, basic investigations on the traits of micro-mutations and the frequency of their occurrence required much more space, time, work and practice than selection

of macro-mutations. He later from his extensive work (1965, 1966 and 1969) with X-irradiation in barley concluded that irradiation results in a decrease in the mean and an increase in variance. He isolated one micromutant from 1000-lines with an yield capacity 10% higher than the mother cultivar.

Vasudevan et al., (1969) studied variability in quantitative characters of five different doses of X-rays at different dose rates in M_2 generation of barley variety C.138-2. Irradiation of seeds, particularly at higher doses induced greater variability as compared to the control. The mean yield of grains in the highest dose of 16,500 r was also significantly greater than the control.

Bird and Neuffer (1984) studied agronomically and botanically useful EMS-induced mutants in maize. Ethyl methane sulphonate treated pollen of maize Mo 17 was used to pollinate 75 plants of the inbreed A.632. of 1140 M_2 families examined, over 270 had plants that deffered significantly in time to pollination, plant or ear height or other agronomically interesting traits.

An increase or decrease of mean for grain weight, plant height and height of the ears in sorghum after X-irradiation were recorded by Sree Ramulu (1974).

Oil seeds.

Ramanathan (1983) studied the effects of mutagenic treatments, gamma irradiation, EMS and combined treatment on economic characters of groundnut cultivars TMV 9 and Ah 7911 in M_2 and M_3

generations. While there was reduction in the mean values of different characters in M_2 generation, they were equal to that of control in M_3 generation. Mutagenic treatments have resulted in the increase of genotypic variance, heritability and genetic advance of yield attributes. High heritability and genetic advance for pod yield at 40 KR treatment in TMV 9 and 40 mM of EMS treatment in Ah 7911 have shown the possibility of genetic improvement following selection.

Ramanathan and Rathinam (1983) studied the effect of mutagenic treatments on the character association in M_3 generation of two varieties of ground nut. Negative association between height and main stem and pod yield in TMV 9 and number of branches and number of pods in Ah 7911 was observed in the combination treatment against the positive association in the respective parent populations. The positive association between number of flowers on one hand and number of pods and pod yield on the other which existed in the control population of TMV 9 was not observed in 80 mM of EMS treatment. The possibility of selection for yield with improved plant architecture from mutagen treated populations was indicated by the altered character association.

Green and Marshall (1984) studied induced mutations in lin seed (Linum usitatissimum). Two M_2 mutants, induced in the variety Glenelg by dry seed treatment with EMS (0.3 or 0.4%), bore seeds in which linolenic acid constituted appx. 29% of the total fatty acid content compared with 43% for seeds of untreated Glenelg. Linoleic

acid constituted 30% of the total fatty acid content in the mutants, compared with 18% in Glenelg. Both mutants had lower linoleic desaturation ratios (linolenic acid percentage : linoleic acid percentage) than Glenelg. The pattern of variation in the linoleic desaturation ratio (LDR) in the M_3 and M_4 indicated that control may be by a single additive gene, plants with LDRs being homozygous for mutant allele and those with medium LDRs being heterozygous.

Panda (1981) could successfully isolate an adventagious compactly branched plant-type with increased number of seeds/ capsule which augmented the yield to 15% and 19% in Kharif and Rabi season respectively from a mutant MB_{3-7} isolated in M_2 generation from seeds of Binayak treated in 1% EMS solution for 6 hours at $(23^{\circ} \pm 1^{\circ})$ C .

Other plants.

Frey (1965) demonstrated the production of micramutations for seed weight in Oats and their values for altering the traits after irradiation.

Scossiroli in a series of papers (1965, 1966 and 1968) reported the effects of irradiation on Quantitative traits in different crop plants and emphasized the importance of large genetic variation as a source of better response to selection from the breeding point of view .

Goud et al. (1971) studied induced polygenic mutations in two varieties of ragi after treating the seeds with aqueous solutions of 0.2 and 0.3% ethyl methane sulphonate. In M_1 generation, the variance was increased indicating the effectiveness of mutagen in inducing polygenic mutations. In M_2 generation, it was noticed that, for characters which were subjected to previous selection such as plant height and number of fingers per plant, the induced mutations follow the opposite trend but in characters which were not subjected to previous selection like number of tillers per plant the induced mutations are random but with an increase in the variance.

Seeds of K. 221-1 (Setaria italica) were irradiated with gamma-ray with 20 KR, 30 KR and 40 KR doses. M_2 progeny from each treatment was raised in a replicated design. The best 24 lines out of 500 plant progenies were selected on the basis of M_2 progeny row means. The range of genetic variability for plant height, tiller number, ear length and grain yield per plant increased due to gamma irradiation. The deviations in the means were highly significant for most of the progenies in all the three (M_2, M_3 and M_4) generations. Several promising M_3 and M_4 lines with shorter plants and increased tiller number and grain yield per plant were selected (Madhava and Goud, 1973).

Lawrence (1975) practised selection for high and low number of seed per pod in families derived by selfing single irradiated plants from a homozygous line Arabidopsis thaliana (Heyn.). Such

plants were given a single initial dose of 100, 200 or 300 Krads of ^{60}Co gamma-rays. Selection was also carried out in the control. Selection in the high lines acted principally to reconstitute the control genotype, though this was not entirely successful and most high lines became homozygous for deleterious mutations "Positive" mutations the increased the number of seeds/pod to above the control level were at best very rare and expressed only in certain environments.

C. intybus, L. serriola and three cultivars of L. sativa were used to study their response to gamma-irradiation at doses of 10-80 KR. The parameters studied included growth traits such as seedling plant height, plant height at maturity, number of branches per plant, number of leaves per plant and reproductive traits such as number of seed bearing heads, weight of fertile heads per plant, number of seeds/head, weight of 100 seeds, in both M_1 and M_2 generations. Results indicated a general trend of reduction with the increase of dose levels. C. intybus was much more radioresistant than Lactuca and the wild L. serriola more radiosensitive than the cultivars of L. sativa .

Sinhamahapatra and Rakshit (1984) observed that, X-irradiation of dry seeds of Corchorus capsularis L. cv. 'Fanduk' induced variations in plant height, as evidenced by the high values of genotypic variances and heritability estimates in M_3 generation. Selection on the basis of line mean of plant height in M_3 was effective in increasing plant height as well as fibre yield in M_4

generation. A higher response of plant height rather than for fibre yield itself was, however, observed in lower radiation dose. Further evaluation in M_5 and later generations confirmed the worth of selection. Distribution of selected lines on fibre yield classes revealed that 50% of the selected lines were higher yielder than the control. When all the top ten lines were selected, the average increase in fibre yield was 14%. The top two lines, however, separately registered 41% and 30% higher fibre yield than that of the control. Some of those selections also gave promising results in prerelease field trails.

Mutation Research in Grain Legumes.

Broad bean (Vicia faba L.).

Macromutations.

Kasprzyk (1970) irradiated dry seeds of the cultivar Nadwislanski (Vicia faba L.) with 2500-7500 R and observed reduced seedling vigour, seed production and fertility of pollen. Mutations detected in the M_2 and M_3 included, besides chlorophyll mutations, changes in flower colour, leaf width and seed colour, size and form. Three dwarf mutations with short internodes were also isolated. The highest proportion of mutations was induced by doses 5000-7500 R, which gave 12.6% as against 2.4% from 2500 R; 22% of progenies contained two different mutations.

Nagl (1979) obtained some mutants following irradiation of seed of the cultivar Kornberger Kleinkoringe (Kornberg Small-

grained) with gamma rays or fast neutrons, for the following traits : habit, leaf shape and size, flower morphology, flower pigmentation (which may be correlated with tannin content of the seed coat), seed size, pod shattering and protein content.

Filippetti and Marzaro (1984) treated dry seeds of Aguadulce (major type) and Manfredini (minor type) with 5-8 KR gamma rays or with 1.2 and 1.7% EMS. In the X_1, the percentage of emerged and surviving plants decreased with increasing mutagen dose. Chlorophyll and morphological mutations were observed in the X_2, the mutagenic effect of EMS being 2-3 times greater than that of gamma rays.

Micromutations .

Bohac and Hudec (1972) treated dry seeds of broad bean with 6000 R gamma rays. In the M_2 and M_4 , 1000-seed weight showed a decrease, but this was not significant. The average values for other important characters also decreased .

Vlk (1975) subjected plants of four varieties of Vicia faba to chronic gamma irradiation. In M_2 and M_3, changes in height and seed yield/plant in comparison with untreated controls was observed. The greatest increases in yield occurred in some lines of Povazsky, particularly in response to the 510 rad immediate radiation dose. In one line this depended entirely on an increase in the number of seeds per plant; in another line on increased 100-seed weight also. Treatment of lines of two varieties with ethyl methane

sulphonate produced in the M_1 little change in the mean values for height, number of flowers, pods and seeds per plant and seeds per pod (where gamma irradiation tended to increase all these values) but the variability of each of these characters was greater after this treatment than after gamma irradiation .

Ismail et al. (1976) treated two of the most common Egyptian broad bean cultivars with various concentrations of EMS. The amount of induced genetic variation for many yield influencing characters was calculated from M_3 populations. The results showed that an appreciable amount of heritable variation could be induced in comparison with the untreated controls. Such variation might be profitably utilised for the improvement of yield in this crop. Differences due to the concentration of the mutagen and the variety were also observed. Such differences should be considered when similar mutation breeding programmes are conducted .

Following selection for high seed yield and protein content in the M_2 and M_3 from treatment with gamma rays or ethyl methane sulphonate, studies of Hussein and Abdella (1976-78) revealed that five out of nine mutants of Giza-2 and four out of six mutants of Rabaya 40 out yielded their parental varieties in both the M_4 and M_5, and that 5 Giza-2 mutants and two Rebaya 40 mutants were superior in protein yield to their parents in both generations. Of the increase in amino acid content observed in protein-rich mutants in the M_4, 17-28% was for arginine, 14-22% for glutamic acid, 5-14% for aspartic acid and 7-9% for leucine; with the exception of one mutant showing a decrease in methionine content, relative increase of 0.49-0.98% was observed for this aminoacid .

When air-dried seeds of Sinjar, Egyptian and French were treated with doses of 0.1 - 200 KR from ^{60}Co, Sinjar proved more sensitive to doses above 1 KR than the other varieties, judging by germination percentage and plant survival percentage. Egyptian was the most resistant to irradiation (Shamsi et al., 1978).

Hussein and Abdella (1979) treated seeds of the Egyptian varieties Giza-2 and Rebaya-40 with gamma rays and ethyl methane sulphonate. Selection in M_2 for seed yield and in the M_4 and M_5 for seed yield and protein content resulted in the detection of five mutants of the former variety and three of the latter which gave higher yields than those of their parents but which had similar protein percentages. It is concluded that seed yield and protein content are apparently not strongly associated in V. faba and breeding for high yield should increase total protein yield.

Seeds of mutant 28/1, originally derived from Kornberger Kleinkornige (Kornberg Small-grained), were exposed to 4, 5 or 7 KR gamma rays. Mean values and deviation parameters are presented for eleven agronomic characters of the M_2 population and large increases in variability over the original population were apparent for grain weight and percentage protein content. Yield and protein content were positively correlated. Analysis of four high, four medium and four low protein mutants revealed a negative correlation between protein content and content of essential aminoacids, particularly lysine. Morphological variants were selected for utilization in breeding programmes (Nagl, 1978/79).

Hussein and Abdella (1978/79) exposed seeds of Vicia faba 'Giza-2' and 'Rebaya 40' to 2.5, 5 and 10 KR gamma rays or 0.025, 0.050 and 0.100 % ethyl methane sulphonate (EMS). Separate sample of Giza-2 were treated with four combinations of both mutagens. selection for high yield was performed in the M_2 and protein content was assessed in the M_3. Some gamma ray induced mutants showed increased seed production without alteration of protein content, whereas some EMS induced mutants showed increased protein content without yield alterations. Mutants derived from combined treatments showedincreased seed yield (> 40%) and reduced protein content (5-10%). Analysis of the protein rich mutants E 25 and E 50 and their original cultivar Rebaya 40 revealed variation in amino acid content .

Abo-Hegazi (1984) outlined the problems of breeding for high seed protein content combined with high seed yield. A small number of promising mutants were obtained by two cycles of selection in the M_4 following gamma-irradiation (0.5-10 KR) of seeds of the variety G-2. Seed protein content of M 257 was 34.9% higher than that of G-2 while M_{1011} had a seed protein content and seed yield 9.6% and 5.2%, respectively, higher than those of G-2 .

Soya bean (Glycine max).

Macromutations.

Chirkova and Tokar (1976) treated seeds of the varieties Blekki, Demetskaya, Kinel and Piper prior to sowing. In the M_2

and M_3 they obtained forms with alterations in growth period, growth rate, size and shape of the leaves and pods and other characters.

Singh and Jha (1978) reported a mutant of T 49, induced by irradiation with 15 KR gamma rays, has less than ten stamens, more than five sepals and petals and more that one pistil. Segregation pattern in the M_2 and M_3 revealed that the trait is conditioned by a single recessive gene, designated ft (transformed flower). Since normal and mutant plants are phenotypically similar until flowering, it is considered that they are isogenic, except for the difference at the Ft locus.

Mashkin (1979) applied doses of 8, 4 and 2 KR gamma rays to air dried seeds of the varieties Smena (change), Yantarnaya (Amber), Salyut 216 (Salute 216) and Amur 310. Twenty one types of morphological mutation and eight types of chlorophyll mutation were found in the M_2. Salyut 216 had the most chlorophyll mutations, followed by Yantarnaya and Amur 310.

Mashkin (1979) treated root tips of Smena (change) and Yantarnaya (Amber) with N-nitroso-N-ethylurea, dimethyl sulphate and ethyl eneimine, a much higher frequency of structural chromosome rearrangements occured after all treatments than in the controls, particularly at high concentrations of the mutagens (0.05 and 0.02%). Anaphase disturbances included chromosome fragments, bridges and logging. Yantarnaya had a higher frequency of structural rearrangements than Smena.

Nong et al., (1979) treated Smena (Change), Yantarnaya (Amber), Salyut 216 (Salute 216) and Amur 310 varieties with N-nitroso-N-ethylurea (NEU), dimethyl sulphate and ethyl eneimine and observed that, the frequency and spectrum of changes in the M_1 and M_2 were greatest with NEU. The change of corolla colour from purple to white, and also certain types of variegated leaf, were inherited in the M_2.

In the M_2 after the gamma irradiation of seeds of B 19 and Gigas with doses of 10, 20, 30 and 40 KR, chlorophyll mutations occured with frequencies approximately proportional to the dose but generally higher in the Gigas population than in B 19. The chlorina and maculata nutations were the commonest. Among 30 morphological and physiological mutations noticed, lateness, pigmented stem, small branch-insertion angle, cordate leaves, dark-brown pods, large seeds and white-striped black hilum were commoner in B 19 than in Gigas. About a dozen other features, notably earliness, crenate leaf margins and varicoloured seeds, occur more commonly in Gigas. Particularly valuable for breeding purposes were large seeds (occuring with a frequency of 6.9% in the M_2 population from B 19), reniform seeds (over 6% in both populations) and modification of leaf form. Most of the mutations seen in the M_2 were recessive. Several mutations could be present in a single plant, suggesting pleiotropic effects of some of the genes involved (Muresan et al., 1984).

Brogaman (1984) treated seeds of cultivar century with 2500 ppm of ethyl methane sulphonate (EMS) and observed in the M_1 and M_2 significant genetic variation for fatty acid composition and for agronomic traits. The distributions of fatty acids were skewed toward high levels of oleic acid and low levels of linoleic and linolenic acid. Agronomic traits were skowed toward low-yielding, late maturity and lodging suceptible lines. The mean of each trait for the EMS treated lines did not differ significantly from the mean of the same trait in the untreated population.

Micromutations.

The purposes of this study were to determine the effects of irradiation of seeds with thermal neutrons and X-rays on yield, plant height, maturity and seed size in soyabeans and to evaluate the potentialities of such irradiations in soyabean breeding programmes. Progenies of R_2 and control plants of the Adams and Hawkeye varieties were used to gain information on genetic variation and heritability and to predict the possibilities of selecting superior genolypes from irradiated material. Significant amount of genetic variability were present for all characters in all treatments except for yield in the controls. The estimates of genetic variance in the irradiated treatments averaged five times as large as those in the controls, and the predicted genetic gains from selection indicated that an advance could be expected for all characters except plant height. However, the increased variability

in yield was largely in the negative direction, and any gains possible by selecting for yield in irradiated treatments were offset by reduced means. It does not appear likely that higher yielding genotype can be easily extracted directly from irradiated material (Rawlings et al., 1958).

Giosan and Nicolae (1970) treated two varieties of soyabean, Chippewa and Lincoln with thermal neutron, X-ray and gamma ray and obtained an M_2 showing a decrease of free amino acid content in the leaves and an increase in the seeds compared with the control, proportional to the size of the dose. Sugar content was reduced in the leves and increased in the seeds. Protein content increased in the seeds with all treatments and doses, although some gave better results than others.

Giosan and Nicolae (1972) obtained six mutants by treating the varieties Chippewa and Lincoln with X-rays gamma-rays or thermal neutrons which may be used directly or as breeding materials. Their main advantages over the initial varieties are high yields, earliness, large seeds, good forage yields and large number of flowers per inflorescence.

Gerasimenko and Enken (1973) irradiated seeds of varieties differing in morphological and biological characters and in number of recessive and dominant characters with 7 KR gamma rays. Varieties which had many dominant characters were more mutable than varieties with many recessive characters.

Varieties of similar genotypes resembled one another in the frequency and spectrum of mutation, while varieties less close to one another genetically had different mutation frequencies and spectra.

Kunn et al. (1973) derived the new variety KEX-2, from X-irradiation of Keum-kang-dai-rib which matures eleven days earlier and gives higher yields than the original variety.

By presowing gamma irradiation of seeds of Lincoln 8, Tokmak and VIR 29 and subsequent directional individual selection, Akilov (1974) obtained high-yielding stable forms with a high protein content. The yield of green matter and seeds mutant 430, 359 and 448 a were outstanding, outyielded the standard by 8-20% in seeds and 12-27% in green matter and containing 2.7-2.5% more protein in the seeds than the standard.

Akilov (1975) irradiated dry seeds of Kormovaya Linkol'n 8 (Fodder Lincoln 8), Tomak and VIR 29 with doses of 8, 16 and 24 KR. In the M_2 and M_3 a large percentage of mutants was obtained, many of which gave high yields of green matter and seed, together with good values for earliness and protein content. Promising stable forms are undergoing production trails. The best of these outyields the standard by 21-30% and contains 2.7-5.8% more protein.

Kwon and Im (1973) studied the occurrence of sensitivity differences in varieties from Korea, U.S.A., Taiwan and Vietnam when dry seed was exposed to gamma rays. Height was retarded by

10-20 KR and root length by 25-30 KR . Varietal sensitivity can be expressed by the constant K in the equation $1/10 = 1-(1-e^{-KD})$, irrespective of dose (D) used.

Ala (1975) treated seeds of five stable lines of the variety Amur 42 were treated with a 7 KR gamma-ray dose. A study was made of the effectiveness of intraline selection in the M_4 - M_5 for seed size. A large seeded mutant was obtained with 1000-seed weight of 190 gm. Compared with 130 gm. without selection.

Ala (1975) treated seeds of Amur 42, Khabarovak-4 and Pionerka (Pioneer) with gamma rays and an aqueous solution of N-nitroso-N-ethylurea. With gamma radiation, mutants were obtained in the M_6 which exceeded the control by 11-12% in seed yield and by 19-31% in seed size .

Nine M_3 populations obtained by applying each mutagen in three doses, were compared with a control for pod number per plant, 100-seed weight and total seed weight per plant. The means for individual yield components were not significantly altered by the mutagenic treatments but a comparison of the frequency distributions of populations from treated and untreated seed revealed differences for some treatments. The most effective mutagen for increasing variability of the yield components was ethyl methane sulphonate (Conger et al., 1976).

Rubaihayo (1976) irradiated seeds of the variety Bukalasa-4 which gave rise to shatter-resistant, shorter, and early maturing mutants in the M_2. Assessment in the M_3, M_4 and M_5 generations

showed that several of the mutants yielded more than Bukalasa 4, one giving 40% more. The mutants equalled Bukalasa 4 in protein content per 100 g. of seed flour but excelled it in protein content on the basis of unit area of production.

The percentage germination and percentage of plants that survived to maturity were reduced in the M_2 after seeds of Lee and Sepaya Black were irradiated with gamma rays at 10-40 KR. (Choudhary and HaQue, 1976).

Chirkova and Tokar (1976) treated seeds of the varieties Blekki, Demetskaya, Kinel' and Piper prior to sowing. The M_2 of Blekki and the M_3 of Kinel' included forms with a growth period reduced by 8-12 days. Useful changes in height of insertion of the lowest pods, number of pods per plant and seed size were observed in Piper, in the M_2 of Blekki and the M_3 of Kinel'.

Choudhary and HaQue (1976) reported the 100-seed weight of seeds from M_2 plants derived from gamma irradiated seeds of Sepaya Black was higher than that of the unirradiated control for the 10, 20 and 30 KR treatments.

Nicolae et al. (1977) irradiated soyabean seeds with gamma-rays on thermal neutrons and noted data on height, growth period, number of fertile pods per plant, number of grains per plant, 1000-seed weight and grain yield in eleven high yielding lines; most were later and taller than original variety and two were earlier. Some were resistant to drought, lodging and diseases.

Upadhyaya and Singh (1979) estimated the magnitude of induced genetic variability for different quantitative characters in the M_3 generations of seven soyabean (Glycine max (L.) Merril) varieties irradiated with 10 KR, 15 KR and 20 KR gamma rays. In mean performance irradiated populations were not significantly different from the unirradiated populations for most of the characters. However, the total variances within irradiated populations were significantly higher than the variances in control populations for most of the characters indicating induced genetic variability. The magnitude of differences in variance for yield per plant was highest between 'Ankur' 15 KR and 'Ankur' 0 KR.

Nong et al. (1979) treated four varieties of soyabean with N-nitroso-N-ethylurea (NEU), dimethyl sulphate and ethyl eneimine. Useful characters found in the M_2 included high pod insertion (18 cm. higher than in the initial form), larger number of pods per plant (>100) and shorter growth period (96 days as against 109 in the control).

The seeds of five lines of Glycine usguriensis, G. max cv. Gibrid 1501 and the F_2 hybrid Primorskaya 494 x Friihe Gelbe (Early yellow) were gamma irradiated with either 7 KR (the cultivated material). The M_1 and M_2 of all the material had larger and heavier seeds than the initial forms. The increase in seed size in the M_2 was on average 4% in the cultivated material and 7-28% in the wild.

Nirmako et al. (1982) treated Bedford seeds with 0.05 M ethyl methane sulphonate and subsequent generations were found to segregate for normal and dwarf habit. Data on tea traits from ten normal and ten dwarf plant showed that the mutant is about one third shorter, and most other traits are reduced, compared with normal Bedford. Dwarfness was conditioned by a monogenic recessive trait.

Seeds of the mutant lines B 19 and Gigas were treated with gamma irradiation in doses of 10, 20, 30 and 40 KR. The time to emergence was longer the greater the radiation dose, while the percentage of emergence, of plants which flowered and of plants reaching maturity and a number of fertile pods and of seeds per plant were lower. Several other harmful effects of treatment were also recorded. In most respects, Gigas was more sensitive than B 19, though not in number of seeds per plant. As the dose increased, so did 1000-seed weight, especially in B 19 (Muresan et al., 1984).

French bean (Phaseolus vulgaris L.) .

Macromutations .

Rukmanski (1972) in a study of frequency and spectrum of chlorophyll mutations in varieties Processor and 1026, found eleven types following gamma irradiation or treatment with ethyl eneimine or other chemical mutagens, Xantha mutants being the most common and variomaculata the least. Processor was the more mutable variety; it had both a higher frequency and a wider spectrum of visible mutation, and the numbers of chlorophyll and morphological mutations in Processor were significantly correlated .

Ilieva-Staneva (1973) taken dry seeds of Phasolus vulgaris var. subcompressus and (1) irradiated with 175-1575 rad rast neutrons and (2) soaked in 0.6 on 0.3% ethyl methane sulphonate (EMS) for six hours or in 0.15 or 0.075% EMS for 24 h. EMS mostly induced chlorophyll mutations and fast neutrons more frequently induced morphological mutations. Valuable mutants with 13-18 and 20-28% higher seed yields than the initial variety were obtained.

Batikyan and Egiazaryan (1973) induced mutations by treating seeds with 5, 8 and 10 KR dose of gamma ray. Drastic mutations involving sterility or change of testa colour were observed. Chlorophyll mutations, mainly yellow-white (lethal) or yellow-green (semilethal or sterile) were isolated. The optimum doses for inducing mutations were 8 KR with single irradiation and 5 KR with triple irradiation. In the former case morphological mutations continued to appear in the M_2-M_4, but in the latter case only in the M_2.

Meono (1975) after gamma irradiation of french bean obtained five types of mutant, all lethal, which were : albino, cream, yellow, yellow-green and lightgreen. Their segregation ratios were always lower than expected for Mendelian segregation.

Tedoradze and Kodua (1975) studied the appearence of chlorophyll mutations in French bean after treatment with gamma rays. A dose of 13 KR induced a high frequency of chlorophyll mutations in different varieties (1.3 - 9.8); with a dose of 7 KR

the frequency was much lower (0.5 - 4.6%). The highest frequency of chlorophyll mutations in the M_1 occured in Tsanava 3 and Vegetativnyi II (Vegetative II), while the radiation-induced mutant Saparake 75 gave the lowest frequency of chlorophyll mutations. In the M_2 the reverse was the case.

Mohan (1979) treated seeds of the black-seeded variety Porrillo sintetico (Porrillo Synthetic) with ethyl methane sulphonate and reported the appearance of a dwarf mutant in the M_2 which was much shorter than the original variety, having shorter internodes, though more nodules, and shorter rachis, petioles, racemes and pods, and smaller seeds. Number of pods per plant reduced by half and the leaves were dark green and wrinkled in appearence. Segregation ratios indicated that a single dominant gene controls these features.

After treatment of a Mexican variety and Bomba Pestraya (both having coloured seeds) with 10 KR and 15 KR gamma ray doses, white-seeded mutants were selected in the M_2. A study of the stable mutants in more advanced generations (M_4-M_6) indicated that one of them differed from the original variety only in having white seeds (Kazanzhi et al., 1984).

When dry seeds of Phaseolus vulgaris breeding line 7-1404 were treated with 10 or 20 KR of gamma radiation, 9 markar mutations were produced from 412 separate M_2 progenies. The mutations changed leaf shape and texture and produced dwarfism and various chlorophyll deficiencies. Mutations affecting

leaves included rnd (round leaf), dgs (darkgreen savoy leaf), dia (diamond leaf), cc (chlorotic cup leaf) and sl (stipeless lanceolate leaf). Mutant do (dwarf out crossing) had small leaves, short internodes and pods and a natural outcrossing frequency of 10-56%. Mutant cs (chlorotic stem) had a milky white stem, while sil (silver leaf) had its leaf colour modified by a silvery reflectance. In mutant pc (progressive chlorosis), leaves emerged normally coloured but became chlorotic with age. All mutants were controlled by single recessive genes (Nagata and Bassett, 1984).

Micromutations.

Marcos et al. (1972) studied the effect of gamma rays on french bean and found the germination capacity of seeds of both varieties decreased as the dose increased. Doses of 12.0 and 24.0 KR reduced germination capacity considerably and doses of 36.0 KR and 48.0 KR reduced germination to zero. Rosinha was the more radiosensitive at the higher doses.

Mujeeb and Greig (1973) recovered four mutants designated SDM-1 and SDM-2 (semidwarfs), LfHy (late flowering high yielding) and PSHy (pod shape high yielding) in the M_2 generation. The mutants were tested for character stability until the M_4 generation. The semidwarf mutants were determinate and twining. They germinated, flowered and matured later than the parental control (unirradiated). SDM-1 and SDM-2 exhibited minus (lower than control) changes in number of pods, 100-seed weight and yield.

LfHy had plus (better than control) changes in number of pods, seeds and yield but a minus change in 100-seed weight. PSHy had flattened pods and oval seeds and gave significantly higher yields than the control. It had more pods and seeds than the parent. Yield in all four mutants was significantly influenced by number of pods. The protein content of all the mutants similar to that of the control.

Sarafi (1973) treated the varieties Naz and Pinto-III with neutrons and gamma rays. Variations in seed size and protein percentage were studied in three high-yielding M_3 lines differing morphologically from the varieties from which they were selected. There was a positive correlation ($r = 0.703$) between the characters mentioned. The mutant M_3-1-Pi-10N from Pinto III, obtained by neutron irradiation of 10,000 rad, 12.8% larger seeds and 14.89% more protein than the original variety.

A comparison of a control variety and mutants in the M_4 selected from M_3 following irradiation of Naz with neutrons showed that : (1) the number of pods per plant was significantly higher than the control in one of the mutants; (2) the number of seeds per pod was reduced in most mutants; and (3) the 100-seed weight was significantly higher in two of the mutants (Sarafi, 1974).

When bush-type mutants of Mexico-142 were selected in the M_2 and subsequently evaluated in the M_3, M_4 and M_5 generations, several mutants gave higher yields than the initial variety. The

mutants retained the protein content of Mexico-142, as determined in flour from 100 g of seed but showed increased protein yield per unit area (Rubaihayo, 1975).

Rubaihayo (1975) treated air dry seeds of the determinate, bushy, early variety Banja-2 with 7-21 KR gamma-rays. In the M_1, (1) height at maturity was increased by all treatments except 17 and 21 KR, and (2) 100-seed weight was increased by all treatments but seed yield decreased. M_2 data indicated that the white-testa and white flower characters were controlled by different genes. In the M_3- M_5, four lines showed higher seed yield and slightly higher protein contents than Banja-2 .

Vardanyan (1979) made a study of seven single gene mutants differing in seed colour obtained from Haykakan Karmin (Armenian Red) by means of treatment with 0.02% ethyl eneimine (EI) and 0.01% dimethyl sulphate (DMS). The EI induced mutants were heterozygous for the mutant gene, whereas those induced by DMS were homozygous. Economically useful mutants had more pods per plant, higher insertion of the lowest pod, greater 1000-seed weight and uniform ripening.

In a study of the effect of gamma irradiating 13 lines belonging to four varieties on chickgrowth by means of a growth assay using a diet containing about 50% Phaseolus vulgaris, irradiated lines of Pinto and Pink gave significantly better chick growth than those of Red Mexican and white pea. The gain : feed ratio tended to be improved by irradiation, but the improvement was significant only for the Red Mexican breeding line RS 59 (Reddy et al., 1979).

Winged bean (*Phosphocarpus tetragonolobus*) :

Seeds of *Phosphocarpus tetragonolobous* were exposed to 15-20 KR gamma rays, of 0.05 - 2.0% ethyl methane sulphonate. Mutants of leaf colour, leaf shape, reduced internodes and early flowering were noted in the M_2 generation, although the desired mutant with a determinate habit was not detected (Kesavan and Khan, 1978).

Micromutations.

Mutants with a bushy habit and varying degrees of earliness were obtained from Trivandrum local cultivar following exposure to 10-15 KR gamma rays. The plant produced 5-6 pods with 5-6 seeds each (Shivashankar, 1982).

Red gram (*Cajanus cajan* L.).

Macromutations.

Six male-sterile mutants of tall or dwarf habit were isolated in the M_2 of *Cajanus cajan*, 'Pusa Ageti' following treatment of presoaked seeds with 0.1-0.3% ethyl methane sulphonate for 6 h. Apart from differences in branching, the tall mutants possessing fewer branches, both types of mutant showed a delay in flowering of almost two months, reduced inflorescence length, an increase in sepal, petal and carpel number, lack of fruiting, a reduction in stamen number and a high degree of pollen sterility (78.06 - 92.13% in the tall mutants and 95-100% in the dwarfs) (Chaturvedi and Sharma, 1978).

Rao and Reddy (1984) studied the induction of mutations in Cajanus cajan (L.). When T 21, ICP 7409 and ICP 2836 were treated with various doses and concentrations of gamma rays, diethyl sulphate, ethyl methane sulphonate and hydrazine, gamma rays proved to be the most potent while R 21, followed by ICP 2836 and ICP 7409, was the most sensitive variety. A wide range of mutants were obtained, of which mutants with different forms and reduced stature and of habit were the most common. Several mutants with profuse branching, prolific pod clusters and bold-seeded pods appeared promising for increasing yield.

Das and Tickoo (1977) studied effect of ethyl methane sulphonate (EMS) on germination and seedling injury in different varieties of pigeon pea (Cajanus cajan L.). Germinating shoot as well as primary root length of all the pigeon pea varieties decreased with increase in concentration of EMS. None of the varieties showed 50% reduction in germination indicating L.D. 50 for germination lay above 0.2% EMS solution, the highest concentration used. Root and shoot inhibition due to EMS treatment suggest that the varieties studied fall into two distinct groups : (a) NP-69 and NP(WR)-15 group (more than 50% inhibition) and (b) AS-3 and AS-5 group (less than 50% inhibition). Genetic divergence is suggested to be responsible for differential varietal response to EMS treatments.

Natarajan et al. (1983) studied six quantitative characters in the M_2 following treatment of Cajanus cajan seeds with

gamma rays and diethyl sulphate separately indicated that the range of variation had increased at both ends but the mean values were lower than those of the control for all characters except days to maturity. Greatest variance was recorded for pods per plant and plant height.

Gram (Cicer arietinum L.).

Macromutations.

Thombre and Phadnawis (1974) treated plants of varieties Dacca, N-59, N-31 and green gram with gamma rays and growed in the field. On the basis of morphological characters, five mutants were isolated from Dacca, four from N 59, and one from N 31 and two from green gram. The elongated leaf mutant, elongated pod mutant and white flower mutant from Dacca showed a 3 to 5% increase in crude protein content over the normal variety. The N 59 mutants for leaf size, pink flower and white flower also showed increases in protein content. Mutants for leaf size and flower colour in N 31 and green gram, respectively, also showed a high crude-protein content.

Micromutations.

Chandola et al. (1976) studied pile neutron induced variability in Cicer arietinum L. when 20 seeds of RS_{10} were each treated with the sub lethal doses 2.5×10^{12}, 4.5×10^{12} and 6.5×10^{12} n/cm^2 pile neutrons, one M_1 plant and its M_2 and M_3

progeny derived from the 4.5×10^{12} n/cm^2 treatment matured 18-22 days earlier than the untreated control. Yields of the treated line and the untreated control were similar. Details are tabulated of the yield components of the early-maturing mutant.

Rajput (1977) studied gamma irradiation in gram (Cicer arietinum L.). Of five varieties, Black Chana was most affected, on the basis of seedling emergence, pod production and yield with necessary dosage, when seeds were subjected to 10-20 KR gamma rays. Germination was least affected in 6192, pod production least in P 67 and yield least in C 727. Weight of 100 seeds was most affected in P 67 and least in 6192.

Lentil (Lens culinaris Medic.) .

Macromutations .

A stetile mutant, designated Tendril 1, in which tendrils develop in place of any leaflet, segregated in the M_2 following treatment of dry seeds of the variety L 235 with 6 KR gamma rays or 0.01% N-nitroso-N-methylurea (NMU). Segregation data revealed that the mutation is controlled by a single recessive gene designated ten. A fertile mutant, designated tendrill 2, in which tendrils develop in place of the top two or three terminal leaflets, appeared in the M_3 following treatment of dry seed with 0.01% NMU. Segregation data revealed that the mutation is controlled by a single recessive gene (Sharma and Sharma, 1978) .

Sharma and Sharma (1979) studied induced alterations in seed colour of lentil. Seed coat colour mutants were induced with 0.01% N-nitroso-N-methylurea at a frequency of 0.3% among M_2 plants of three small-seeded Lens culinaris var. microsperma varieties, whereas, gamma irradiation in 10 KR doses produced only one seed colour mutant in a single M_2 generation of 1885 individuals.

Sharma and Sharma (1980) described two new mutations in lentil. 'Long peduncle' mutation was semi-fertile induced with 0.01% NMU in the variety L-258 and 'Multiflorate' mutation recovered in the variety L-235 after treatment with 0.005% NMU was sterile. The mode of inheritance revealed that both were monogenic recessive macromutants. The gene symbol proposed for 'long peduncle' and 'multiflomte' mutations are lp and mf respectively. Towards the end of growth period, there is proliferation of the peduncle into a branch and that of flower into a shoot in these mutations, probably under the influence of increased temperature and day length. The gene mutations have, thus, increased the sensitivity of the mutants to these environmental conditions leading to a reversion of the reproductive phase to vegetative state.

Four mutations affecting chlorophyll synthesis in two small seeded (microsperma) and two large seeded (macrosperma) varieties of lentil (Lens culinaris Medic.) were recorded following treatment with gamma-rays and N-nitroso-N-methyl urea (NMU). Albina and Xantha were completely lethal. Chlorina with green-yellow colour

had partial variability, and viridis mutants reached to maturity. The frequency of chlorophyll mutations was correlated with the dose of gamma-rays and NMU in both the varietal groups. At a common biological parameter (LD 50 for plant survival), the frequency of chlorophyll mutations was 1.5-2 times greater in the NMU treatment than with gamma-irradiation. There were no varietal or mutagenic differences with regard to the spectrum and relative proportion of chlorophyll mutations. The induction of four different chlorophyll mutations with similar relative proportion is a reflection of parallelism in genetic variability. NMU was 2.5 - 5 fold more effective and 1.4-1.8 fold efficient than gamma-rays. The chlorophyll mutations of the same categories induced in the microsperma varieties had better survival and fertility than in the varieties from the macrosperma group (Sharma and Sharma, 1981).

Micromutations.

True breeding mutants with pods which were larger or longer than those of the parent form were obtained in the M_2 following exposure of dry seeds of L 235 to 6 KR gamma rays; mutants with pods which were smaller or very much smaller were obtained with 10 KR gamma rays. Increase on decrease in pod size was accompained by a concomitant change in seed weight, except in the mutant with large pods. Pod surface area and 1000-seed weight were significantly correlated, indicating that pod size may be used as a selection criterion for seed weight. Monohybrid segregation patterns revealed that all the mutations were controlled by single recessive genes (Sharma and Sharma, 1978).

Ravi et al. (1979) studied induced mutations for quantitative traits in lentil. Following treatments of seeds of Lens culinaris 'L9-12' with ethyl methane sulphonate (EMS) and gamma-rays, selection for increased height and for more primary branches, pods and seeds per plant was performed in the M_3. In M_5 and M_6 trails of the five high yielding progenies selected in the M_4, two progenies in the M_5 and four in the M_6 outyielded the control, and one EMS - treated progeny out yielded the control in the M_4, M_5 and M_6.

Sharma and Sharma (1981) studied the effect of mutagens on character association in lentil. In the M_3 generation of early flowering mutants induced through N-nitroso-N-methylurea (NMU) in 'L 259' variety of small-seeded lentil (Lens culinaris Medic. var. microsperma Zhukovsky), the phenotypic correlations in the original population were strengthened, weekened, reversed or remained unaltered as confirmed by the changes in means and ranges. Since the nature of selection practised in the treated and control population was the same, any difference in the correlation coefficients between control and treated populations can be attributed to the effect of mutagens on linkage and the altered effect of the newly mutated genes. Higher phenotypic association for certain attributes indicated the possibility of improving and obtaining correlated response for seed yield components.

Sharma and Sharma (1982) compared the quantum of induced polygenic variability for five economic characters in the M_2 and M_3 generations after treating the seeds of two lentil varieties

with gamma-rays and NMU. There were neither varietal nor mutagenic differences for the release of the genetic variability in both the generations. However, the characters differed in the manifestation of variability in different generations. The appropriate generation for the selection of the micromutations, is the one, which exhibits the highest variability and stabilization of the mean in a favourable direction. Accordingly, selection for days to flowering and branches/plant should be started in M_2, whereas for 1000-seed weight in the M_3 generation. The selection of the plants for higher pods and seed yield/plant will be more effective in the M_3 and M_2 generation. The conclusion of the present study need not be generalised as the effect of the mutagens and behaviour of mutations might vary depending on the genotype, mutagen and their interaction.

Tyagi and Sharma (1984) studied association of seed size with morphological markers in lentil (Lens culinaris Medik). Association of seed, pod, leaf size and seeds per pod in 48 genotypes revealed that seed size was significantly correlated positively with leaf and pod size and negatively with seeds per pod. Leaf and pod size were also positively correlated. Therefore, leaf size can be used as fairly reliable selection index for selection for seed size in segregating populations even at seedling stage.

Mutagenic effects of gamma-rays and N-nitroso-N-methylurea (NMU) were studied for the induction of micro-mutations in M_2 and M_3 generations of lentil (Sharma and Sharma, 1984). Estimates of variability for production traits were larger in the mutagenised

populations than the untreated controls. The magnitude of the induced genetic effects was comparable at doses of gamma-rays and N-nitroso-N-methylurea causing similar reductions in plant survival. There was no relation between the mutagen treatments and the doses inducing the most micro-mutations. The higher values of predicted heritability and genetic advance suggested that the mutations have mostly occured at loci having additive effects. A comparison of the correlation in M_3 generation grown from the selected M_2 population and the control revealed that interrelationships between yield and its component traits increased. The results suggested that the mutagenic treatments plus selection could increase the strength of the correlations between any two characters.

Selection for micromutations can be carried out even in M_2 generation on the basis of character mean and variance. The efficiency of early generation selection varies with character, and some characters do not show greater response to selection in the advanced generations. The M_2 progenies segregating for macro-mutations are likely to yield greater variability also for polygenic traits than their sister non-mutated families. Therefore, selection efficiency for micromutations can be increased by concentrating attention on the normal looking plants in them macromutational progenies. Selection efficiency for polygenic mutations can be further increased by identifying plants with maximum mutagenic damage in the M_1 generation. By applying the selection sieves early it is possible to reject a large part of

the non-mutated or poorly mutated material, the volume of material can be reduced, and the remaining material can be saturated with mutations to a greater extent. This would make it possible to select micromutations with high degree of reliability in M_2 generation, bringing the micromutations at par with macromutations (Sharma, 1986).

Cow pea (Vigna unguiculata).

Macromutations.

Pokle (1972) studied X-ray induced mutations in cow pea. A white flowered mutant of variety 2, induced by 80,000 R X-ray treatment, was found to have simple monogenic inheritance, with white flower colour (v) recessive to violet (V).

Narsinghani and Kumar (1975) treated seeds of cow pea with 0.25% ethyl methane sulphonate (EMS) or 0.025% methyl methane sulphonate (MMS). Chlorophyll mutants were observed only in the M_2. Treatment with EMS resulted in albino, xantha, chlorina and striata mutant and treatment with MMS resulted in albino, xantha and chlorina mutants. Leaf mutations, affecting size and shape, were observed in M_1 and M_2. Meiotic aberrations included reciprocal translocations, inversions, unequal chromosome separation and laggards. Fewer aberrations per cell were observed in the M_2 than in the M_1.

Chowdhury (1983) reported about a bold seeded dwarf mutant of cow pea. The mutant was obtained in the M_2 following

irradiation of dry seeds of V 16 with 40 KR gamma rays. Compared with V 16, the mutant is 50% shorter (height 28-40 cm), but has increased values for pods per plant, seeds per plant, 100-seed weight (a 40% increase) and seed yield per plant; it matures 10-12 days earlier than V 16.

Micromutations.

Narsinghani and Kumar (1976) treated seeds of cow pea with 0.25% ethyl methane sulphonate (EMS) or 0.025% methyl methane sulphonate (MMS). Survival, number of pods, seed yield per plant and pollen fertility were reduced in the M_1 and less so in the M_2. A few mutants had pods 63.5-76 cm long, compared with 20-25 cm for normal pods, but the long pods contained few seeds.

Vasudevan et al. (1984) obtained two non-twining, erect and two semierect mutants in the M_2 (8000 single seed bulk) following 20 KR gamma irradiation of the seeds of the variety C 28. There were significant differences between the mutants in the M_3 and M_4 and C 28 with respect to plant height, branch number and yield per plant, the mutants giving the higher yields. Although the erect mutants showed a reduction in height compared with C 28, their green yield/plant was higher as a result of more branching. The mutants were resistant or tolerant to unspecified nematodes.

Peas (Pisum sativum L.).

Macromutations.

From a gamma ray mutant containing a chlorophyll mutation and a translocation, a line containing only the mutation was

selected, a segregating population from crosses of this line was grown under controlled conditions and the development of the mutant and normal types was compared. In the mutants, chlorophylls gradually degenerated, photosynthesis was reduced and growth was retarded, especially when they were grown in the light; young seedlings formed no stipules; when the mutants were induced to form flower and seeds by grafting on to green plants their flowers were also abnormal. The progeny bred true. Owing to this pleiotropic effect, the mutant is ascribed to a small delcetion (Gostimskiĭ, 1972).

Gostimskiĭ (1973) after treating seeds of pea with ethyl methane sulphonate isolated a lethal chlorophyll mutant which appeared to be monofactorial. Although the leaves of the mutant contained 80% chlorophyll, they produced 7.5 times less oxygen than normal, which indicates a blockage of certain photosynthetic reactions.

Ghosh et al. (1973) studied the induction of mutation in pea by gamma irradiation. The % frequency of chlorophyll mutations induced in Bonneville was linearly related to dose. A wide spectrum of both lethal and viable mutations resulted from exposure to the effective dose range. Among the viable mutants, a few where maturation period, seed type and pod number have been affected are of practical value.

Das and Kumar (1974) studied four chlorophyll mutants induced by gamma rays. They had light-yellow, light-green, white-spotted and orange-yellow spotted leaves. A spontaneous mutant with

yellow pollen was also studied. F_2 data showed that all were recessive characters with a monogenic segregation ratio except for the white-spotted character which showed a duplicate gene ratio.

Completely sterile ethyl methane sulphonate induced mutants were produced by segregation from heterozygons normal M_2 plants in the M_3 or following generations, of 26 sterile M_2 mutants, 21 were rejected in the M_3 as unsuitable for use in the attempt to find fertile plants in succeeding generations while four of the remaining five were finally obtained in a fertile condition (Wellensiek et al., 1975).

Mutant lines obtained from pea variety Torsday (Thursday) using gamma rays, ethyl methane sulphonate and ethyleneimine differed from the initial form in shape of the stem, leaf colour and height. All mutants except one compact form were monofactorial recessives. The exception showed semidominance. Some mutant characters were stable, while others varied according to environmental conditions (Bobodzhanov and Sidorova, 1975).

Gostimskiĭ (1977) studied ten lethal chlorophyll mutants of pea obtained after treatment of the seeds with radiation and chemical mutagens. In two mutants, a genetic block retarded the photosynthetic reaction. Two others had alterations in chloroplast structure. The mutant chl 10 had a primary disturbance associated with Fe metabolism. In the leaves of the remaining five mutants, a

gradual break down in chlorophyll occurred in the course of growth; the causes of chlorophyll instability in three mutants remained unexplained.

Ezhova et al. (1977) studied allelic desynaptic mutations in pea. In two lines of Kapital, obtained by treating the seed with ethyl eneimine (line 9) and ethyl methane sulphonate (line 12), recessive monofactorial mutations were found which caused disturbances in the formation of chaismata during PMC meiosis, leading to the occurrence of univalents, lagging chromosomes and micronuclei. Pollen sterility was 54.2% in line 9 and 83.4% in line 12, compared with 4.79% in Kapital. In the progeny of both mutants a small percentage of aneuploids occured (3.7% in line 9). Evidence was found that the desynaptic mutation also affected megasporogenesis in both lines, leading to a fall in the percentage of developed seeds.

Ezhova and Gostimskiĭ (1979) analysed genetically the chlorophyll mutants of pea. In most of the 20 mutant lines analysed, the induced chlorophyll deficiency was caused by a recessive point mutation, but in two lines the mutant gene was partially dominant. Deviations from the expected monohybrid segregation ratios and chromosome aberrations at meiosis were found in some lines a result of (1) digenic control of the mutant character, (2) additional point mutations or chromosome aberrations arising at the same time as the chlorophyll mutations, (3) gametic selection and (4) low percentage of the mutant genes. Chromosome aberrations occured only after treatment with physical

mutagens (gamma rays and neutrons); chemical mutagens caused only point mutations.

Vasileva (1979) in a study of 14 mutants of the acacia-leaf type (one spontaneous and the rest induced) derived from Roman '77, Kazan, Ireg 5, Muralia and Krasnoufimsk confirmed that acacia leaf type is due to a monogenic recessive mutation. All three of the mutants tested for allelism proved allelic and two of them were phenotypically similar. Some of the mutants were high yielding and are being used as breeding material, notably mutant 1/101, obtained from Roman '77 with a 20 KR gamma-ray dose.

Micromutations.

Vereshchaka (1969) studied the use of gamma irradiation in breeding peas. Presowing exposure of seeds to gamma rays combined with hybridization and other methods is promising for developing initial breeding material. Of 16 F_2 families from crosses between irradiated varieties, eleven outyielded the ordinary hybrids, in some cases by 40-50%.

Migacheva (1979) observed changes in both quantitative and morphological characters in M_1 pea plants treated with ethyl eneimine and N-nitroso-N-ethylurea. Germination rate and survival decreased with increase in concentration of the mutagens.

Quednau (1979) tested fifteen neutron and X-irradiation induced mutants immediately after germination to detect genetic differences compared with the parental line. In twelve of them

significant differences in development rate were recorded and two showed a change in the number of secondary roots. In two cases where the mutated gene has reduced penetrance its influence on development rate was restricted to part of the plants. In those mutants which showed superior vigour in the later stages of growth, the first apparent effect of the mutated gene was a marked retardation of growth which changed later into a sudden acceleration. The mutants probably produce such a high concentration of growth substances that development delayed during the earliest (and most sensitive) stages of development.

Sidorova et al. (1973) made a study of some 1000 mutant lines. Most of the mutants were recessive, but some dominant and semidominant ones were found. Most of the mutant genes had a high degree of pleiotrophy, affecting 10-12 characters.

Debelyĭ et al. (1974) treated seeds of the variety Nemchinovka 766 with gamma rays and chemical mutagens. Mutant lines were obtained with a number of useful characters, including high yield and high protein content.

Vasileva (1975) irradiated nine varieties of pea with fast neutron and gamma rays. Pottentially useful metations were isolated and stabilized over several generations of selection. The mutants include high seed yielder, high protein content, tall and high number of pods per plant.

A mutant R-V 18, obtained in 1963 as a result of chronic gamma irradiation of plants of the variety Raman, was, by the M_{11}

superior to Raman in seed yield by between 30% and 50% but lacked stability of yield. Plant height and insertion height of the lowest pod were stable but number of seeds per plant and mean seed yield per plant were strongly affected by year and sowing rate. Also strongly affected by sowing rate was the number of fertile tillers, and in this respect the mutant was much more sensitive than Raman. The mutant was four to seven days earlier than Raman (Vlk, 1976).

In the central Volga area the M_5-M_6 mutant 2, obtained at the Novosibirsk Institute of Cytology and Genetics in the USSR from Torsday (Thursday), had a growth period 6-8 days shorter than that of local varieties. Using this mutant, stable hybrid forms were produced combining large - seeds with earliness (Evdokimova, 1976).

Alieva and Akhund-Zade (1976) obtained some mutants from the Pakistani form 8 3 after treatment with ethyl methane sulphonate, N-nitroso-N-methylurea, 1,4-biadiazoacetylbutane and gamma-rays. Most of the mutants had a higher seed yield per plant than 83, chiefly on account of an increase in the number of pods per plant. Some mutants had larger and some smaller seeds than 83. During flowering, total sugar content in the dry leaves was slightly higher in some mutants (15.4 - 16.3%) than in the control (13.6%). The short-stemed mutant 51 had a low sugar content (8%). Most of the mutants had a lower protein content, but a higher content of non protein N, than did 83.

Popova (1977) treated pea seeds with 0.012% N-nitroso-N-ethylurea and obtained mutants of determinate forms, forms with altered growth period, lodging-resistant and compact forms and forms with a larger number of pods per peduncle. The compact form contained less cellulose in the stems and leaves than the control, and could be used in salads.

Uzhintseva and Sidorova (1977) treated seeds of pea with gamma rays, ethyl methane sulphonate and N-nitroso-N-ethylurea and obtained mutants ripening five, ten and twelve days earlier than the initial forms. In all the mutants, the first flower was formed earlier than in the initial forms. Early formation of the first flower was not always associated with short growth period. Recessive monogenic mutations were invdved in all but one case, in which two genes mutated. Genetic analysis of mutants for allelism indicated that, in addition to Lf controlling the node at which the first flower is formed, there is another locus responsible for the same character and that Lf and the other locus, which has a series of alleles, are situated in different linkage groups. In studies of mutants from Torsdag (Thursday) for day length, mutant 218 had neutral reactions.

In a study of twelve stable M8 - M10 induced mutant lines derived from Torsdag (Thursday), Falenki 42, Parvus and Saratovskiĭ mestnyĭ (Saratov Local), Uzhintseva and Sidorova (1979) observed that, early flowering was not always associated with a short growth

period. All the early flowering forms were monogenic recessive point mutations. Tests for allelism with Nono for node at which the first flower forms revealed a new allele of this gene designated no^b. Four allele of this gene are therefore, known to exist : No^1 resulting in formation of the first flowers at nodes 18-20, no^m in their formation at nodes 11-14, no in their formation at nodes 8-9 and no^b in their formation at nodes 5-7.

Kaul et al. (1979) isolated two early-flowering and two-early ripening mutants that produce fully fertile normal flowers following treatment of Bonneville with X-rays. Crosses between these mutants show that the genes controlling earliness are non-allelic. The mutant designated EM_1 gives higher yields and had larger grains than the mutant designated EM_2. Seeds of EM_2 contain more protein than those of EM_1. The F_1 derived from EM_1 x EM_2 gave lower yields than EM_1 but had a seed protein content similar to that of EM_2. Seed protein content was reduced in the F_2 and crosses of either of the mutants to the original line. Maternal effects were observed for plant height and days to flowering.

A study of the variety Roman'77 and of its recessive early mutants M_{11}, M_{175} and S_{18}, obtained by gamma irradiation, showed that earliness in the mutants was associated not only with formation of the flower buds at lower nodes than in Roman'77, but to an even greater extent with more rapid rates of microsporogenesis and embryo development. Pollen sterility was greater in M_{11} (10.3% and M_{175} (8.5%) than in Roman'77 (6.1%) and S 18 (4.9%) (Tsitlenok and Petukhova, 1979).

Rao et al. (1984) studied seed proteins of some chromosome mutants in Pisum. Seed proteins (albumins and globulins) of 8 mutants, characterized by chromosome translocations were electrophoretically analysed and compared with those of two genotypes having normal chromosomes. Quantitative differences in globulin electrophoretic patterns in the 40-70 and 20-25 KD zone were observed among the mutants and between them and the normal genotypes. Moreover, almost all the mutants were characterized by the presence of a doublet in the 14 KD zone, which was absent in the normal genotypes. The albumin patterns of some mutants were characterized by the presence of high molecular weight bonds (90 and 50 KD), while those of other mutants were characterized by variation in the amount of the major band (about 28 KD).

Green gram (Vigna radiata L. Wilczek).

Macromutations.

Nine of the 500 M_2 plants derived from seed treatment with 50 KR gamma rays were dwarfed, and had smaller flowers, anthers, leaves and stipules, and notched, incompletely trilobed leaflets, while four out of 500 M_3 progenies segregated for mutant leaflet form. Although the mutants were pollen and seed sterile, meiosis was nonmal. A 3:1 segregation ratio of normal to mutant plants suggested that the mutants differed by one gene, but in view of the many characters affected, pleiotropy or close linkage is thought to be involved (Saini et al., 1974).

Ganguli (1973) studied X-ray induced floral modifications in green gram (Phaseolus aureus Roxb.). The free keel mutant was obtained in a segregating progeny row of X-2 generation at 60,000 r dose. The mutant plants produced flowers which had free keel instead of united keel (normal). Some of the mutant flowers were associated with abnormal positions of the wings, where one or both the wings were developed from inner side of the keel. Both normal and abnormal flowers were produced in the same plant. The mutants were highly sterile, although the pollen was 91 to 94% fertile. The mutant characters appeared to be controlled by a single recessive gene. The mutant gene was found to have incomplete penetrance as well as variable expression. Further, pleiotropic action of the gene was observed which affected fertility and other morphological characters of the mutant.

Bandyopadhyay and Bose (1979) had irradiated seeds of Vigna radiata with 10 kR X-ray after pre-soaking the seeds with distilled water and 0.01% solution of ethyl methane sulphonate (EMS), hydroxyl amine and ethyl eneimine (EI) and identified variants like (1) "stunted', (2) 'dwarf', (3) 'trailing' , (4) 'bushy' and (5) 'tall and bushy' .

Singh et al. (1979) irradiated Vigna radiata cv. T - 44 and ML - 26 with 10-50 kR gamma rays. Chlorophyll mutants like albina, xantha and chlorina were segregated in the M_2 generation in 1 mutant : 15 normal ratio indicating digenic recessive inheritance in this case.

The unifoliate mutants were obtained following X-irradiation of dry seeds of green-gram (Phaseolus aureus Roxb.) at 60 kR and 30 kR dose. The mutant plants had simple leaves instead of normal trifoliate leaves and exhibited total loss of sepals, petals, stamens and carpels. Instead, groups of stiff, green, perianth-like structures were borne on each floral axis. All the mutants were phenotypically identical. Anatomical evidences showed that the unfoliate condition had resulted from suppression of the lateral leaflets and not due to the fusion of the leaflets (Ganguli, 1980).

Ganguli (1981) observed ten types of chlorophyll mutations after X-ray treatments and all of them other than viridis, virescent and variegated are lethal and all of them were controlled by single recessive gene .

Ganguli (1981) studied reciprocal translocation in mung bean (Vigna radiata L. Wilczek). Semi-sterile plants were detected in segregating progeny row of M_4 generation obtained from X-irradiation of 60,000 r. 56% of the grains produced by the plants were shurnken, abnormal sized, empty and distinguished also in having clustered pods. The pods were gappy, containing 2-3 seeds only. About 50% of the pollen as well as ovule were found to be sterile. Segregation for semi-sterility and meiotic behaviour indicates the presence of a reciprocal translocation.

Rao et al. (1984) had shown that the combine treatment with gamma rays and EMS in Vigna radiata was superior to single mutagen treatment but was inferior to recurrent and sequential treatment with respect to higher frequency and wider spectrum of chlorophyll mutation.

Micromutations.

Data on yield and six quantitative traits are presented for M_5 progenies following treatments of Col. (Phaseolus aureus Roxb.) with six levels of gamma irradiation. Number of pods and clusters generally increased with treatment compared with the control and plant height was reduced (Krishnaswami et al., 1973).

Rajput (1974) exposed seeds of the cultivar 6601 to gamma radiation at doses of 10 to 40 KR and studied the effect of flowering time, plant height, number of pods per plant, pod length, number of grains per pod, 100-grain weight and yield per

plant. In the M_2 generation, positive ~~or~~ of negative shifts occurred in the mean values for all the polygenic traits except mean pod length, which remained unchanged. The coefficient of variability increased in all treatments for all the traits.

Dahiya (1973) irradiated the seeds of Pusa baisakhi and hyb. - 45 with 30 and 70 kR gamma rays and observed that where the intensity of the treatment increased the range of yield and number of pods/plant were also found to be increase but the more intensive treatment had greater effect in increasing the number of days to flowering.

Prasad (1976) isolated ten mutants with a higher number of pods per plant than the Phaseolus radiata parent RS_4 from the M_2 after treatment of seeds with 0.02% or 0.03% ethyl methane sulphonate (EMS). The growth of the selected mutants tended to be more compact than that of RS_4. In the three years grown, only the mutant M 8 significantly outyielded RS_4 and the variety S 8. M 8 matured earlier than RS_4 and had good tolerance of drought.

Shakoor et al. (1979) obtained four early, drarf, determinate, synchronously maturing mutants in the M_2 following

treatment of the Vigna radiata varieties Pak 17 and Pak 13 and 6601 with gamma rays. Compared with their parents, the mutants give higher yields and have a higher harvest index.

Singh et al. (1979) studied the gamma ray induced variability for flowering in green gram where varieties T-44 and ML-26 were irradiated with 10-15 KR. The mean number of days to flowering in ML-26 had shifted towards lateness but no change observed in T-44.

Ganguli and Bhaduri (1980) studied in the M_1 generation the effects of X-ray and neutron irradiation. Though the germination of seed was not affected, the growth rate, height, number of branches, pollen fertility and yield were much reduced and flowering was also delayed.

Chaturvedi and Singh (1980) treated the seeds of Pusa baisakhi with different concentrations of aqueous solutions of EMS, nitrosomethylurea. All treatments except 0.1% EMS gave some synchronously mutants in the M_2. The mutants breed true in the M_3 and also gave higher yields than the control.

Singh and Chaturvedi (1980) obtained some large seeded high yielding mutants by treating seeds of the Pusa baisakhi and S-8 with EMS, N-nitroso-N-methylurea and gamma rays separately and in combinations; but highest yield in mutants of Pusa baisakhi and S 8 were isolated from the chemical mutagen and 40 KR gamma rays respectively.

Thakare et al. (1980) exposed c.v. S8 to gamma rays and fast neutrons and selected some plants with increased number of pods per plant and by selection for three successive generations, two mutants e.g., TP-6 and TP-7 were established which gave 25-30% m more yield than control.

Ilyas et al. (1980) following the gamma-ray irradiation of some cultivars of mungbean were able to establish some high yielding mutants that matured uniformly and also were earlier than the control by 1 to 2 weeks.

Tickoo and Jain (1980) treated the seeds of Pusa baisakhi and S-8 with 4 mutagens like EMS, N-nitro-N-methylurea, hydroxyl amine and gamma rays. Variances for the yield and yield contributing characters were found to increase in the M_2 and M_3 generations and according to him as the variance in the M_2 was much more than in the M_3 generation, the selection in the M_2 generation would be more effective.

Krishnaswamy and Rathinam (1982) studied the effect of gamma-irradiation (20 and 40 KR), EMS (20 mM and 40 mM) and combined effect of the two treatment. They found that the coefficient of genetic variation and genetic advance had increased for yield and yield contributing components but they found the differential effects of the treatment on the different varieties like c.v. Pusa-baisakhi, SL-122 .

Singh and Yadav (1982) isolated some mutants after gamma-ray treatment that showed improvement in yield and its contributing characters.

Khan (1982) irradiated dry seeds of Vigna radiata c.v. G-65 with 8 doses of gamma rays ranging from 0-40 KR and observed that the greatest variability was generated in the M_2 generation for yield number of pods and 100-seed weight.

Kwon et al. (1983) following irradiation of seeds of Vigna radiata with X-rays and selection upto M_5 obtained high yielding but late maturing eleven mutants.

Sharma and Singh (1983) developed a high yielding mutant from c.v. M.L.-26 of Vigna radiata after exposure to 10 KR gamma rays.

Shammugasundaran et al. (1983) treated seeds of the cultivated long duration variety CO 1 with gamma irradiation. A high yielding mutant named CO 4 was isolated in the M_3 generation which yielded 910 kg/ha as against 710 kg/ha and 610 kg/ha for CO 3 and KM_2 respectively under rainfed cultivation. The strain is also resistant to tip blight, powdery mildew, root rot and mosaic virus.

Pod length, seeds per pod, 100-seed weight and total seed yield were evaluated in the M_1, M_2 and M_3 of Phaseolus aureus (Vigna radiata) c.v. PS 16 following exposure of dry seeds to 10-40 KR gamma rays. In general, treatment increased the mean values and the range of variation of all traits. Increases in genetic variability (not dose dependent) and in estimates of heritability and genetic advance were found, and these varied depending on trait (Khan, 1983).

Khan (1984) exposed dry seeds of Phaseolus aureus (Vigna radiata) c.v. PS 16 to 20 KR gamma rays or presoaked the seeds in distilled water and then treated with 0.03% ethyl methane sulphonate or 0.04% hydrazine for 6 h. The M_1, M_2 and M_3 generations were evaluated for number of days to flowering, number of fertile branches per plant and number of pods per plant. In all three generations, the mean values and variances of all three traits were higher than in the controls. The highest genotypic coefficients of variation and values of heritability were recorded in the M_3. Estimates of heritability in the M_3 were highest for number of pods per plant (79.34-80.54), followed by number of days to flowering (75.63-76.06) and number of fertile branches per plant (48.48-76.11).

Verma and Singh (1984) observed in the M_3-generation that the mean values of yield and yield contributing characters were increased for all the doses from 20-50 KR gamma-rays and the mean of days to maturity decreased at 50 KR dose.

Black gram (Vigna mungo L. Hepper) .

Macromutations .

Jana (1962) studied X-ray induced mutants of black gram. The irradiation of dry seeds of var. 7-9 with X-rays gave rise to several mutants mostly at 60,000 r dose. Among the sterile mutants, i.e., which did not produce any fruit, three mutants, viz., unifoliate, asynaptic I and semi sterile were found, of which the unifoliate mutant had deep green simple leaves and no

flower or fruit formation. Asynaptic I showed 90-98% pollen sterility and its meiotic study showed lack of pairing at diakinesis and metaphase - I, formation of large number of univalents and irregular anephase division. The semi-sterile type had about 50% pollen sterility and the fruits were gappy. Half of its progeny was normal and the remaining half was semi-sterile.

The twining mutant was characterised by its tall habit, elongated vegetative and floral parts and failure in producing viable seeds. The mutant was found to be conditioned by a single recessive gene (tw). Ray leaflet mutant was conspicuous for its dwarf habit, minute leaves and lack of reproductive organs. The small leaf mutant was weak growing with leaves about one third of the size of the normal. The bud mutant produced small sized buds which failed to bloom and produce any fruit. The tall mutant was characterised with greater stem height, longer internodes and early flowering. The mutant was found to be controlled by a single recessive gene (t). The malformed flower mutant had adnate type of branching. The flowers were light green in colour and produced only a few fruits and seeds. Rolled-leaf mutant, keel mutant and basal branch mutants were also found which were controlled by a single recessive gene. Large pollen mutants formed as a result of the absence of second meiotic division were also observed.

Jana (1963) obtained different chlorophyll mutants after X-ray irradiation in blackgram. The mutants included albina, which

was completely white, xanthoalbina was yellowis white, xantha was yellow and chlorinâ was light green in colour. All these mutants died at first leaf stage . The variegated and virescent mutants had normal first pair of leaves. The later leaves of variegated and virescent had white and yellow patches over green colour. Both these, variegated and virescent mutants produced fruits and seeds. The chlorophyll mutants were found to be mostly conditioned by single recessive gene. The gene symbols proposed are alb (albina), x alb (xanthoalba), xa (xantha), ch (chlorinâ), var (variegated) and vir (virescent) .

Jana and Rao (1974) studied the inheritance of pigmentation in black gram. Mutations affecting anthocianin pigmentation in various plant parts have been recovered after different mutagenic treatments of dry seeds of blackgram (Phaseolus mungo L.) variety T-9. Of these, the anthecianin negative I and anthocianin negative II have no purple pigment in cotyledons, hypocotyl, epidotyl, stem, petiole, peduncle, unlike T-9, which has anthocianin pigmentation in all these parts except cotyledons which are green. Absence of pigmentation in these mutants is due to recessive genes at one of two loci which are complementary to each other. In the purple cotyledon mutant, the cotyledon colour changes to purple, a character that is controlled by an inhibitory gene .

Plants which had flowers with protruding stigmas were isolated in the M_2 of X-irradiated and ethyl methane sulphonate (EMS)-treated seeds of Phaseolus mungo. The mutations, which are

recessive to normal allele and monogenic, were designated crumpled petal (crpt.) and resulted in plants where the petals were reduced in size and were folded inwards enclosing the stamens. The pistil was normal but self fertilization was restricted (Rao and Reddy, 1975).

After treatment with X-rays or ethyl methane sulphonate or both, the following chlorophyll mutations were obtained (by Rao and Jana, 1975) : viridis, chlorotica, chlorina-terminalis, chlorina-virescens and albo-virescens, for which the symbols Vim, Chi, Chres and Alves respectively are proposed. In reciprocal crosses of normal plants with the mutant types, the F_1 plants were all normal and the F_2 segregated 3 normal : 1 mutant. Also recovered was an aureo-virescens mutant in which the progeny had the phenotype of the female parent in the F_1 and F_2. All the mutant types were viable but were less vigorous than the normal plants and had a lower seed yield.

Rao and Jana (1976) following treatments of seed with X-rays and ethyl methane sulphonate obtained four new leaf mutant, crinkled-leaf, waxy-leaf, narrow leaf and unifoliate leaf. The crinkled-leaf and waxy-leaf mutants had normal fertility, whereas the narrow-leaf mutant was partially sterile and the unifoliate, an extreme dwarf, completely sterile. Three of the mutations were monogenic recessive to the normal. The unifoliate mutation, however, appeared to be caused by a chromosome aberration .

Bandyopadhyay and Bose (1980) treated dry seeds of black gram var. T-9 with 0.1% and 0.2% ethyl eneimine and hydroxyl amine(HA).

Percentage of chromosomal aberrations induced was the highest in 0.2% HA. Pollen sterility were 12.92% in 0.1% EI, 14.01% in 0.02% EI, 12.39% in 0.1% HA, 13.77% in 0.2% HA and 2.24% in control. In the M_1-generation, variations in plant-height, leaf shape, pod shape and pod size were observed. In the M_2, % of germination which was the lowest in 0.02% EI was 60% as compared to 90% in control. Chlorophyll mutants were mostly albinos which did not survive for more than 3-4 days. Percentage of seedling mutants was maximum in 0.02% EI. Among plant mutants, tall, bushy, dwarf and stunted types were isolated.

Micromutations .

Singh *et al.* (1979) reported shift in mean and variance caused by gamma irradiation in genus *Vigna*. Following irradiation of *V. radiata*, *V. mungo* and their amphidiploid, increases in height and protein and methionine content were observed in the M_2. Coefficients of variation increased for all the characters studied, with the greatest response being observed for number of pods per plant and seeds per pod.

Kundu and Singh (1981) studied EMS induced variability in black gram. Treatment of dry seeds cv. T-9 with aqueous solutions of ethyl methane sulphonate (EMS) led, in the M_2, to an increase in variation for flowering time from 0.25% treatment and to a reduction in plant height and yield per plant from the 0.05% treatment .

Treatment of dry seeds of T-9 with gamma rays led to increase in the mean values for pods per plant and yield per plant in the M_2 and M_3 and a general increase in variability (Kundu and Singh, 1982).

Role of mutation on nodulation and nitrogen fixation.

Oblisami et al. (1973) studied rhizobial nodulation of induced mutants of black gram. Of eight induced mutants of Phaseolus mungo 'Col', seven had shorter tap roots and six had fewer nodules than the parent. It is suggested that the Rhizobium : root relationship should not be over looked in breeding programmes. One of the mutants (M_6) had significantly more nodules on the tap root than Col. All the mutants were selected in the M_4 generation following treatment of Col with physical and chemical mutagens.

Meherchandani and Rana (1977) identified ten lines from an M_4 population obtained after gamma ray treatment of Vigna unguiculata "C-15-2", that proved superior in nodulation to the original variety. Of 75 varieties of Cicer arietinum assessed for nodulation characters, several proved superior to C 235. Nodule characters were related to dry matter accumulation but not to grain yield. A study using ten varieties of C. arietinum showed different strains of Rhizobium to differ in their effectiveness on different host varieties. H 551 and H 355 were the most responsive varieties.

Meherchandani (1979) following gamma irradiation of seeds of Vigna unguiculata performed selection for superior nodulation in the

$M_3 - M_4$. Pure lines with improved nodulation were obtained in the M_5, and from progeny row yield studies, 35 lines have been selected for further yield trials.

Nodules of Rhizobium japonicum were studied on the initial variety U 70 and the mutant M_{103} derived from it in Vietnam. The mutagens applied were 5-14 KR gamma rays + 0.01% ethyl eneimine (EI), DI and maleic hydrazide. Wide variation was found in the number of nodules of nitrogen fixing bacteria on initial and mutant plants; for example, treatment with EI + 7 KR gamma rays resulted in 96.8-99.7 nodules in M_{103} compared with 60.8 in U 70. The surface of the nodules differed between the initial form and the mutant. The high number of nodules during flowering and well developed vascular system of the bacterial tissue of M_{103} indicated enhanced physiological activity associated with N-translocation at the height of flowering (Chan Long et al., 1984).

Carroll et al. (1986) treated seeds of soyabean cv. Bragg with EMS, gamma rays, or sodium azide and observed EMS was the most effective in generating chlorophyll deficient variants in the M_2. Of 25,000 M_2 plants screened for nodulation ability after inoculation with Bradyrhizobium japonicum strain CBI 1809 (=USDA 136), 3 stable non nodulating mutants were recovered. Mutant node 4a was isolated from a mixture of M_2 populations and also failed to nodulate with Rhizobium fredii strain USDA 257, which nodulated the parent cultivar. Mutants nod 772 and nod 139 came from segregating EMS derived M_2 families .

Achievements through induced mutations •

In spite of the positive results available, many geneticists and plant breeders are still very sceptical with regard to the effectiveness of the application of mutagenesis in plant breeding. It is true that only little success was had during a relatively long initial period. This is due to the fact that plenty of positive and negative experiences were necessary for learning to handle these methods in promising way. At present, about 500 officially released varieties, derived from experimentally induced mutants, are available (Gottschalk and Wolf, 1983).

Some important induced mutants, authers and characters (quantitative) altered are presented in table 1 •

Table - 1. Some important induced mutants, authors and characters altered •

Species	Authors	Mutagens	Characters altered
CEREALS			
Oryza sativa	Bilquez et al. (1965)	X-rays	Plant size, grain characters, heading data.
	Rao and Siddiq (1977)	X-rays, EMS	Tillering, grain size, grain yield •
	Okuno and Kawai (1978 a,b)	X-rays, gamma rays, EMS, EI	Plant height, number of panicles per plant, number of spikelet per panicle, grain size, heading date •

Species	Authors	Mutagens	Characters altered
Triticum aestivum	Tavcar (1965)	gamma-rays	Plant height, ear length, number of kernels per ear.
	Borojevic and Borojevic(1968), Borojevic (1965, 1966)	X-ray, neutrons	Plant height, ear length, number of kernels per ear.
	Goud (1967,1968)	gamma-ray, EMS, neutrons	Tillering, spike number, number of spikelets, grain weight .
	Mehta (1972)	gamma-rays, EMS, NMU	Grain number per ear .
	Kumar (1977a)	gamma-rays	Plant height, tillering, spike length, number of spikelets/spike, grain weight, grain hardness.
	Khamankar *et. al.* (1978)	gamma-rays, NMU, HA	Number of grains per ear, grain size
Sorghum subglabrescens	Sree Ramulu (1974 b)	X-rays, gamma-ray, EMS	Plant height, ear weight, grain weight .
PULSES			
Lens culinaris	Uhlik and Urban (1976)	Neutrons, EMU	Plant height and weight, seed weight, seed set .
Phaseolus aureus	Dahiya (1973)	gamma-rays	Number of pods per plant, grain size, days to flower.

Species	Authors	Mutagens	Characters altered
Phaseolus vulgaris	Swarup and Gill (1968)	X-rays	Number and size of pods, number of seeds per pod, seed size and seed yield.
Vicia faba	Ismail *et al.* (1976)	EMS	Plant height, number of pods and seeds per plant, number of branches, seed weight per plant.
	Abdalla and Hussein (1977)	gamma-rays, EMS	Plant height, tillering, number of pods and seeds per plant, seed weight, seed yield per plant.
OIL SEEDS			
Arachis hypogaea	Bilquez *et al.* (1965)	X-rays	Size of pods and seeds, oil content
	Patil (1971, 1972)	X-rays	Seed size
Brassica campestries	Kumar and Das (1977)	gamma-rays	Plant height, number of branches per plant.
Linum Usitatissimum	Rai and Das (1976)	gamma-rays	Number of tillers, number of capsules per plant, number of seeds per capsule.

High yielding mutants of pulses .

A summarised review is presented on different mutants of pulses showing increased yields .

Pisum sativum .

The fasciated mutants of the collections showed a strongly increased seed production. Some other genotypes with deviating leaf shape, narrow leaves, long internodes, or stem per bifurcation were found to be equal to or some what better than the mother variety, considering yield trails 6-16 generations (Gottschalk 1966, 1977a, 1978c, Gottschalk and Hussein, 1975).

- A pea mutant with an about 20% increased seed yield as available in Russia (Sidorova et al., 1969).

- An Indian early ripening pea mutant is significantly better than its mother variety, but not better than the released varieties. Because of its earliness, however, it is a prospective partner in cross breeding (Kaul, 1977).

A list of authors reporting high yielding mutants in different important pulses is also given here .

Phaseolus vulgaris.

(Swarup and Gill, 1968; Rubaihayo, 1975; Hussein and Disouki, 1979).

Glycine max .

(Josan and Nicolae,1974; Rubaihayo, 1976 b).

Lathyrus sativus •

(Chekalin, 1977) •

Cicer arietinum •

(Kharkwal, 1981)•

Vigna trilobata, aconitifolia, radiata •

(Subramanian, 1980; Singh and Chaturvedi, 1981 b)•

The success achieved through mutation breeding in different crop plants and ornamentals is presented in Table 2•

Table - 2. Different mutagens used for developing 485 released or approved varieties of different crops and ornamentals

Mutagens	Sexually propagated crops		Vegetatively propagated crops		All crops	
	No. of varieties	Percentage	No. of varieties	Percentage	No. of varieties	Percentage
X-rays	87	36.3	125	51.0	212	43.7
gamma-rays	94	39.2	103	42.1	197	40.6
^{32}P beta-rays	2	0.8	-	-	2	0.4
Neutrons	29	12.1	9	3.7	38	7.9
Combination of different rays	2	0.8	5	2.0	7	1.4
Total physical mutagens	214	89.2	242	98.8	456	94.0
Chemical mutagens	23	9.6	2	0.8	25	5.2
Combination of physical and chemical mutagens	3	1.2	1	0.4	4	0.8
Grand Total	240	100.0	245	100.0	485	100.0

MATERIALS AND METHODS

Two popular black gram (Vigna mungo L. Hepper) varieties namely T-9 and B-76 were taken for the study. A brief description of the two varieties is given below :

T-9.

Early maturing, erect, non-twining, photoneutral, lanceolate leaf, non hairy pods, dry pod colour black, seed surface rough, seed coat colour mosaic on oleivaceous, medium sized seeds, recommended for all over the country.

B-76.

Plant erect with twining tip, lanceolate narrow leaf, photoneutral, narrow leaved, dry pod colour black, pods glabrous, seed coat colour mosaic, seed surface rough, seed size bold, recommend for West Bengal.

Mutagenic treatments.

Two physical mutagens viz., X-ray and gamma-ray and one chemical mutagen namely, ethyl methane sulphonate (EMS) was used. Dried seeds of 10-12% moisture content were exposed to 10 kR, 20 kR, 30 kR and 40 kR doses of X-rays and gamma-rays. For gamma-rays the irradiation was done at the rate of 3000 r per minute in the gamma cell at Jute Agricultural Research Institute, Barrackpore, West Bengal. For X-rays the irradiation was done at the rate of 1600 r per minute at JARI, Barrackpore, West

Bengal. Ethyl methane sulphonate (EMS) was used in the concentration of 0.5%, 1.0% 1.5% and 2.0% using distilled water. Six hours treatment with intermittent shaking was done following eight hours presoaking in distilled water for each dose of EMS. The treated seeds were washed under running tap water and sown immediately in the field after drying the surface of the seeds in the folds of filter papers. For each mutagenic treatment 100 seeds were used. The seeds were sown immediately in the field after drying the surface of the seeds in the folds of filter papers. For each mutagenic treatment 100 seeds were used. The seeds were sown in the month of April, 1984. The plants thus raised was designated as M_1 plants and the generation as M_1 generation and subsequently M_2 and M_3 generations were grown.

M-1 generation.

A randomized row design with two replications was followed to raise the M_1 population. Different mutagenic treatments were randomized along with the controls irrespective of the varieties. A single row was used for each treatment and variety. Fortyfive cm. distance was maintained between the rows and fifteen cm. between plants.

M-2 generation.

To raise M_2 population, ten normal looking M_1 plants were selected from each treatment of both the varieties. The seeds of the individual plants were harvested in the month of June, 1984

and were kept separately in dessicator. The control plants were harvested and the seeds were bulked for each variety. For M_2 plantation, ten progeny rows were developed with a single row of respective control variety for each treatment and variety. The seeds were sown in the month of October, 1984 and the experiment was replicated two times. Randomization of treatments was done keeping the progeny rows or families of each treatment serially i.e. from one to ten. The row to row distance was 35 cm, and plant to plant distance was 10 cm. The crop was harvested in the month of January-February, 1985. During the entire crop period proper cultural operations were followed.

M-3 generation.

Materials for the M_3 generation comprised of sixty six selected families or lines from the M_2 population. The selection was practiced on the basis of family means considering the traits early maturity, dwarfness and high pod numbers. Bulk seeds of three plants for each of the selected family along with the controls were sown in March, 1985. A randomized row design with three replications was followed. 45 cm. distance was maintained between family rows and 10 cm. between plants in a row. Normal cultural operations were followed. The crop was harvested during last week of December, 1985.

Observations.

M-1 generation .

Observations were recorded on individual plant basis. Ten

normal looking M_1 plants were selected and tagged for each treatment and variety in either replications. Data on the following characters were recorded :

i) Percentage of germination.

ii) Percentage of survival (at 6th day, at first flowering and at maturity).

iii) Plant height (cm.) at flowering, and at maturity .

iv) Pollen fertility (%) .

v) Seeds per pod .

vi) Days to flowering .

vii) Days to first pod maturity .

viii) Pods per plant and

ix) Pod length (cm.) .

M-2 generation.

For the study of micro-mutations, following observations were recorded in M_2 generation : i) days to flowering, ii) plant height at flowering, iii) clusters per plant, iv) pods per cluster, v) pod length (cm.), vi) seeds per pod, vii) pods per plant, viii) seeds per plant and ix) yield per plant (gm.). The above observations were recorded individually on three normal plants from each family of each treatment in a replication.

Along with these, several morphological and viable mutants were also recorded .

M-3 generation.

The following observations were recorded on micromutations in M_3 generation : i) days to flowering, ii) days to maturity, iii) plant height (cm.), iv)clusters per plant, v) pods per plant, vi) pod length (cm.), vii) seeds per pod, viii) seeds per plant, and ix) yield/plant (gm.).

However, few plants with morphologically changed features were segregated from some lines and records were also made for those morphological mutants.

Nodulation :

The study of nodulation was conducted at four different stages of plant growth in M_3 generation. The stages are (a) preflowering stage, (b) first flowering stage, (c) peak flowering stage and (d) first 4/5 pod maturity stage. Five selected lines along with the controls (T-9 and B-76) were used in M_3 generation. For the study of nodulation, the following observations were recorded : i) nodules on tap root per plant, ii) nodules on lateral roots per plant, and iii) nodules per plant (number).

Statistical Procedures .

M-1 generation.

Normal statistical procedures was followed to calculate the mean and standard deviation for each treatment over replications.

The mean in M_1 generation was based on ten selected normal plants. The mean of each treatment of each variety within a replication was also calculated separately and the mean data was subjected to standard procedure of analysis of variance. The scheme of analysis of variance is presented in Table 3.

Table 3. Analysis of variance for treatment means in M_1 generation

Source	Degree of freedom (df)	Mean sum of squares (ms)	F (calculated)
Replications (r)	r - 1	M_1	M_1/M_3
Treatments (t)	t - 1	M_2	M_2/M_3
Error (e)	(r-1)(t-1)	M_3	
Total (T)	rt-1		

Significance test was done by comparing the calculated 'F value' with the tabulated 'F' value given in the Fisher and Yates (1953) table for respective degrees of freedom at P=0.05 and 0.01 level of significance.

M-2 generation.

A brief account of the various statistical parameters followed for the analysis of data in M-2 generation is given below.

Let Xijk be the value of jth plant in a sample drawn from ith family of kth replication. Let 'f' be the total number of families in a treatment of a variety, 'n' be the number of plants of a family in a replication and 'r' be the number of replications. Let 'N' be the total number of plants in a replication of a treatment of a variety.

Then, $N = \sum_{i=1}^{f} n = fn$

Total of ith family within a replication

$= X_{ik} = \sum_{j=1}^{n} X_{ijk}$

Mean of ith family within a replication

$= X_{ik} = \frac{1}{n} \sum_{j=1}^{n} X_{ijk}$

Family mean of ith family (Mean of ith family over replications)

$= \bar{x}_i = \frac{1}{r} \sum_{K=1}^{r} \bar{x}_{iK}$

Population mean of a treatment of a variety within a replication

$= \bar{X}_K = \frac{1}{N} \sum_{i=1}^{f} \sum_{j=1}^{n} X_{ijk}$

$= \frac{1}{f} \sum_{i=1}^{f} \bar{X}_{iK}$

Population mean of a treatment of a variety over replications

$$= \bar{X} = \frac{1}{m} \sum_{K=1}^{r} \sum_{j=1}^{f} \sum_{j=1}^{n} X_{ijk}$$

$$= \frac{1}{f} \sum_{i=1}^{f} \bar{X}i$$

Intra-family variance of ith family

$$= \frac{1}{r} \left\{ \sum_{K=1}^{r} \frac{1}{n-1} \left(\sum_{j=1}^{n} x^2_{ijk} - \frac{x^2_{ik}}{n} \right) \right\}$$

Inter-family variance (Between families variance)

$$= \frac{1}{f-1} \left\{ \sum_{i=1}^{f} \frac{x_i^2}{m} - \frac{1}{mf} \left(\sum_{i=1}^{f} x_i \right)^2 \right\}$$

Population variance of a treatment of a variety over replications.

$$= \frac{1}{fr} \left\{ \sum_{i=1}^{f} \sum_{K=1}^{f} \frac{1}{n-1} \left(\sum_{j=1}^{n} x^2_{ijk} - \frac{x^2_{ik}}{n} \right) \right\}$$

Analysis of variance for population means.

To study the effects of different doses of mutagens in respect of induced variability the population mean data was subjected to analysis of variance as per Vasudevan *et al.* (1969).

The scheme of analysis is summarized in Table 4, where 'r' represents the number of replications, 'V' represents the number of varieties and 't' represents the number of treatments.

Table 4. Analysis of variance for population means in M_2 generation

Source	Degrees of freedom(D.F.)	Mean sum of squares(M.S.)	F (calculated)
Replication (r)	(r-1)	M_1	M_1/M_5
Varieties (v)	(v-1)	M_2	M_2/M_5
Treatments (t)	(t-1)	M_3	M_3/M_5
v x t	(v-1)(t-1)	M_4	M_4/M_5
Error (e)	(r-1)(vt-1)	M_5	
Total	rvt-1		

Significance test was done by comparing the calculated 'F' value with tabulated 'F' value given in the Fisher and Yates (1963) table for respective degrees of freedom at P=0.05 and 0.01 level of significance.

Table 5. Expectations of mean sum squares (E.M.S.) for the analysis of variance in M_2 generation

Source	M.S.	Expectation of M.S.
Replication (r)	Mr_{11}	$\delta^2 e_{11} + t\delta^2 r_{11}$
Variety (v)	Mv_{11}	$\delta^2 e_{11} + t\delta^2 r_{11} + r\delta^2 tv_{11} + rt\delta^2 v_{11}$
Treatment (t)	Mt_{11}	$\delta^2 e_{11} + r\delta^2 tv_{11} + rv\delta^2 t_{11}$
v x t	$M(vxt)_{11}$	$\delta^2 e_{11} + r\delta^2 tv_{11}$
Error (e)	Me_{11}	$\delta^2 e_{11}$

Where,

Mr_{11} = mean sum of square of replication

Mv_{11} = mean sum of square of variety

Mt_{11} = mean sum of squares of mutagenic treatments

$M(v \times t)_{11}$ = mean sum of square of v x t

Me_{11} = mean sum of square of error

$\delta^2 e_{11}$ = environmental variance

$t\delta^2 tv_{11}$ = variance due to replication

$r\delta^2 tv_{11}$ = variance due to variety x treatment interaction

$rt\delta^2 v_{11}$ = variance due to variety

$rv\delta^2 t_{11}$ = genotypic variance

The phenotypic variance ($\delta^2 p$), genotypic variance ($\delta^2 g$) and environmental variance ($\delta^2 e$) were calculated as follows :-

Step - I.

$$\delta^2 e_{11} = Me_{11}$$

$$\delta^2 tv_{11} = \left\{ M_{(t \times v)_{11}} - Me_{11} \right\} / t$$

$$\delta^2 t_{11} = \left\{ Mt_{11} - M_{(v \times t)_{11}} \right\} / rv$$

$$\delta^2 v_{11} = \left[(Mv_{11} + Me_{11}) - \left\{ Mr_{11} + M_{(v \times t)_{11}} \right\} \right] / tr$$

Step - II.

$$\delta^2 p = \delta^2 e_{11} + \delta^2 t_{11} + \delta^2 tv_{11}$$

$$\delta^2 g = \delta^2 t_{11}$$

$$\delta^2 e = Me_{11}$$

Where,

t = total number of treatments

rv = number of replications x number of varieties

tr = number of treatments x number of replications

Coefficients of variability.

Coefficients of variability were calculated as follows :

Phenotypic coefficient of variability (PCV).

$$\frac{\sqrt{\delta^2 p}}{x} \times 100$$

Genotypic coefficient of variability (GCV).

$$= \frac{\sqrt{\delta^2 g}}{\bar{X}} \times 100$$

Where,

$\delta^2 p$ = phenotypic variance

$\delta^2 g$ = genotypic variance and

$\bar{x}$ = grand mean of the character

Heritability (%).

Heritability % (in bread sense) was calculated by dividing the genotypic variance by phenotypic variance and multiplying by 100 .

$$H\% = \frac{\delta^2 g}{\delta^2 p} \times 100$$

Genetic advance .

The expected genetic advance (GA) was calculated as follows :

$$GA = (Z/P) \times \delta g \times \sqrt{\frac{\delta^2 g}{\delta^2 p}}$$

Where, Z/P is the selection differential in standard units; for the present study it was 2.06 at 5% level of selection (Lush, 1949) .

$\delta^2 g$ = genotypic variance, $\delta^2 p$ = phenotypic variance

δg = square root of genotypic variance and

GA = expected genetic advance .

Genetic advance as percentage of mean (Expected genetic gain).

This was calculated by the following formula :

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

where, $\bar{X}$ = grand mean of each character.

Heterogeneity test for family means.

The heterogeneity of family means was analysed for each mutagenic treatment of each variety. For this, interfamily variance (between families variance) was calculated. It was then tested against within families variance. Significance of inter-family variance indicated the presence of heterogeneity between family means. The scheme of analysis is given in Table 6.

Table 6. Analysis of variance to test the heterogeneity of family means

Source	D.F.	M.S.	F (calculated)
Inter-family	(f-1)	M_1	M_1 / M_2
Within families	rf(n-1)	M_2	

Significance test was done by comparing the calculated 'F' of the Fisher and Yates (1953) table for corresponding degrees of freedom at P = 0.05 and 0.01 level of significance.

selection of promising families •

Selection of the promising families was based on three important characters viz•, dwarfness, earliness and high pod numbers• The significance test of the deviations of individual M_2 families of each treatment from the control population mean was done by 't'-test•

$$t = \frac{m_1 - m_2}{s} \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

Significance test was done by entering the value of t in the table of t with $n' = n_1 + n_2 - 2$ degrees of freedom • The individual families, irrespective of treatment and variety showing mean values significantly shifted towards desired direction were selected and advanced to the M_3 generation to see the effectiveness of M_2 selection •

M-3 generation•

In M_3 generation, observations were recorded on four randomly taken plants for each family or line in a replication for quantitative characters• The mean of each family within a replication and over replications were calculated• The analysis of variances were computed to test the significance of mean data•

The scheme of analysis of variance in M_3 generation is presented in Table 7•

Table 7. Scheme of analysis of variance for M_3 generation

Source	Degrees of freedom (D.F.)	Mean sum of squares (M.S.)	F (calculated)
Replications (r)	r - 1	M_1	M_1/M_3
Families (f)	f - 1	M_2	M_2/M_3
Error (e)	(r-1)(f-1)	M_3	
Total (T)	rf - 1		

Significance test was done by comparing the calculated 'F' with tabulated 'F' of the Fisher and Tates (1953) table for corresponding degrees of freedom at P = 0.05 and 0.01 level of significance.

The mean values for each of the M_3 families was compared with the respective control population mean by 't'-test as done in M_2. The population variance of each treatment for each character was compared with the respective control population variance as done in M_2 generation.

The expectations of mean sum squares (E.M.S.) for the analysis of variance in M_3 generation are presented in Table 8.

Table 8. Expectations of mean sum squares for the analysis of variance in M_3 generation

Source	MS	Expectation of MS
Replications	Mr_{11}	$\delta^2 e_{11} + f\delta^2 r_{11}$
Families	Mf_{11}	$\delta^2 e_{11} + r\delta^2 f_{11}$
Error	Me_{11}	$\delta^2 e_{11}$

Component of variances. Phenotypic, genotypic and environmental components of variance were calculated as follows :-

$$\delta^2 g = \frac{M_{f_{11}} - M_{e_{11}}}{r}$$

$$\delta^2 e = M_{e_{11}}$$

$$\delta^2 p = \delta^2 g + \delta^2 e$$

The phenotypic and genotypic coefficients of variation, critical difference, heritability, genetic advance and genetic advance as percentage of mean were calculated as per the methods mentioned in M_2 generation .

The scheme of analysis of co-variances in M_3 generation is presented in Table 9.

Table 9. Scheme of analysis of co-variances

Source	Degrees of freedom(DF)	Mean cross product (M.C.P.)	F (calculated)
Replications (R)	r-1	M_1	M_1/M_3
Families (F)	f-1	M_2	M_2/M_3
Error (E)	(r-1)(f-1)	M_3	
Total (T)	rf-1		

The expectation of mean cross products for the analysis of covariance is presented in Table 10.

Table 10. Expectations of mean cross products for the analysis of covariance

Source	M.C.P.	Expectations of M.C.P.
Replications (R)	Mr_1r_2	$\delta e_1e_2 + f\delta r_1r_2$
Families (F)	Mf_1f_2	$\delta e_1e_2 + r\delta f_1f_2$
Error (E)	Me_1e_2	δe_1e_2

$$\delta g_1g_2 = \frac{M_{f_1f_2} - M_{e_1e_2}}{r}$$

$$\delta e_1e_2 = Me_1e_2$$

$$\delta p_1p_2 = \delta g_1g_2 + \delta e_1e_2$$

Correlations.

The correlation coefficients were calculated at phenotypic and genotypic levels as follows :

$$\text{Phenotypic correlation } (r_p) = \frac{\text{P.Cov. } X_1X_2}{\sqrt{\text{P.V } (X_1) \quad \text{P.V. } (X_2)}}$$

$$\text{Genotypic correlation } (r_g) = \frac{g \cdot Cov \cdot X_1 X_2}{\sqrt{g \cdot V (X_1)\ g \cdot V (X_2)}}$$

Where, $P \cdot Cov \cdot X_1 X_2$ = phenotypic covariance between characters X_1 and X_2

$P \cdot V (X_1)$ = phenotypic variance of X_1

$P \cdot V \cdot (X_2)$ = phenotypic variance of X_2

$g \cdot Cov \cdot X_1 X_2$ = genotypic covariance between characters X_1 and X_2

$g \cdot V (X_1)$ = genotypic variance of X_1

$g \cdot V (X_2)$ = genotypic variance of X_2

RESULTS AND DISCUSSION

The cultivation of crop plants was initiated long long ago by the primitive farmers. With the increase in population, scarsity of animal flesh started and the ancient peoples who were solely dependent on the same was forced to search some alternative source of food for their survival. In this way the domestication of crop plants was started nearly ten thousand years ago. But all the crop plants which we consider important today were not domesticated at the same time. The history of domestication of cereals like wheat is the oldest and compared to that, the domestication history of pulses can be considered as recent.

Agriculture, for most of its ten thousand years, has been of a traditional kind so that few inputs were applied for higher crop productivity. Improvement of the crop plants in the past, was completely dependent upon the variation created by the nature following selection by farmers as well as by nature itself. The process of modernization of agriculture using scientific techniques of crop breeding and management with the use of industrial inputs of various kinds including chemical fertilizer and pesticides started more seriously only about fifty years back. The pulses has been neglected since ancient times. Much more attention was paid to the cultivation of cereals which occupied all fertile lands and other agronomical facilities like, irrigation and manuring was done mainly to them. Selection was performed mainly to increase seed

yield in cereals. On the other hand, very little attention was paid to the cultivation of pulses by the primitive as well as by modern farmers. They have been grown largely in marginal land of low soil fertility and inadequate moisture availability and the selection for pulses have been performed mainly for adaptation to stress environments characterized by moisture and fertility stress. A deep root system, an extensive vegetative growth, spread over a long period of time, depending upon the availability of moisture were more important. It is the answer to the question, why most of the pulse crops show a plant type marked by extensive and indeterminate growth habit, a non-synchronous development and a low harvest index. The plants tend to be aggressive in their vegetative growth but seed yield is relatively low.

The pulses have lost a great deal of variability for yield and some other yield contributing characters because of their evolutionary history of the kind discussed above. However, in the recent past, plant breeders have been trying to increase the variability by restructuring the plant types through classical methods of crop improvement such as hybridization and selection of different pulse crops.

The history of mutation breeding is almost recent compared to the conventional breeding methods like hybridization and selection. The importance of micro-mutations in evolution was first stressed by Baur (1924) and subsequently by Stubbe and Wettstein (1941). Later,

the usefulness of micro-mutations in plant breeding was established by Gregory (1956, 1961). In fact, the technique has served little purpose at least in terms of varieties evolved through induced polygenic variability. In the front of crop improvement through mutagenesis, for the small number of experiments that succeed, the proportion of failure is very large. However, it is well established that, induced mutations can increase yield as well as improve other agronomic characters (Brock, 1971; Gaul, 1961; Gregory, 1968; Gustafsson, 1965; Sigurbjornsson et al., 1969). The growing emphasis on micro-mutations as a valuable tool for improvement of cultivated species has assumed greater significance in recent years due to the fact that more than a dozen field crop varieties evolved by this method have been released at the global level (Kumar and Das, 1977). At present, about 500 officially released varieties, derived from experimentally induced mutants, are available (Gottschalk and Wolf, 1983) which are presented in Table 2 (Review of Literatures).

Bateman (1959) for the first time, came out with the hypothesis that induced polygenic mutations follow a particular direction which is always opposite to that of the direction of previous selection. This hypothesis has been supported and extended by Brock (1965) and Goud (1967, 1968). Brock advanced the hypothesis that "In species which have previously been subjected to breeding and selection random mutation results in an increase in the variance and a shift in the mean away from the

direction of previous selection". Thus the increase of genetic variability permits selection in either direction. Brock also states that, while improvement in the fitness character, such as yield, may be expected in unimproved groups, it would be more difficult in plants which have been subjected to long time selection. Goud (1968) has clearly pointed out, in wheat, how the previous selection affects the direction of maximum mutations and he also pointed out that selection has to be applied simultaneously for all economic characters as one is likely to lose one character in trying to improve the other .

Contrary to Brock's hypothesis, Gaul and Aastveit (1965, 1966) formulated a new hypothesis stating that "By random mutation a change in the mean value of almost any Quantitative character of interest in plant breeding is to be expected in a direction associated with reduced vitality and the alteration of the mean is largely dependent of the genotype used for the mutagenic treatment".

Black gram (Vigna mungo L. Hepper) is an important grain legume in India, grown for its protein rich seeds. Attempt for improving this crop has, in the past, mostly been made through selection from cultivators' stocks. Mutation studies in this crop for Quantitative characters is scanty. Keeping the domestication history of pulses (including black gram) and result of different mutagenic experiments in view, it was therefore, felt appropriate to induce variability in this important pulse crop through ionizing

radiations and chemical mutagen as well. The supporting hypothesis is that, induced mutations can be expected to offer greater possibility of inducing variability in pulses than in cereal crops, where variability has already been preserved and selected. With this expectation, we planned the present experiment with blackgram, an important grain legume to generate variability through mutations for different quantitative characters influencing seed yield including nodulation. The results obtained are presented and discussed separately for the different mutant generations.

M-1 Generation.

In general, manifestation of induced variability takes place with higher degree of magnitude in later generations i.e., M_3 on wards. But the process is initiated much earlier, precisely, after the mutagenic alterations in the genetic material. The polygenic variability could express itself even earlier than M_2 if the tissues of the M_1 plants were homogeneous in either composition. But since most M_1 plants are chimeral, the small part of the mutated tissue may not have much impact on the character manifestation of the entire mutagenized material. Though the increase in variance in M_1 is very small, it can not be ignored completely rather, it can be used fruitfully.

An attempt was therefore, made to guage the intensity of radio- and chemosensitivity in respect of some quantitative characters in M_1 generation of blackgram.

Mean, standard deviation and variance •

The results obtained with respect to M_1 parameters are given in Table 11 (mean and standard deviation) and their analysis of variance are given in Table 12•

It is interesting to note that for most of the characters in either genotypes the standard deviation was increased due to mutagenic treatments in comparison to control• This would suggests that, substantial variability was released due to mutagenic treatments• However, effects of treatments on individual characters are presented and discussed •

Germination per cent•

Seed germination was stimulated atleast to some extent by lower doses of X-ray and gamma ray treatments (10 kR) in both T-9 and B-76, particularly for B-76• In B-76, the maximum germination was 78% at 10 kR gamma rays followed by 77•67% at 10 kR X-rays, whereas it was 76% in control• This increase in seed germination though very low, might be due to the genotypic changes in embryonic tissue of seed resulted by irradiation• As expected, these mutated cells are responsible for the formation of enzyme molecules which are essential for the metabolic activities needed for germination• From the analysis of variance it was found that, the variation among the different treatments for this character was highly significant in both the varieties showing differential effect of different treatments•

Several investigators, e.g., Singh (1941) in dormant seeds of wheat, corn and chick pea; Mackey (1956) in cereals; Stein and Ritcher (1961) in lettuce and Torne (1964) in Rauvolfia serpentina reported enhancement in percentage of germination of seed irradiated with X-rays and gamma rays. Sparrow (1963) has opined that the low doses of the ionizing radiations shorten or break the period of dormancy, thereby showing the stimulatory effect. Ehrenberg et al. (1973) have suggested that a major chemical effect of irradiated tissues is the oxidation of thiols to disulphides on consumption of thiols by secondary reactions and that the dose irradiation under conditions of limiting assess of glucose, is able to eliminate thiol suppression of RNA synthesis thus causing stimulation.

Percentage of germination was affected adversely by all higher doses of treatments for both the genotypes. Practically germination percentage decreased with the increase in dose. Maximum decrease was observed at 2.0% EMS treatment (36.5% for 7-9 and 40% for B-76). In fact, all the doses of EMS reduced germination more than 50% except, EMS 0.5% in 7-9 (51%). This result indicated that, in case of EMS treatments LD 50 lies at 0.5% for 7-9 and slightly below 0.5% for B-76. In case of all X-ray and gamma-ray treatments, none of the varieties showed 50% reduction in germination thereby indicating that LD 50 in these cases would likely to be more than 40 kR.

Several authors reported the reduction in germination percentage with increasing doses of treatment of mutagens. Roy *et al.* (1971) in *Cucumis* recorded decrease in the seed germination with an increase in the exposure of gamma rays. Selim *et al.* (1974) in *Pisum sativum* have attributed reduction in germination percentage with an increase in exposure to the enhanced production of active radicals which are responsible for seed lethality, while Gordon (1957) has correlated it with the inhibition of auxin synthesis. In lentil, Shamma and Sharma (1986) reported reduction in germination with increasing doses. In pigeon pea (*Cajanus cajan* L.), Das and Tickoo (1977) observed that, germination decreased gradually as the concentration of EMS increased. They concluded that, LD_{50} for germination lay above 0.2% EMS, the highest concentration used. Filippetti and Marzaro (1984) observed after treatment of seeds of *Vicia faba* L. with gamma rays and EMS that, in X_1 percentage of seedling emergence decreased with increasing mutagen dose.

Survival per cent.

Plant survival percentage was studied at three different stages of growth, viz., at 6th day, at first flowering and at maturity. Survival percentage significantly decreased at 6th day and maturity stage for all treatments in T-9 as compared to control. On the other hand, survivability decreased significantly at all three stages for all treatments in B-76. However, a few

exceptions were also recorded only at 6th day where in few cases for both the genotypes survivability did not show significant change .

In case of T-9, the lowest survival percentage was observed for gamma ray 30 kR and 40 kR doses (42.76% and 43.56% respectively) as compared to 65.59% for the control at maturity whereas in B-76 the lowest was observed at 1.0% and 1.5% EMS treatments (46.51% and 46.74% respectively) as against 72.09% for control indicating differential response of genotypes to different mutagens.

Parallel to these observations, several authors recorded decrease in survivability in different crop plants. The reduction in the percentage of survival following ethyl enemine and N-nitroso-N-ethylurea treatment in peas was reported by Migacheva (1972). This finding was supported by Narasinghani and Kumar (1976) in cow pea. In green gram, Ganguli and Bhaduri (1979) observed that, the survival percentage declined after 30,000 r of X-rays. Filippetti and Marzaro (1984) in Vicia faba L. and Sharma and Sharma (1986) in lentil also reported decrease in survival with increase in doses .

Plant height (cm.) .

Plant height was measured at flowering stage and at maturity. No significant change in height was observed for lower doses of treatments of X-ray and gamma ray, while all

concentrations of EMS used induced appreciable reduction. In general, height decreased with increase in dose of X-ray and gamma ray. Maximum decrease was observed for 2.0% EMS in both the genotypes and the plant height was recorded to be around 15.0 cm. Statistical analysis showed that at both stages plant height of T-9 was significantly reduced while in B-76 significant plant height reduction was at flowering stage only (Table 12).

Ashraf et al. (1973) observed that in green gram the plant height was adversely affected in M_1 generation as an effect of gamma irradiation. Ganguli and Bhaduri (1980) also observed reduction in plant height following X-ray and neutron irradiation in green gram. Das and Tickoo (1977) in pigeon pea reported progressive decrease with the gradual increase of EMS concentration. In lentil, Sharma and Sharma (1983) also reported reduction in shoot length with increasing doses of treatments. In blackgram, this decrease in plant height might be due to the inhibition of some growth hormones needed for plant growth and resulted from mutation of genes concerned at vital metablic pathways.

Pollen fertility (%) .

Pollen fertility was decreased by all the treatments of X-ray, gamma ray and EMS as compared to control in both the genotypes and this decrease was more pronounced with the increase in doses. The most drastic effect was observed for EMS 2.0% in

B-76 and T-9 where the pollen fertility came down to around 50%, as compared to 90-92% pollen fertility in controls. The significant observation is that at highest dose of X-ray and gamma ray used e.g., 40 kR both genotypes showed differential response. In fact, at this dose, pollen sterility per cent was less in T-9 in comparison to B-76 indicating more susceptibility of the latter for high dose of X-ray and gamma ray. Of the two physical mutagens X-ray appeared to induce more pollen sterility in both genotypes.

Different authors also reported increase in pollen sterility with increased doses of mutagenic treatments. Narsinghani and Kumar (1976) in cow pea, Ganguli and Bhaduri (1980) in greengram and Sharma and Sharma (1986) in lentil reported decrease in pollen fertility with increase in dose in M_1 generation .

Seeds per pod.

Only slight increase was observed for 10 kR X-ray in T-9 and 10 kR X-ray and 10 kR gamma ray in B-76 for seed number. For almost all other treatments a slight decrease in seed number per pod was observed for both the genotypes. However, analysis of variance indicates that none of the mutagens was able to create any considerable variation for seed number per pod in both genotype . Similar observations in broad bean (Vicia faba L.) was recorded by Vik (1975) who observed little change in the mean

values for seeds per pod in M_1 generation after treatment with ethyl methane sulphonate. On the contrary, in soyabean, Muresan et al. (1984) and in Latuceae, Haque and Godward (1986) observed lower number of seeds per pod after treatment with gamma rays. It is interesting that, in spite of high per cent pollen sterility following mutagenic treatments blackgram genotypes produce seeds per pod equivalent to non-treated populations. It appears that, even less than 50% viable pollens are sufficient enough to realize effective seed development.

Days to flowering.

Early flowering (two days earlier than control) was observed for lower doses of X-ray and gamma ray treatments in both genotypes. On the other hand, flowering was delayed (1 to 2 days) by higher doses of physical mutagens. All EMS treatments delayed flowering (1 to 3 days) particularly at higher doses in both the genotypes. The effect of mutagenic treatments for this character is significant for T-9 but not significant for B-76 (Table 12). Early flowering was observed in gram (Cicer arietinum L.) by Chandola et al. (1976) in M_1 generation after treatment with pile neutrons. Ganguli and Bhaduri (1980) reported delay in flowering in M_1 generation of green gram after treatment with X-ray and neutrons. In the same crop Khan (1984) also observed delay in flowering in M_1 after treatment with gamma rays.

Days to first pod maturity.

In general, high dose of EMS caused delay in maturity for both the genotypes. On the other hand, high dose of gamma ray (40 kR) caused maximum delay in pod maturity in T-9, while high dose of X-ray (30 and 40 kR) caused maximum delay in pod maturity for B-76. This would suggest differential response of genotypes to different physical mutagens. Variation created by different mutagenic treatments for pod maturity was highly significant for B-76 but not significant for T-9 which further supports the differential response of genotypes used.

Pods per plant.

Different treatments induced significant variation in pod number per plant. Slight increase in pod number per plant was observed for 10 kR and 20 kR X-ray in T-9 only. All other treatments in T-9 and all treatments in B-76 resulted reduced number of pods. The lowest pod number was observed for 2% EMS in both T-9 and B-76 (22.25 and 22.55 as against 31.30 and 33.25 in the controls). Thus, the decrease in pod number in the treated plants may be due to the formation of sterile pods. It is to be noted here that only fertile pods were recorded for counting pods per plant. The present observation is not in conformity with that of Vik (1975) in Vicia faba L., who observed that gamma ray treatments increased mean number of pods. Similarly Khan (1984) in greengram also observed increase in the mean number of pods per plant after

treatment with gamma rays, EMS and hydrazine. However, our present study finds support from the observations of Muresan et al. (1984) in soyabean who observed marked reduction in pods per plant after the treatment with gamma rays (10-40 kR) in M_1 generation and also from Ganguli and Bhaduri (1980) in green gram where they observed marked reduction in pods per plant after treatment with sublethal doses of X-ray (30 and 40 kR) and thermal neutrons.

Pod length.

No significant variation was observed between different treatments for this character in both the genotypes. However, for T-9, pod length was decreased slightly by all the treatments. But the trend was different for B-76 where it was slightly increased or decreased by different mutagenic treatments. Khan (1983) observed increase in mean pod length in green gram after treatment with 10-40 kR gamma rays .

Components of variance and coefficients of variability.

The phenotypic variances ($\delta^2 p$) of all characters were partitioned into genotypic ($\delta^2 g$) and environmental ($\delta^2 e$) variances and subsequently genotypic and phenotypic coefficients of variability (gcv and pcv) were estimated. The treatment variances were considered as genotypic variances. For majority of the characters, $\delta^2 g$ contributed maximum to the total variability

(δ^2_p) with the exception of seeds per pod and pod length in both T-9 and B-76 (Table 13). In other words, variations generated for different characters was due to mutagenic treatments. This further supports our earlier contention.

From the above discussion the following significant points emerge. Of the twelve characters analysed the treatment effects were significant for eight characters in both T-9 and B-76 indicating the potentiality of mutagen treatments for inducing variability in M_1. This by and large supports the earlier observation of Goud *et al.* (1971) in ragi and Khan (1983 and 1984) in mung bean who observed increase in variation for different traits as compared to control following mutagenic treatments in M_1 generation. However, no significant treatment effects were recorded for seeds per pod and pod length in either genotypes. For rest of the characters genotypes showed differential response to different mutagenic treatments. The mutagen treatments caused a shift in the mean values of different characters in negative direction and the magnitude of decrease was not the same for all the characters. In few instances, however, the mean was shifted towards positive direction. In general, pronounced effects were recorded at increased doses of mutagens. However, characters showed more sensitivity towards the treatments of EMS.

Table 11. Mean and standard deviation of twelve characters in M_1 generation for T-9 and B-76

T - 9

Characters

Treatments	% germination		% survival at					
	Mean	SE	6th day		first flowering		maturity	
			Mean	SD	Mean	SD	Mean	SD
Control	80.00	3.54	95.36	2.00	76.49	3.25	65.59	1.52
X-10 kR	80.34	5.18	87.58	13.08	64.13	5.83	54.41	3.87
X-20 kR	70.02	6.63	96.05	3.06	72.58	4.15	58.29	4.14
X-30 kR	74.00	0.95	88.34	8.77	64.03	9.74	51.37	4.48
X-40 kR	68.34	8.01	90.29	1.32	62.44	1.05	50.97	0.13
ɣ -10 kR	80.67	0.94	95.04	0.06	63.62	2.76	52.05	2.90
ɣ -20 kR	73.34	1.89	93.62	1.45	63.86	17.07	51.12	16.71
ɣ -30 kR	72.75	0.35	94.95	0.30	48.48	9.00	42.76	3.40
ɣ -40 kR	72.67	2.83	91.26	2.78	56.54	0.86	43.56	4.07
EMS 0.5%	51.00	1.41	83.73	5.28	68.54	6.42	62.69	3.80
EMS 1.0%	45.00	1.41	79.94	3.78	66.70	2.09	48.81	4.75
EMS 1.5%	40.00	2.83	82.58	2.31	64.92	2.48	54.89	3.19
EMS 2.0%	36.50	2.12	75.08	1.97	69.51	1.53	52.79	0.22

B - 76

Control	76.00	1.41	95.05	2.43	83.60	0.38	72.09	2.95
X-10 kR	77.67	3.30	92.96	4.19	73.78	5.34	58.11	4.40
X-20 kR	72.67	2.83	92.71	2.31	74.40	4.19	54.15	0.81
X-30 kR	71.16	4.48	86.58	0.44	66.94	0.38	49.26	2.43
X-40 kR	67.34	6.60	94.31	5.04	72.56	5.71	55.99	11.09
ɣ -10 kR	78.00	2.83	93.21	2.17	68.43	2.48	50.53	5.46
ɣ -20 kR	72.17	5.42	97.23	1.04	74.01	7.90	56.05	7.31
ɣ -30 kR	70.67	1.89	95.90	1.21	71.65	3.42	53.71	5.24
ɣ -40 kR	63.33	8.48	90.74	3.22	73.19	8.32	58.32	6.32
EMS 0.5%	46.00	2.83	76.32	7.76	65.53	10.18	52.46	9.38
EMS 1.0%	48.00	5.66	81.64	6.68	66.78	1.98	46.51	11.38
EMS 1.5%	43.00	4.24	77.29	10.91	60.76	6.00	46.74	4.61
EMS 2.0%	40.00	2.83	72.31	5.49	59.90	2.84	47.50	0.18

contd.

Table 11. contd.

T - 9

Characters

Treatments	Plant height (cm.) at flowering Mean	SD	Plant height (cm.) at maturity Mean	SD	Pollen fertility(%) Mean	SD	Seeds/Pod Mean	SD
Control	19.30	0.42	24.85	0.21	91.06	2.33	5.65	0.07
X-10 kR	20.24	0.62	24.75	0.35	89.74	0.37	6.10	0.14
X-20 kR	19.62	1.11	24.60	0.57	88.65	1.84	5.30	0.14
X-40 kR	17.97	2.45	21.95	0.07	62.53	1.93	5.35	0.07
ɣ -10 kR	19.90	0.99	24.58	0.83	91.03	0.17	5.50	0.14
ɣ -20 kR	18.80	0.28	22.75	1.06	80.74	2.86	5.50	0.14
ɣ -30 kR	18.17	1.18	22.40	1.13	79.18	1.16	5.40	0.14
ɣ -40 kR	17.50	1.65	21.17	0.71	73.49	1.60	5.35	0.35
EMS 0.5%	17.40	1.32	22.15	0.49	85.47	2.01	5.45	0.07
EMS 1.0%	17.12	1.25	22.50	0.71	74.31	3.26	5.40	0.14
EMS 1.5%	16.58	1.53	20.74	0.09	58.98	1.45	5.20	0.28
EMS 2.0%	15.45	0.31	19.36	0.21	50.11	2.06	5.30	0.14

B - 76

Control	20.12	0.66	24.05	0.07	92.75	3.35	6.00	0.14
X-10 kR	20.50	1.17	24.00	1.88	88.94	0.62	6.65	0.21
X-20 kR	19.74	0.37	23.20	2.26	69.56	9.23	6.00	0.14
X-30 kR	18.92	1.29	23.09	0.59	73.94	4.31	5.80	0.14
X-40 kR	17.74	0.37	22.04	2.31	52.22	7.14	5.85	0.49
ɣ -10 kR	20.00	0.71	23.24	2.21	89.00	0.51	6.45	0.35
ɣ -20 kR	18.64	1.36	22.55	0.21	84.69	4.33	6.00	0.00
ɣ -30 kR	18.74	0.09	22.50	2.69	67.64	7.43	5.95	0.21
ɣ -40 kR	18.06	0.37	20.30	0.42	63.84	5.42	5.45	0.07
EMS 0.5%	17.67	0.94	22.84	0.23	84.15	0.65	6.05	0.21
EMS 1.0%	16.55	1.34	22.06	1.33	74.25	3.18	5.55	0.49
EMS 1.5%	15.92	0.59	20.83	0.71	66.96	2.35	5.75	0.49
EMS 2.0%	15.40	0.57	20.34	0.47	51.56	0.62	5.75	0.35

contd.

Table 11. contd.

T - 9

Characters

Treatments	Days to flowering		Days to first pod maturity		Pods/plant		Pod length (cm)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Control	36.00	1.41	54.50	0.71	31.30	1.84	3.94	0.09
X-10 kR	34.50	0.71	54.50	1.29	32.00	1.56	3.89	0.04
X-20 kR	35.00	0.00	54.50	0.71	32.90	0.14	3.87	0.23
X-30 kR	36.00	1.41	54.00	2.83	28.45	2.05	3.78	0.17
X-40 kR	38.50	0.71	57.00	0.00	25.80	1.13	3.77	0.14
γ -10 kR	35.50	0.71	54.50	2.12	30.45	0.35	3.87	0.33
γ -20 kR	35.00	0.00	56.00	1.41	29.55	0.64	3.53	0.52
γ -30 kR	37.50	0.71	56.50	0.71	27.55	0.78	3.53	0.58
γ -40 kR	38.00	1.41	59.00	2.83	26.80	1.13	3.75	0.10
EMS 0.5%	36.50	0.71	57.00	1.41	27.90	0.57	3.75	0.06
EMS 1.0%	37.00	0.00	58.00	1.41	27.20	1.13	3.55	0.10
EMS 1.5%	37.50	0.71	57.50	2.12	26.10	2.97	3.53	0.06
EMS 2.0%	39.00	1.41	60.00	2.83	22.25	1.06	3.48	0.14
			B - 76					
Control	38.00	1.41	55.50	0.71	33.25	0.64	3.69	0.01
X-10 kR	38.50	2.12	55.00	1.41	32.20	3.39	3.92	0.11
X-20 kR	39.00	1.41	56.00	1.41	32.70	0.14	3.63	0.18
X-30 kR	38.50	0.71	60.00	1.41	30.85	3.32	3.55	0.14
X-40 kR	39.00	0.00	62.00	0.00	27.65	1.91	3.86	0.08
γ - 10 kR	36.50	0.71	57.00	2.83	31.15	0.92	3.83	0.11
γ - 20 kR	37.00	1.41	57.50	2.12	30.30	3.25	3.75	0.35
γ - 30 kR	39.00	0.00	57.50	0.71	30.35	3.75	3.57	0.18
γ - 40 kR	39.50	0.71	58.00	1.41	28.65	2.47	3.78	0.18
EMS 0.5%	38.50	0.71	57.00	0.00	26.30	1.27	3.53	0.04
EMS 1.0%	39.00	1.41	60.50	2.12	26.90	2.97	3.60	0.21
EMS 1.5%	40.00	0.00	60.00	1.41	27.30	2.69	3.58	0.04
EMS 2.0%	40.50	0.71	61.50	2.12	22.55	1.20	3.80	0.07

Table 12. Analysis of variance of twelve characters in M_1 generation

Source	D.F.	Mean sum of squares (M.S.)											
		% germination	% survival at 6th day	% survival at flowering	% survival at maturity	Plant height at flowering	Plant height at maturity	Pollen fertility (%)	Seeds per pod	Days to flowering	Days to first pod maturity	Pods per plant	Pod length
					T-9								
Replication (r)	1	4.00	60.49	0.38	42.39	14.21	0.08	0.99	0.08	0.15	2.46	0.0002	0.12
Treatment (t)	12	507.40**	89.43*	96.76^{NS}	84.83*	3.91**	5.91**	338.86**	0.06^{NS}	4.09**	7.43^{NS}	18.35**	0.06^{NS}
Error (e)	12	14.45	21.99	49.35	31.33	0.62	0.43	5.39	0.15	0.90	3.54	2.10	0.05
Total (T)	25	250.65	55.90	70.15	57.45	2.74	2.97	165.28	0.20	2.41	5.37	9.82	0.06
					B - 76								
Replication (r)	1	126.41	189.27	261.85	339.98	0.51	7.55	23.01	0.02	0.15	3.12	10.73	0.008
Treatment (t)	12	395.02**	141.49**	80.65**	93.22**	5.29**	3.16^{NS}	369.98**	0.21^{NS}	2.38^{NS}	10.55**	18.49*	0.035^{NS}
Error (e)	12	11.42	11.40	9.83	12.75	0.76	1.81	21.95	0.10	1.28	2.45	5.55	0.026
Total (T)	25	200.15	80.96	53.87	66.62	2.93	2.66	188.08	0.15	1.74	6.36	11.97	0.03

* Significant at 5%

** Significant at 1%

Table 13. Components of variance and coefficients of variability of twelve characters in M_1 generation

Characters	$\delta^2 g$	$\delta^2 e$	$\delta^2 p$	g.c.v.	p.c.v.
T-9					
% germination	246.47	14.45	260.92	24.16	24.86
% survival - 6th day	33.72	21.99	55.71	6.54	8.41
- first flowering	23.70	49.35	73.05	7.54	13.20
- maturity	26.75	31.33	58.08	9.75	14.37
Plant height - flowering	1.64	0.62	2.62	7.03	8.25
maturity	2.66	0.43	3.09	7.21	7.77
Pollen fertility %	166.74	5.39	172.13	16.79	17.06
Seeds per pod	0.08	0.03	0.11	5.20	6.10
Days to flowering	1.59	0.90	2.49	3.44	4.31
Days to first pod maturity	1.94	5.48	7.42	2.47	4.83
Pods per plant	8.12	2.10	10.22	10.12	11.35
Pod length	0.005	0.05	0.055	1.91	6.32
B-76					
Per cent germination	191.80	11.42	203.22	21.80	22.44
% survival - 6th day	65.04	11.40	76.44	9.15	9.92
- first flowering	35.41	9.83	45.24	8.49	9.59
- maturity	40.23	12.75	52.98	9.05	13.49
Plant height - flowering	2.26	0.76	3.02	8.21	9.49
- maturity	0.67	1.81	2.48	3.66	7.03
Pollen fertility %	174.01	21.95	195.96	17.87	18.97
Seeds per pod	0.06	0.10	0.16	4.12	6.73
Days to flowering	0.55	1.28	1.83	1.92	3.50
Days to first pod maturity	4.05	2.45	6.50	3.45	4.38
Pods per plant	6.47	5.55	12.02	8.70	11.86
Pod length	0.005	0.026	0.031	1.91	4.76

$\delta^2 g$ = genotypic variance (Treatment variance)

$\delta^2 e$ = environmental variance

$\delta^2 p$ = phenotypic variance

gcv = genotypic coefficient of variability

pcv = phenotypic coefficient of variability

M-2 generation.

Micromutations.

To study the effectiveness of physical and chemical mutagens in inducing polygenic mutations in M_2 generation, observations were recorded on nine quantitative characters namely, days to flowering, height at flowering, clusters per plant, pods per cluster, pod length, seeds per pod, pods per plant, seeds per plant and yield per plant. Two statistical parameters e.g., means and variances were examined for different families of different treatments for two genotypes. Following 't'-tests of individual family means for each treatment, families were grouped for each character in three categories i.e., either no change, significant positive change or significant negative change as compared to control population mean. The variances generated by mutagenic treatment in each family were examined by calculating intra (within) family variances and inter (between) family variances. 'F'-test between them would indicate heterogeneity for family variances in each treatment. Analysis of variance was also done based on family means for each character separately and subsequently phenotypic, genotypic and environmental coefficients of variability, heritability and genetic advance were calculated for each character.

Days to flowering.

Means.

Means of different families for different treatments of two black gram genotypes are given in Table 14. Varieties,

treatments, variety x treatment (v x t) interaction were significant (Table 15) indicating significant effects of mutagenic treatments for different families in both varieties. However, different mutagenic treatments induced different magnitude of effects in different families. Thus, most of the families for different treatments in each variety showed significant change in $\bar{x}$ values as indicated by 't'-tests (Table 16). The change was either towards positive or towards negative direction. The grouping of family means for different mutagenic treatments (Table 17) indicates that higher percentage of families showed lateness in flowering for both varieties irrespective of treatments and early flowering families as compared to controls were few in number. However, more families in T-9 showed earliness in flowering than B-76. In general, lower doses of X-ray and gamma ray (10 kR and 20 kR) induced earliness in flowering in either of the varieties. On the other hand, late flowering families were observed in different EMS treatments (Table 17).

Variance.

Population variances for each treatment over all families, within (intra) families variances and inter (between) families variances were calculated and are given in Tables 18 and 19. In T-9, maximum variation was observed in gamma 10 kR treatment followed by gamma 40 kR treatment and EMS 1.0% treatment. On the other hand, in B-76, 10 kR X-ray induced highest amount of varia-

tion. In other words, lower doses of treatments generated variances of higher magnitude as compared to controls. Interesting enough, highest intra family variance was exhibited at 10 kR dose of gamma ray and 50% families under this treatment showed greater amount of within family variances in T-9, on the other hand, in B-76, the treatment of 10 kR X-ray induced highest amount of intra family variance.

The above results thus indicate a differential varietal response to different mutagenic treatments. In general, irrespective of treatments, lateness in flowering was recorded in the present study for both genotypes. However, T-9 showed proportionately more number of families with early flowering than B-76 and lower doses of gamma ray and X-ray induced earliness effectively in either of the varieties. The amount of variability is found to be conspicuously more at lower doses. Such effects of mutagens inducing earliness or lateness in flowering were reported in many crop plants. Gonzelez and Frey (1965) recorded early and lateness in equal frequencies following irradiation. Several other authors also reported early maturity mutants in different crops viz., Giosan and Nicolae (1972), Kuun et al. (1973), Akilov (1975) and Rubaihago (1976) in soyabean; Uzhintseva and Sidorova (1979) and Kaul et al. (1979) in pea; and Sharma and Sharma (1982) in lentil. However, early formation of first flower was not always associated with short growth period in pea (Uzhintseva and Sidorova, 1977, 1979).

Table 14. Family means of days to flowering in M_2 for T - 9 and B - 76

T - 9

Treatment	Family										
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	57.50	57.50	56.33	56.33	55.33	54.66	51.50	52.00	50.33	52.50	54.40
X-20 kR	54.16	54.33	52.00	54.50	55.17	55.50	54.50	56.50	54.33	53.66	54.47
X-30 kR	54.83	55.83	57.33	57.83	58.33	56.16	59.00	53.00	58.00	59.83	57.02
X-40 kR	57.00	57.66	58.66	57.00	55.66	57.66	56.16	56.66	59.33	60.00	57.58
γ-10 kR	54.83	52.50	50.83	50.00	52.66	53.83	53.16	53.50	54.83	57.16	53.33
γ-20 kR	51.83	51.66	51.50	54.83	55.16	53.00	55.00	57.16	57.16	56.66	54.40
γ-30 kR	56.00	56.16	58.33	57.33	57.83	57.00	56.83	56.50	59.66	57.83	57.35
γ-40 kR	59.16	57.00	58.83	59.83	60.50	58.66	56.16	58.13	57.66	58.50	58.52
EMS 0.5%	60.83	61.00	60.50	62.16	60.00	57.66	63.66	64.83	62.50	60.50	61.37
EMS 1.0%	61.66	60.50	59.17	64.00	58.16	60.33	60.00	62.16	61.66	63.16	61.08
EMS 1.5%	61.83	63.16	61.00	64.00	61.33	61.00	60.83	60.00	60.66	60.33	61.42
EMS 2.0%	62.16	62.33	60.66	60.83	59.66	62.50	60.16	59.00	61.00	63.50	61.68
Control											57.09

contd.

Table 14• contd•

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	60•33	57•66	60•16	57•83	57•50	55•00	56•33	58•33	55•00	56•16	57•43
X-20 kR	59•16	58•16	55•33	58•33	60•83	60•16	59•50	60•66	59•00	58•33	58•95
X-30 kR	63•33	65•00	60•33	60•50	59•33	57•83	58•66	59•83	59•16	58•83	62•28
X-40 kR	63•16	60•00	59•50	58•33	60•66	58•00	59•50	60•33	59•83	58•16	59•75
ɣ-10 kR	57•83	58•16	61•66	58•50	57•50	62•16	60•00	55•33	57•33	58•16	58•67
ɣ-20 kR	58•33	57•50	58•83	58•16	59•33	54•83	55•83	56•33	58•33	56•66	57•42
ɣ-30 kR	63•33	59•16	59•17	58•83	58•00	56•66	56•66	58•83	59•33	59•83	58•98
ɣ-40 kR	57•67	57•00	57•50	57•83	61•50	57•66	60•16	60•50	60•83	60•33	59•10
EMS 0•5%	62•33	63•16	60•83	63•00	61•33	57•66	58•50	63•33	62•83	62•16	61•52
EMS 1•0%	59•83	60•83	58•67	58•66	61•66	61•17	60•33	62•66	61•83	61•00	60•67
EMS 1•5%	59•83	61•83	62•00	62•00	62•67	61•00	58•83	60•33	62•50	61•16	61•22
EMS 2•0%	60•00	62•83	62•00	62•33	63•83	62•16	60•16	59•00	61•83	62•00	61•62
Control											58•04

Table 15. Analysis of variance of nine characters in M_2 generation

Sources	D.F.	Mean sum of squares (MS)								
		Days to flowering	Height at flowering	Clusters per plant	Pods per cluster	Pod length	Seeds per pod	Pods per plant	Seeds per plant	Yield per plant
Replication (r)	1	0.46 NS	1.83*	1.50 NS	0.003NS	0.095**	0.0			
Variety (v)	1	45.97**	28.15**	14.86**	0.028NS	0.046*	0.23*			
Treatment (t)	11	19.43**	14.08**	2.79**	0.115**	0.327**	0.683**	15.		0.46**
v x t	11	3.60**	1.14**	0.43**	0.062**	0.082**	0.159**	1.92**	35.80**	0.06**
Error (E)	23	0.29	0.28	0.02	0.016	0.007	0.017	0.17	2.24	0.003
Total (T)	47									

** Significant at 1% level

* Significant at 5% level

Table 16. t-values of family means for days to flowering in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	0.47	0.48	-0.87	-0.88	-2.03*	-2.79**	-6.54**	-5.93**	-7.95**	-5.30**
X-20 kR	-3.43**	-3.20**	-5.99**	-3.08**	-2.24*	-1.86	-3.08**	-0.69	-3.20**	-3.96**
X-30 kR	-2.63**	-1.47	0.28	0.88	1.43	-1.06	2.20*	-4.81**	1.09	3.22**
X-40 kR	-0.11	0.67	1.85	-0.11	-1.63	0.67	-1.07	-0.50	2.58**	3.31**
γ-10 kR	-2.65**	-5.43**	-7.46**	-8.10**	-5.11**	-3.82**	-4.60**	-3.99**	-2.58**	0.08
γ-20 kR	-5.95**	-6.14**	-6.58**	-2.69**	-2.27*	-4.63**	-2.39*	0.08	0.08	-0.51
γ-30 kR	-1.23	-1.08	1.44	0.28	0.85	-0.11	-0.31	0.68	2.99**	0.88
γ-40 kR	2.33*	-0.11	2.05*	3.04**	3.93**	1.86	-1.06	1.02	0.67	1.61
EMS 0.5%	4.40**	4.56**	3.95**	5.82**	3.31**	0.67	7.77**	9.15**	6.27**	3.95**
EMS 1.0%	5.35**	3.82**	2.42*	8.13**	1.22	3.81**	3.37**	5.97**	5.20**	7.14**
EMS 1.5%	5.61**	7.18**	4.53**	8.17**	5.01**	4.56**	4.25**	3.34**	4.18**	3.83**
EMS 2.0%	5.96**	6.20**	4.16**	4.31**	2.95**	6.27**	3.68**	2.24*	4.60**	7.51**

contd.

Table 16. contd.

B - 76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	2.42*	-0.40	2.25*	-0.22	-0.57	-3.24**	-1.81	0.28	- 3.18**	-1.99*
X-20 kR	1.18	0.13	-2.85**	0.30	2.94**	2.22*	0.48	2.76**	1.02	0.30
X-30 kR	5.53**	7.35**	2.45*	2.58**	1.38	-0.22	0.65	1.84	1.18	0.84
X-40 kR	5.45**	2.09*	0.49**	0.29	2.78**	-0.04	1.53	2.46*	1.89	0.13
γ-10 kR	-0.22	0.13	3.84**	0.48	-0.56	4.43**	2.09*	-2.89**	-0.72	0.13
γ-20 kR	0.31	-0.56	0.84	0.13	1.36	-3.40**	-2.37*	-1.83	0.30	-1.45
γ-30 kR	5.53**	1.15	1.19	0.83	-0.04	-1.43	-1.47	0.85	1.34	1.91
γ-40 kR	-0.39	-1.11	-0.56	-0.22	3.68**	-0.40	2.19*	2.63**	2.98**	2.43*
EMS 0.5%	4.49**	5.45**	2.92**	5.08**	3.52**	-0.40	0.49	5.66**	5.12**	4.37**
EMS 1.0%	1.84	3.00**	0.67	0.66	3.70**	3.35**	2.40*	4.83**	4.05**	3.12**
EMS 1.5%	1.90	4.04**	4.11**	4.22**	4.49**	3.15**	0.85	2.36*	4.77**	3.35**
EMS 2.0%	2.05*	5.08**	4.11**	4.53**	6.17**	4.39**	2.27*	1.02	4.04**	4.24**

Table 17. Grouping of family means for nine characters in M_2 for T-9 and B-76

T - 9

Treatment	Days to flowering			Height at flowering			Clusters/plant			Pods/cluster		
	-	No change	+	-	No change	+	-	No change	+	-	No change	+
X-10 kR	6	4	=	-	7	3	1	7	2	1	6	3
X-20 kR	8	2	-	4	5	1	4	4	2	2	6	2
X-30 kR	2	6	2	6	4	-	6	3	1	2	5	3
X-40 kR	-	8	2	6	4	-	10	-	-	4	6	-
ϒ-10 kR	9	1	-	-	3	7	3	3	4	1	5	4
ϒ-20 kR	7	3	-	1	5	4	-	3	7	1	2	7
ϒ-30 kR	-	9	1	3	5	2	5	5	-	8	2	-
ϒ-40 kR	-	6	4	7	3	-	10	-	-	4	6	-
EMS 0.5%	-	1	9	7	3	-	9	1	-	3	4	3
EMS 1.0%	-	1	9	10	-	-	10	-	-	3	6	1
EMS 1.5%	-	-	10	9	1	-	10	-	-	9	1	-
EMS 2.0%	-	-	10	9	1	-	10	-	-	7	2	1
Total	32	41	47	62	41	17	78	26	16	45	51	24
Per cent	26.67	34.17	39.17	51.67	34.17	14.17	65.00	21.67	13.33	37.50	42.50	20.00

Contd.

Table 17. contd.

Treatment	Days to flowering			Height at flowering			Clusters/plant			Pods/cluster		
	-	No change	+	-	No change	+	-	No change	+	-	No change	+
X-10 kR	2	6	2	1	8	1	1	7	2	1	4	5
X-20 kR	1	6	3	1	8	1	7	3	-	5	3	2
X-30 kR	-	6	4	3	7	-	10	-	-	2	7	1
X-40 kR	-	6	4	6	4	-	10	-	-	2	7	1
ϒ-10 kR	1	6	3	-	8	2	4	5	1	2	2	6
ϒ-20 kR	2	8	-	1	7	2	6	2	2	2	7	1
ϒ-30 kR	-	9	1	4	6	-	7	3	-	5	5	1
ϒ-40 kR	-	5	5	6	4	-	10	-	-	5	4	1
EMS 0.5%	-	2	8	6	4	-	10	-	-	4	6	-
EMS 1.0%	-	3	7	6	4	-	9	1	-	3	4	3
EMS 1.5%	-	2	8	9	1	-	10	-	-	2	6	2
EMS 2.0%	-	1	9	9	1	-	10	-	-	3	4	3
Total	6	60	54	52	62	6	94	21	5	36	59	25
Per cent	5.00	50.00	45.00	43.33	51.67	5.00	78.33	17.50	4.17	30.00	49.17	20.83

contd.

Table 17. contd.

T - 9

Treatment	Characters														
	Pod length			Seeds per pod			Pods per plant			Seeds per plant			Yield/plant		
	-	No change	+	-	No change	+	-	No change	+	-	No change	+	-	No change	+
X-10 kR	3	5	2	1	2	7	5	2	3	5	4	1	5	4	1
X-20 kR	6	2	2	3	1	6	5	3	2	7	2	1	5	4	1
X-30 kR	7	3	-	7	1	2	6	3	1	9	1	-	9	1	-
X-40 kR	1	6	3	7	3	-	10	-	-	10	-	-	10	-	-
ϒ-10 kR	1	6	3	1	-	9	4	3	3	7	2	1	7	2	1
ϒ-20 kR	1	4	5	-	2	8	1	1	8	2	4	4	2	3	5
ϒ-30 kR	8	2	-	5	2	3	9	1	-	10	-	-	10	-	-
ϒ-40 kR	8	2	-	5	3	2	10	-	-	10	-	-	10	-	-
EMS 0.5%	6	4	-	2	3	5	10	-	-	10	-	-	10	-	-
EMS 1.0%	9	1	-	6	3	1	10	-	-	10	-	-	10	-	-
EMS 1.5%	10	-	-	10	-	-	10	-	-	10	-	-	10	-	-
EMS 2.0%	10	-	-	10	-	-	10	-	-	10	-	-	10	-	-
Total	70	35	15	57	20	43	90	13	17	100	13	7	98	14	8
Per cent	58.33	29.17	12.50	47.50	16.67	35.83	75.00	10.83	14.17	83.33	10.83	5.83	81.67	11.67	6.67

contd.

Table 17. contd.

B - 76

Treatment	Pod length			Seeds per pod			Pods per plant			Seeds per plant			Yield/Plant		
	-	No change	+	-	No change	+	-	No change	+	-	No change	+	-	No change	+
X-10 kR	2	8	-	-	3	7	5	5	-	7	3	-	7	3	-
X-20 kR	-	8	2	2	4	4	8	2	-	10	-	-	10	-	-
X-30 kR	6	4	-	6	4	-	10	-	-	10	-	-	10	-	-
X-40 kR	7	3	-	8	2	-	10	-	-	10	-	-	10	-	-
ϒ-10 kR	5	4	1	3	5	2	6	4	-	10	-	-	10	-	-
ϒ-20 kR	5	3	2	3	6	1	6	3	1	8	2	-	9	1	-
ϒ-30 kR	8	2	-	6	2	2	10	-	-	10	-	-	10	-	-
ϒ-40 kR	9	1	-	7	3	-	10	-	-	10	-	-	10	-	-
EMS 0.5%	6	4	-	5	3	2	10	-	-	10	-	-	10	-	-
EMS 1.0%	3	6	1	4	5	1	9	1	-	9	1	-	10	-	0
EMS 1.5%	5	5	-	5	4	1	10	-	-	10	-	-	10	-	-
EMS 2.0%	8	2	-	7	3	-	10	-	-	10	-	-	10	-	-
Total	64	50	6	56	44	20	104	15	1	114	6	0	116	4	0
Per cent	53.33	41.67	5.00	46.67	36.67	16.67	86.67	12.50	0.83	95.00	5.00	0	96.67	3.33	0

Table 18. Intra-family variances for days to flowering in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	4.00	4.00	3.17	2.66	5.16	2.16	1.33	3.33	1.33	0.33	2.75
X-20 kR	1.16	4.16	1.83	1.00	0.74	2.33	1.00	4.00	0.66	2.66	1.95
X-30 kR	2.66	3.66	2.33	1.16	3.16	1.66	4.00	1.00	0.33	2.66	2.26
X-40 kR	2.00	1.66	1.66	1.00	4.16	0.66	3.16	0.66	5.16	7.33	2.74
♂-10 kR	2.16	1.00	2.66	7.00	5.16	3.16	2.16	8.50	5.16	5.66	4.26
♂-20 kR	1.66	4.16	2.33	0.66	0.66	2.50	4.33	1.66	3.66	2.16	2.33
♂-30 kR	2.50	2.66	2.33	2.66	4.16	3.50	2.33	2.50	3.16	0.66	2.65
♂-40 kR	2.16	2.00	1.66	8.33	4.83	0.66	5.16	4.33	2.66	4.00	3.58
EMS 0.5%	1.83	2.50	4.00	5.16	6.50	1.16	1.16	1.33	3.33	1.00	2.98
EMS 1.0%	0.66	7.00	3.33	2.50	6.66	1.66	1.93	2.66	5.16	1.66	3.32
EMS 1.5%	1.33	1.66	2.33	1.33	1.16	2.50	3.16	5.83	2.66	0.66	2.26
EMS 2.0%	1.66	0.66	4.16	3.16	2.16	1.00	3.66	1.33	1.00	2.33	2.11
Control											2.66

Contd.

Table 18. contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	2.33	1.66	1.66	1.66	2.33	1.00	1.33	9.16	4.00	1.66	2.68
X-20 kR	2.66	1.66	4.16	1.66	1.66	0.66	1.00	3.66	1.83	3.16	2.21
X-30 kR	2.66	2.50	0.66	2.33	0.66	5.66	0.66	5.33	3.16	2.66	2.63
X-40 kR	1.66	1.00	0.33	5.16	0.66	0.33	4.33	0.66	1.66	2.66	1.84
γ-10 kR	1.66	1.16	3.16	1.00	1.83	0.66	1.00	0.33	7.66	3.66	2.21
γ-20 kR	0.66	5.33	1.16	1.16	2.33	1.66	0.66	0.66	2.16	1.66	1.74
γ-30 kR	3.16	2.66	0.33	2.16	2.33	4.16	2.16	0.66	2.66	1.66	2.19
γ-40 kR	0.83	2.50	7.33	4.66	0.33	3.66	0.66	0.83	0.83	3.16	2.48
EMS 0.5%	3.16	0.66	0.66	1.83	0.66	3.66	2.33	0.66	0.66	0.66	1.49
EMS 1.0%	1.66	0.33	1.33	0.66	2.16	0.83	1.16	1.66	1.66	3.33	1.48
EMS 1.5%	2.33	0.66	1.00	1.00	2.33	1.00	0.66	3.66	1.33	0.66	1.46
EMS 2.0%	5.33	0.66	1.00	1.16	0.66	0.66	1.16	1.00	1.66	0.83	1.41
Control											2.20

Table 19. Population variance and interfamily variance of days to flowering in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	2.75	2.68	39.85	21.02
X-20 kR	1.96	2.21	8.38	15.18
X-30 kR	2.26	2.63	25.57	29.81
X-40 kR	2.75	1.85	11.55	13.73
γ-10 kR	4.26	2.21	25.30	25.64
γ-20 kR	2.33	1.80	30.63	12.57
γ-30 kR	2.65	2.20	7.41	21.07
γ-40 kR	3.58	2.48	9.92	17.37
EMS 0.5%	2.98	1.50	24.47	23.65
EMS 1.0%	3.32	1.48	19.29	10.35
EMS 1.5%	2.26	1.46	9.56	9.21
EMS 2.0%	2.11	1.41	11.96	12.73
Control	2.66	2.20		

Table 20. Test of heterogeneity of family means (Calculated 'F' values) for nine characters in M_2

T - 9

Treatments	Days to flowering	Height at flowering	Clusters per plant	Pods per cluster	Pod length	Seeds per pod	Pods per plant	Seeds per plant	Yield per plant
	Characters								
X-10 kR	14.49**	4.86**	9.24**	1.92	13.75**	34.35**	32.62**	37.38**	36.34**
X-20 kR	4.27**	41.02**	6.90**	2.93**	15.28**	22.87**	51.51**	38.22**	35.83**
X-30 kR	11.31**	14.23**	6.45**	1.84	8.51**	10.76**	34.45**	21.51**	20.77**
X-40 kR	4.18**	24.53**	2.20*	1.00	3.76**	7.65**	5.36**	4.39**	4.47**
γ-10 kR	5.94**	11.62**	8.86**	2.24*	9.11**	17.33**	15.22**	17.91**	17.30**
γ-20 kR	13.15**	12.71**	10.57**	2.22*	7.54**	19.28**	12.56**	20.57**	22.71**
γ-30 kR	2.80*	23.56**	1.95	0.84	13.09**	23.63**	8.28**	6.88**	6.67**
γ-40 kR	2.77*	17.35**	1.37	1.44	16.45**	14.52**	3.33**	5.50**	5.62**
EMS 0.5%	8.21**	8.21**	3.16*	3.41**	2.81*	10.32**	4.59**	4.80**	5.62**
EMS 1.0%	5.81**	7.32**	2.58*	2.82*	5.67**	31.83**	4.90**	4.00**	4.12**
EMS 1.5%	4.23**	5.37*	4.43**	1.74	10.67**	17.57**	4.70**	2.87*	3.18**
EMS 2.0%	5.67**	8.87**	1.43	2.52*	8.83**	5.48**	2.96**	3.60**	3.91**

Contd.

Table 20. contd.

Treatments	Days to flowering	Height at flowering	Clusters per plant	Pods per cluster	Pod length	Seeds per pod	Pods per plant	Seeds per plant	Yield per plant
X-10 kR	7.84**	9.44**	2.99**	3.02**	1.36	19.12**	8.06**	13.32**	9.13**
X-20 kR	6.87**	15.72**	6.05**	3.18**	4.26**	8.88**	13.41**	11.36**	11.47**
X-30 kR	11.33**	9.69**	1.36	2.82*	3.29**	9.53**	6.48**	2.21*	1.67
X-40 kR	7.42**	7.82**	2.00	1.37	15.29**	17.73**	8.70**	12.13**	11.90**
γ-10 kR	11.60**	3.16**	7.87**	3.22**	9.50**	7.88**	8.84**	6.88**	6.03**
γ-20 kR	6.98**	6.72**	6.46**	2.18*	8.92**	7.25**	6.54**	5.70**	5.66**
γ-30 kR	9.58**	4.50**	5.88**	1.32	4.51**	28.00**	5.24**	5.41**	5.67**
γ-40 kR	7.00**	14.05**	2.12	1.37	3.76**	3.75**	4.19**	5.53**	6.53**
EMS 0.5%	15.77**	5.26**	2.03	1.42	5.98**	16.81**	4.63**	5.30**	5.73**
EMS 1.0%	6.99**	4.74**	5.24**	4.15**	14.04*	9.42**	21.69*	26.55**	28.95**
EMS 1.5%	6.31**	3.83**	2.95**	1.48	9.05**	5.83**	2.10	2.35*	19.69**
EMS 2.0%	9.03**	14.79**	1.32	1.66	11.45**	28.17**	1.53	2.02	2.09

* Significant at 5%

** Significant at 1%

Height at flowering.

Mean.

The family means of all the treatments of the two varieties (T-9 and B-76) are presented in Table 21. From the analysis of variance (Table 15), it was found that varieties, treatments and variety x treatment (v x t) interactions were significant which suggest significant difference between treatments and also between the two varieites in respect of plant height. All EMS treatments resulted in reduced plant height at flowering for both the varieties. With the increase in doses of physical mutagens there was decrease in height. In general, at lower doses of either X-ray or gamma ray height was increased. To record the change in mean value for height as compared to controls the family means were grouped in three categories viz., significantly increased mean, significantly reduced mean and no significant change in mean. This was done by 't'-test and the results are presented in Table 22. Grouping of family means (Table 17) indicated differential response of T-9 and B-76. Thus in T-9, 14.17% families were shifted towards tallness and 51.67% towards dwarfness. On the other hand, for B-76, 5% families were shifted toward tallness and 43.33% families toward dwarfness.

Variance.

Population variances and inter family variance for each treatment over all families are given in Table 23. Intra (within) family variances are presented in Table 24. The variances of all

the treatments for both the varieties were low as compared to the controls indicating release of very poor amount of variability in M_2 generation for plant height at flowering. However, when inter-family variances were tested against intra-family variances for each treatment (Table 20), they were highly significant indicating heterogeneity of variances for different family means.

Several earlier authors also reported reduction in mean plant height due to mutagenic treatments in a number of crop plants, e.g., Borojevic and Borojevic (1969) in wheat, Madhava and Goud (1973) in Setaria italica, Rubaihayo (1976) and Nimako et al. (1982) in soyabean, Shakoor et al. (1979) in green gram and Kundu and Singh (1981) in black gram. On the contrary, increase in plant height was observed by Goud et al. (1971) in ragi, by Mujeeb and Greig (1973) in french bean, in soyabean by Nicolae et al. (1977) and by Vaseleva (1975) in pea.

Clusters per plant.

Mean.

Table 25 represents the means of individual families of different treatments of the two genotypes (T-9 and B-76). There was significant difference between different treatments and also between the two varieties as indicated from the analysis of variance (Table 15). Different mutagenic treatments induced different magnitude of effects in different families. In

Table 21. Family means of height at flowering in M_2 for T-9 and B-76

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	20.45	20.15	19.08	19.75	18.23	20.80	20.76	18.36	19.15	18.12	19.49
X-20 kR	23.78	19.92	18.20	15.22	17.75	13.75	17.56	13.25	18.41	14.08	17.19
X-30 kR	17.15	15.30	15.13	17.88	17.90	16.23	12.76	19.82	15.70	13.76	16.16
X-40 kR	15.53	16.40	16.88	14.43	12.98	10.53	18.41	15.60	17.38	15.30	15.35
♂-10 kR	20.57	18.68	19.51	21.37	21.13	16.85	24.05	22.61	21.43	23.03	20.93
♂-20 kR	18.20	19.25	19.33	20.15	22.10	21.91	15.56	21.91	19.63	21.03	19.91
♂-30 kR	15.90	21.13	16.41	18.90	21.03	15.65	17.32	15.30	17.80	19.53	17.90
♂-40 kR	14.83	19.73	13.25	18.12	14.45	16.70	15.61	16.05	13.51	15.35	15.76
EMS 0.5%	17.23	14.53	15.02	16.05	13.83	14.98	11.96	16.31	16.12	16.20	15.23
EMS 1.0%	15.67	15.53	12.68	15.55	13.85	14.38	14.68	16.28	13.53	12.78	14.50
EMS 1.5%	15.78	17.47	15.73	15.32	14.65	15.08	15.40	14.08	12.81	15.63	15.20
EMS 2.0%	16.27	16.03	13.08	15.00	13.63	14.65	15.06	15.75	16.75	14.58	15.08
Control											18.30

contd.

Table 21. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	16.45	18.18	14.75	16.70	16.32	15.76	19.88	17.95	17.01	17.31	17.03
X-20 kR	17.83	20.33	17.93	14.90	15.58	18.20	17.32	17.43	13.85	16.57	16.99
X-30 kR	14.28	13.72	17.21	17.45	17.05	15.35	16.21	13.70	15.72	15.61	16.63
X-40 kR	13.86	15.15	15.23	16.17	12.21	14.66	14.10	14.45	15.53	12.65	14.40
γ-10 kR	19.52	15.95	18.01	19.12	18.10	17.01	17.01	17.46	17.78	17.50	17.65
γ-20 kR	19.03	14.75	18.61	18.28	17.36	17.66	19.16	18.58	17.81	17.63	17.89
γ-30 kR	15.00	12.80	16.17	14.05	16.10	16.40	15.58	14.96	16.18	14.25	15.15
γ-40 kR	13.91	11.81	18.51	19.40	13.76	13.03	14.85	15.26	15.28	16.93	14.58
EMS 0.5%	14.35	15.77	14.16	16.36	15.06	12.88	14.17	12.56	14.48	15.03	14.48
EMS 1.0%	15.86	13.66	13.50	15.35	12.35	14.07	15.71	15.00	14.52	13.78	14.38
EMS 1.5%	14.38	13.68	13.06	13.98	12.88	14.00	12.28	15.07	13.05	13.61	13.60
EMS 2.0%	14.43	13.21	12.25	12.35	10.38	10.12	13.16	16.23	11.98	11.02	12.52
Control											16.81

Table 22. t-values of family means for height at flowering in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	2.09*	1.78	0.76	1.41	-0.07	2.42*	2.22*	0.06	0.83	-0.17
X-20 kR	5.16**	1.56	-0.10	-3.02**	-0.54	-4.37**	-0.72	-4.87**	0.11	-4.10**
X-30 kR	-1.12	-2.87**	-3.06**	-0.40	-0.38	-2.03*	-5.28**	1.46	-2.51*	-4.27**
X-40 kR	-2.63**	-1.85	-1.36	-3.70**	-5.19**	-7.52**	0.10	-2.56*	-0.89	-2.93**
♂-10 kR	2.19*	0.36	1.12	3.00**	2.73**	-1.42	5.50**	4.19**	2.98**	4.51**
♂-20 kR	-0.10	0.92	0.10	1.75	3.68**	3.50**	-2.62**	3.45**	1.29	2.67**
♂-30 kR	-2.32*	2.77**	-1.85	0.58	2.61**	-2.56*	-0.94	-2.94**	-0.49	1.20
♂-40 kR	-3.36**	1.39	-4.93**	-0.18	-3.76**	-1.55	-2.58**	-2.20*	-4.66**	-2.79**
EMS 0.5%	-1.04	-3.64**	-3.18**	-2.20*	-4.33**	-3.23**	-6.22**	-1.93	-2.11	-2.03*
EMS 1.0%	-2.56*	-2.66**	-5.44**	-2.67**	-4.33**	-3.83**	-3.51**	-1.96*	-4.66**	-5.39**
EMS 1.5%	-2.43*	-0.80	-2.47*	-2.92**	-3.56**	-3.02**	-2.81**	-4.10**	-5.36**	-2.60**
EMS 2.0%	-1.98*	-2.20*	-5.06	-3.24**	-4.40**	-3.56**	-3.16**	-2.46*	-1.52	-3.62**

contd.

Table 22. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	-0.38	1.47	-2.18*	-0.11	-0.49	-1.13	3.30**	1.18	0.21	0.53
X-20 kR	1.10	3.75**	1.19	-2.02*	-1.32	1.43	0.55	0.65	-3.15**	-0.25
X-30 kR	-2.71**	-3.32**	0.37	0.65	0.26	-1.58	-0.64	-3.33**	-1.17	-1.30
X-40 kR	-3.13**	-1.78	-1.71	-0.68	-4.97**	-2.32*	-2.93**	-2.55*	-1.37	-4.49**
♂-10 kR	2.78**	-0.92	1.30	2.46*	1.36	0.21	0.21	0.67	1.02	0.73
♂-20 kR	2.33*	-2.22*	1.93	1.57	0.57	0.91	2.46*	1.82	1.05	0.88
♂-30 kR	-1.95	-4.31**	-0.68	-2.85**	-0.74	-0.43	-1.29	-2.00**	-0.66	-2.65**
♂-40 kR	-3.07**	-5.37**	1.81	-4.72**	-3.26**	-4.06**	-2.09*	-1.65	-1.63	0.13
EMS 0.5%	-2.62**	-1.09	-2.76**	-0.48	-1.88	-4.15**	-2.84**	-4.55**	-2.50*	-1.92
EMS 1.0%	-0.99	-3.31**	-3.56**	-1.55	-4.81**	-2.93**	-1.18	-1.92	-2.45*	-3.27**
EMS 1.5%	-2.61**	-3.33**	-3.90**	-2.80**	-4.20**	-3.01**	-4.48**	-1.88	-4.04**	-3.41**
EMS 2.0%	-2.55*	-3.85**	-4.88**	-4.77**	-6.85**	-7.16**	-3.89**	-0.62	-5.21**	-6.22**

* Significant at 5%

** Significant at 1%

Table 23. Population variance and interfamily variance of height at flowering in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	1.34	1.28	6.52	12.09
X-20 kR	1.54	1.31	63.17	20.60
X-30 kR	1.86	1.20	26.47	11.63
X-40 kR	1.27	1.19	31.15	9.31
γ-10 kR	2.37	2.04	27.54	6.45
γ-20 kR	1.93	1.42	24.54	9.55
γ-30 kR	1.72	1.83	40.53	8.23
γ-40 kR	1.40	1.80	24.29	25.29
EMS 0.5%	1.69	1.56	13.88	8.20
EMS 1.0%	1.31	1.57	9.59	7.45
EMS 1.5%	1.65	1.56	8.86	5.97
EMS 2.0%	0.91	1.41	8.07	20.85
Control	3.98	3.60		

Table 24. Intra-family variance for height at flowering in M_2

T-9

Family

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	1.400	1.525	1.385	0.485	2.165	1.450	1.285	1.215	2.015	0.490	1.34
X-20 kR	1.285	3.565	2.360	0.440	1.000	0.650	1.695	0.730	2.155	1.520	1.54
X-30 kR	0.370	3.460	4.160	2.000	2.060	0.305	0.540	2.235	1.135	3.340	1.86
X-40 kR	4.330	0.700	0.090	2.045	0.330	2.890	1.660	0.790	0.360	0.530	1.27
♂- 10 kR	2.605	2.225	2.220	1.010	2.555	1.075	3.500	1.780	2.780	3.955	2.37
♂- 20 kR	0.340	1.650	2.275	5.275	5.365	0.930	0.840	4.305	0.650	2.555	1.93
♂-30 kR	3.610	0.345	0.545	1.020	3.475	2.745	3.930	0.575	0.345	0.675	1.73
♂-40 kR	3.050	0.680	0.740	0.475	0.455	2.735	3.865	0.385	0.490	1.105	1.40
EMS 0.5%	0.345	3.235	3.060	1.265	2.315	1.200	0.260	1.190	2.420	1.700	1.70
EMS 1.0%	1.340	1.930	2.860	0.710	1.655	0.295	0.955	1.930	0.940	0.480	1.31
EMS 1.5%	0.885	1.640	3.940	0.450	0.690	2.705	1.775	2.345	0.110	1.965	1.65
EMS 2.0%	1.125	0.315	2.285	0.380	0.425	1.665	0.475	1.150	0.705	0.580	0.91
Control											3.98

contd.

Table 24. contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	2.110	0.665	1.945	3.200	2.285	0.200	0.810	0.635	0.460	0.545	1.29
X-20 kR	1.305	2.240	1.330	0.950	0.230	1.790	0.940	0.800	2.325	1.210	1.31
X-30 kR	1.800	0.615	1.630	2.545	0.415	0.580	0.280	1.590	1.195	1.390	1.20
X-40 kR	1.150	0.475	0.745	1.330	0.240	0.125	1.990	3.820	1.795	0.275	1.19
γ - 10 kR	2.980	1.315	0.305	3.110	1.345	0.890	0.995	0.175	5.855	3.480	2.04
γ - 20 kR	1.740	0.460	0.185	0.820	3.095	0.965	0.770	4.665	1.105	0.400	1.42
γ -30 kR	0.515	1.240	1.325	2.915	0.370	3.990	2.185	0.575	1.735	3.450	1.83
γ -40 kR	3.015	0.755	2.945	0.945	2.135	0.785	2.385	2.190	0.350	2.510	1.80
EMS 0.5%	0.720	3.050	4.615	1.010	0.805	2.685	0.485	1.255	0.645	0.365	1.56
EMS 1.0%	4.115	0.165	1.160	2.630	1.620	2.355	1.330	1.080	0.760	0.500	1.57
EMS 1.5%	0.690	0.955	2.925	0.890	1.105	2.560	2.105	0.790	0.640	2.930	1.56
EMS 2.0%	0.825	0.680	0.920	2.175	2.900	1.940	1.065	2.230	0.615	0.765	1.41
Control											3.60

other words, the same mutagenic treatment produced some families with positive change and some families with negative change. In T-9, the population mean of almost all the treatments (except 10 kR X-rays and 10 and 20 kR gamma rays) were shifted towards negative direction. On the other hand, in B-76, all the population means were shifted towards negative direction. In fact 10 kR X-ray produced as many as 9 cluster per plant in one of the families while 10 kR and 20 kR gamma ray produced around 8 clusters per plant as against 5 cluster per plant in control. Grouping of the family means was done on the basis of reduced means, increased means and similar means to the controls (Table 17), following 't'-tests of family means (Table 26). From the grouping of family means it was found that, only 13.33% families of T-9 and 4.17% families of B-76 were shifted towards positive direction. On the other hand 65% families of T-9 and 78.33% families of B-76 were shifted towards negative direction indicating shifting of majority of the families towards negative direction for both the varieties. The shifting of the means in the desirable direction was caused by lower doses of physical mutagens (X-ray 10 kR, gamma ray 10 and 20 kR) in both the varieties. All EMS treatments and higher doses of physical mutagens resulted significant decrease in mean for clusters per plant.

Variance.

The intra and inter family variances and population variances are presented in Tables 28 and 27. In general, the

Table 25. Family means of clusters per plant in M_2 for T-9 and B-76

T-9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	4.84	4.84	4.50	4.00	4.80	4.50	4.50	5.50	8.67	6.17	5.23
X-20 kR	6.00	7.00	5.00	3.84	4.00	4.67	4.33	4.33	5.17	4.67	4.90
X-30 kR	4.84	4.00	4.33	4.50	4.84	4.33	3.50	5.84	4.17	3.33	4.27
X-40 kR	4.00	3.83	3.84	3.67	4.34	3.50	3.50	3.50	2.50	4.00	3.67
♂ - 10 kR	5.17	6.17	5.17	3.67	6.33	3.67	6.34	5.33	3.00	5.84	5.07
♂ -20 kR	7.67	8.17	5.33	8.34	6.00	6.67	4.84	4.84	6.84	5.84	6.45
♂ -30 kR	5.00	4.00	4.50	4.17	5.50	3.67	4.50	3.67	4.50	4.00	4.35
♂ -40 kR	3.84	3.00	3.00	2.84	3.33	4.17	3.84	3.84	3.84	3.00	3.47
EMS 0.5%	3.84	4.17	4.17	4.00	3.50	3.17	2.50	3.00	3.67	5.00	3.70
EMS 1.0%	3.00	3.00	3.67	3.33	3.34	3.50	3.00	3.00	1.67	3.84	3.13
EMS 1.5%	3.33	3.84	2.50	2.50	2.33	3.33	2.17	3.67	3.17	2.84	2.97
EMS 2.0%	3.00	2.67	2.17	2.17	2.17	2.84	3.17	3.00	2.84	2.17	2.67
Control											5.04

contd.

Table 25. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	4.84	3.67	5.00	4.17	3.67	4.00	4.17	5.50	4.17	3.17	4.23
X-20 kR	3.00	4.84	3.33	3.67	3.50	3.50	3.67	2.00	2.33	3.00	3.28
X-30 kR	2.84	3.00	3.50	2.50	2.67	2.33	2.17	2.50	3.00	2.84	2.73
X-40 kR	3.00	2.17	2.84	3.17	2.84	1.83	1.84	3.00	2.33	2.67	2.57
♂ - 10 kR	4.84	4.17	2.67	4.17	2.67	4.50	3.17	3.84	4.83	3.17	3.80
♂ - 20 kR	3.17	3.00	4.84	4.67	3.50	3.50	4.33	5.17	2.84	3.00	3.80
♂ - 30 kR	4.50	3.67	2.67	4.17	2.67	2.84	2.50	3.00	2.15	3.00	3.12
♂ - 40 kR	3.33	3.00	2.33	2.00	2.17	3.33	1.84	2.84	2.84	2.50	2.62
EMS 0.5%	3.33	3.00	2.67	2.17	2.00	2.84	2.50	2.17	2.50	3.33	2.65
EMS 1.0%	2.67	4.67	3.17	2.67	2.34	2.33	2.67	3.00	2.17	2.50	2.82
EMS 1.5%	2.84	2.67	2.00	1.84	2.00	2.50	2.00	2.67	2.84	3.50	2.48
EMS 2.0%	2.67	1.84	2.67	2.67	2.00	2.17	2.00	2.50	2.33	2.84	2.37
Control											4.25

Table 26. t-values of family means for clusters per plant in M_2

T - 9

Family

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	-0.57	-0.55	-1.51	-2.95**	-0.57	-1.51	-1.55	1.24	10.05**	3.24**
X-20 kR	2.72**	5.56**	-0.11	-3.44**	-2.95**	-1.06	-2.09*	-2.04*	0.37	-1.06
X-30 kR	-0.57	-2.95**	-2.09*	-1.55	-0.57	-4.97**	-4.47**	2.30*	-0.50*	-4.85**
X-40 kR	-2.95**	-3.47**	-3.44**	-3.93**	-2.01*	-4.47**	-4.47**	-4.42**	-7.29**	-2.95**
γ - 10 kR	0.37	3.20**	0.37	-3.93**	3.61**	-4.03**	3.64**	0.78	-5.78**	2.30*
γ - 20 kR	7.55**	8.37**	0.82	9.35**	2.72**	4.68**	-0.57	-0.57	5.17**	2.30*
γ - 30 kR	-0.11	-3.02**	-0.27	-2.47*	1.34	-3.93**	-1.51	2.04*	-1.51	-2.81**
γ - 40 kR	-3.32**	-5.78**	-5.85**	-6.24**	-4.91**	-2.41*	-3.44**	-3.32**	-3.44**	-5.78**
EMS 0.5%	-3.44**	-2.41*	-2.50*	-3.02**	-4.31**	-5.37**	-7.38**	-5.78**	-4.03**	-0.11
EMS 1.0%	-5.93**	-5.78**	-3.93**	-4.91**	-4.88**	-4.26**	-5.78**	-5.78**	-9.91**	-3.44**
EMS 1.5%	-5.03**	-3.44**	-7.38**	-7.38**	-7.97**	-5.03**	-8.24**	-4.03**	-5.37**	-6.31**
EMS 2.0%	-5.78**	-6.97**	-8.24**	-8.24**	-8.24**	-6.31**	-5.37**	-5.78**	-6.31**	-8.24**

contd.

Table 26. contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	1.93	-1.80	2.42*	-0.27	-1.95	-0.77	-0.25	4.20**	-0.26	-3.58**
X-20 kR	-4.20**	1.90	-3.05**	-1.92	-2.52*	-2.45*	-1.95	-7.46**	-6.45**	-4.09**
X-30 kR	-4.67**	-4.09**	-3.36**	-5.88**	-5.09**	-6.45**	-6.89**	-5.88**	-4.09**	-4.67**
X-40 kR	-4.09**	-6.89**	-4.67**	-3.58**	-4.67**	-8.02**	-7.99**	-3.87**	-6.45**	-5.31**
γ - 10 kR	1.96**	-0.27	-5.31**	-0.27	-5.31**	0.84	-3.58**	-1.36	1.92	-3.58**
γ - 20 kR	-3.58**	-4.09**	1.96*	1.41	-2.42*	-2.52*	0.27	3.05**	-4.67**	-4.09**
γ - 30 kR	0.84	-1.92	-5.31**	-0.27	-5.31**	-4.67**	-5.88**	-4.09**	-6.89**	-4.09**
γ - 40 kR	-2.97**	-4.09**	-6.45**	-7.35**	-6.89**	-3.09**	-7.99**	-4.67**	-4.67**	-5.64**
EMS 0.5%	-2.97**	-4.09**	-5.31**	-6.89**	-7.35**	-4.67**	-5.88**	-6.89**	-5.88**	-3.09**
EMS 1.0%	-5.24**	1.39	-3.58**	-5.31**	-6.33**	-6.45**	-5.31**	-4.09**	-6.89**	-5.88**
EMS 1.5%	-4.67**	-5.31**	-7.35**	-7.99**	-7.35**	-5.88**	-7.56**	-5.31**	-4.67**	-2.52*
EMS 2.0%	-5.31**	-7.99**	-5.31**	-5.31**	-7.35**	-6.89**	-7.35**	-5.88**	-6.45**	-4.67**

* significant at 5%

** significant at 1%

Table 27. Population variance and interfamily variance of clusters per plant in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	1.18	0.98	10.90	2.93
X-20 kR	0.81	0.61	5.59	3.69
X-30 kR	0.58	0.66	3.74	0.90
X-40 kR	0.66	0.73	1.45	1.46
γ - 10 kR	1.00	0.53	8.86	4.17
γ - 20 kR	0.96	0.70	10.15	4.52
γ - 30 kR	1.03	0.58	2.01	3.41
γ - 40 kR	1.03	0.80	1.41	1.70
EMS 0.5%	0.95	0.66	3.00	1.34
EMS 1.0%	0.83	0.59	2.14	3.09
EMS 1.5%	0.46	0.56	2.04	1.65
EMS 2.0%	0.70	0.56	1.00	0.74
Control	0.73	0.58		

Table 28. Intra-family variances for clusters per plant in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	1.165	1.665	1.330	1.000	0.665	1.000	0.330	2.330	1.665	0.665	1.18
X-20 kR	1.000	1.000	1.330	0.665	1.000	0.665	0.330	0.830	0.665	0.665	0.81
X-30 kR	0.665	1.000	0.330	0.830	0.665	0.330	0.330	0.665	0.665	0.330	0.58
X-40 kR	1.000	0.330	0.665	0.665	0.665	0.330	0.330	0.830	0.830	1.000	0.66
γ-10 kR	0.665	1.165	1.165	0.665	1.330	0.330	0.665	2.330	1.000	0.665	1.00
γ-20 kR	0.665	2.330	1.330	1.165	0.330	0.665	0.665	1.165	0.665	0.665	0.96
γ-30 kR	1.000	0.330	1.000	1.165	0.330	0.665	1.000	1.330	1.000	2.500	1.03
γ-40 kR	1.665	1.000	1.000	1.165	0.830	0.665	0.665	1.665	0.665	1.000	1.03
EMS 0.5%	0.665	1.665	0.665	0.330	1.330	0.665	0.330	1.000	0.330	2.500	0.95
EMS 1.0%	0.330	1.000	0.665	0.830	0.665	1.830	1.000	1.000	0.330	0.665	0.83
EMS 1.5%	0.330	0.665	0.330	0.330	0.330	0.330	0.665	0.330	0.665	0.665	0.46
EMS 2.0%	1.000	0.330	0.665	0.665	0.665	0.665	0.665	1.000	0.665	0.665	0.70
Control											0.73

contd.

Table 28. contd.

Treatments	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.665	0.830	1.000	0.665	0.330	2.000	1.665	0.330	1.665	0.665	0.98
X-20 kR	0.330	1.165	0.830	0.665	0.330	0.830	0.330	0.330	0.330	1.000	0.61
X-30 kR	0.665	1.000	0.330	0.330	1.330	0.330	0.665	0.330	1.000	0.665	0.66
X-40 kR	1.000	0.665	0.665	0.665	0.665	0.330	0.665	2.000	0.330	0.330	0.73
ϒ-10 kR	0.665	0.665	0.330	0.665	0.330	0.330	0.665	0.665	0.330	0.665	0.53
ϒ-20 kR	0.665	1.000	0.665	0.330	1.330	0.330	0.330	0.665	0.665	1.000	0.70
ϒ-30 kR	0.330	0.665	0.330	0.665	0.330	0.665	0.330	1.000	0.665	0.830	0.58
ϒ-40 kR	1.330	1.000	0.330	1.000	0.665	0.330	0.665	0.665	0.665	1.330	0.80
EMS 0.5%	1.330	1.000	0.000	0.665	1.000	0.665	0.330	0.665	0.330	0.330	0.66
EMS 1.0%	0.665	0.665	1.000	0.330	0.665	0.330	0.330	1.000	0.665	0.330	0.60
EMS 1.5%	0.665	0.330	1.000	0.665	1.000	0.330	0.330	0.330	0.665	0.330	0.56
EMS 2.0%	0.330	0.665	0.330	0.330	1.000	0.665	1.000	0.330	0.330	0.665	0.56
Control											0.58

population variance was increased for most of the treatments in both varieties. Highest variance was observed for 10 kR X-ray followed by 10 kR, 30 kR and 40 kR gamma rays in T-9. On the other hand, for B-76, highest variance was observed for 10 kR X-ray followed by 40 kR gamma ray and X-ray and 20 kR gamma ray. Thus, highest variance () was observed in general for lower doses of physical mutagens. When inter-family variances were tested against intra family variances (Table 20) for each treatment, they were significant for lower dose of both physical and chemical mutagens in B-76, while in T-9 they were significant at all doses of X-ray suggesting differential response of genotypes to mutagenic treatments.

In lower doses of physical mutagen treatments in many cases no significant change in mean was recorded though significant inter- and intra family variances were observed under these treatments. This may be due to the generation of variability in either directions in equal frequencies. Similar conclusion was also arrived at by Bhadra (1982) in black gram.

Pods per cluster.

Means.

Means of different families of different treatments of the two varieties are presented in Table 29. From the analysis of variance (Table 15) it was found that, treatment and variety x treatment was significant indicating significant difference

between the effects of different mutagenic treatments. Further, different mutagenic treatments induced different magnitude of effects for different families. Thus, in both T-9 and B-76 many families showed increase in number of pods per cluster following 10 kR and 20 kR of X-ray and gamma ray treatments while, others produced decreased number of pods per cluster. The 't' tests of family means (Table 30) confirm this and many families in either T-9 or B-76 showed significant increase or decrease or no shift in mean following mutagen treatments. In general, lower doses of X-ray and gamma ray induced significant shift. From the grouping of mean values (Table 17) it was observed that the shifting of the family means towards positive direction was less as compared to families shifted towards negative direction. 20.0% families of T-9 and 20.83% families of B-76 were shifted significantly towards positive direction and 37.5% families of T-9 and 30.0% families of B-76 were shifted towards negative direction as compared to controls.

Variance.

Within families variances, between families variances and population variances for each family of each treatment were calculated and are presented in Tables 31 and 32. The variance was increased for all the treatments as compared to the controls for both the varieties particularly for lower doses of physical mutagens. Test of heterogeneity of variances of different families (Table 20) indicates that, in general the families of the lower doses of both physical and chemical mutagens were significantly heterogeneous for both the varieties.

Table 29. Family means of pods per cluster in M_2 for T-9 and B-76

T-9

Family

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	3.05	2.61	2.50	2.16	1.78	2.33	2.33	2.50	2.83	2.50	2.46
X-20 kR	2.83	3.16	2.50	1.67	2.00	2.16	2.00	1.83	2.16	2.50	2.28
X-30 kR	2.61	2.05	2.66	2.55	2.22	2.33	1.67	2.55	1.83	2.11	2.26
X-40 kR	2.00	2.00	2.22	2.38	2.50	2.00	2.50	1.83	1.61	2.00	2.10
γ-10 kR	2.83	2.16	2.50	2.22	2.38	1.83	2.66	2.33	2.89	2.67	2.45
γ-20 kR	2.66	2.83	2.67	1.89	2.89	2.72	2.16	2.00	2.83	2.89	2.56
γ-30 kR	1.83	1.88	2.16	2.05	1.94	1.55	1.89	1.67	1.72	1.67	1.84
γ-40 kR	2.16	2.16	2.11	1.72	1.61	2.05	2.16	1.94	1.50	2.16	1.96
EMS 0.5%	2.22	1.89	1.89	2.89	2.67	2.83	2.50	1.89	2.05	2.38	2.32
EMS 1.0%	2.22	1.89	2.00	1.55	1.89	2.50	2.16	2.55	2.89	2.50	2.22
EMS 1.5%	1.89	1.67	1.55	1.89	2.55	1.72	1.55	1.38	1.72	1.89	1.78
EMS 2.0%	2.11	1.33	1.55	1.38	1.67	1.94	2.22	1.83	1.89	2.94	1.79
Control											2.28

contd.

Table 29. contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	3.05	2.38	1.89	1.83	2.50	2.89	3.16	2.22	2.05	2.78	2.48
X-20 kR	2.22	1.89	1.72	2.50	2.83	1.67	1.89	2.27	2.16	1.67	2.08
X-30 kR	2.55	2.16	2.16	2.33	2.39	2.16	2.05	1.72	1.44	2.11	2.11
X-40 kR	1.55	1.89	2.00	2.22	2.00	2.16	1.83	2.00	2.50	2.33	2.05
γ-10 kR	2.67	2.89	3.22	2.16	2.00	1.83	2.55	2.83	2.50	1.89	2.45
γ-20 kR	2.22	2.16	2.05	2.00	1.55	1.72	2.05	2.72	2.33	2.05	2.09
γ-30 kR	2.00	2.22	1.55	1.72	1.83	1.89	2.16	2.22	1.49	1.89	1.89
γ-40 kR	1.83	1.89	1.89	2.22	1.49	1.83	2.50	2.00	1.77	1.83	1.93
EMS 0.5%	1.83	2.22	2.17	1.72	2.00	2.16	1.50	2.16	1.67	2.00	1.94
EMS 1.0%	2.00	2.83	1.89	2.50	2.33	2.50	1.72	1.39	2.22	2.00	2.14
EMS 1.5%	2.16	2.39	2.39	1.67	2.38	1.83	2.22	2.55	2.50	2.22	2.23
EMS 2.0%	2.55	2.00	1.67	1.94	1.55	1.94	1.83	2.66	2.50	1.89	2.06
Control											2.15

Table 30. t-values of family means for pods per cluster in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	5.18**	2.28*	1.57	-0.81	-3.80**	0.37	0.36	1.48	-3.60**	1.40
X-20 kR	3.92**	6.47**	1.48	-3.99**	-1.95	-0.74	-1.69	-3.21**	-0.81	1.62
X-30 kR	2.28*	-1.75	2.35*	1.99*	-0.42	0.32	-4.35**	1.82	-3.21**	-1.08
X-40 kR	-1.83	-2.06*	-0.42	0.74	1.48	-1.94	1.52	-3.21**	-4.93**	-2.06*
♂-10 kR	3.60**	-0.81	1.57	-0.40	0.69	-3.03**	2.48*	0.36	4.49	2.78**
♂-20 kR	2.71**	3.70**	2.70**	-2.87**	3.68**	3.05**	-0.86	-1.78	3.41**	4.10**
♂-30 kR	3.21**	-2.61**	-0.81	-1.64	-2.58**	-5.05**	-2.87**	-4.35**	-3.99**	-4.22**
♂-40 kR	-0.86	-0.86	-1.18	-3.88**	-4.78**	-1.75	-0.86	-2.22*	-5.56**	-0.81
EMS 0.5%	-0.43	-2.55*	-2.87**	4.49**	2.70**	3.92**	1.57	-2.87**	-1.55	0.71
EMS 1.0%	-0.44	-2.78**	-1.78	-5.05**	-2.78**	1.57	-0.86	1.82	4.10**	1.57
EMS 1.5%	-2.87**	-3.99**	-4.52**	-2.62**	1.87	-3.99**	-5.21**	-6.62**	-3.88**	-2.55*
EMS 2.0%	-1.21	-6.99**	-5.05**	-6.62**	-4.35**	-2.58**	-0.40	-3.21**	-2.78**	4.31**

contd.

Table 30. contd.

B - 76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	6.23**	1.80	-1.97*	-2.28*	2.66*	6.12**	5.94**	0.55	-0.73	4.78**
X-20 kR	-0.53	-1.97*	-3.26**	2.66**	5.16**	-3.32**	-2.04*	0.86	0.08	-3.53**
X-30 kR	2.85**	0.08	0.08	1.18	1.66	0.08	-0.81	-3.26**	-5.57**	-0.30
X-40 kR	4.41**	-1.85	-1.04	-0.57	-1.07	0.08	-2.28*	-1.22	2.66**	1.25
γ- 10 kR	3.82**	5.44**	8.39**	0.08	-1.04	-2.43*	2.94**	4.00**	2.23*	-2.04*
γ- 20 kR	0.47	0.08	-0.71	-1.10	-4.55**	-3.26**	-0.81	4.55**	1.37	-0.76
γ- 30 kR	-1.10	0.52	-4.41**	-3.26**	-2.28*	-1.80	0.08	0.57	-5.18**	-1.97*
γ-40 kR	-2.43*	-1.80	-1.85	0.53	-5.01**	-2.21*	2.42*	-1.10	-2.88**	-2.43*
EMS 0.5%	-2.28*	0.57	0.14	-3.26**	-1.22	0.08	-4.93**	0.08	-3.32**	-1.10
EMS 1.0%	-1.07	5.16**	-1.91*	2.66**	1.32	2.66**	-3.26**	-5.96**	0.55	-1.10
EMS 1.5%	0.07	1.71	1.76	-3.53**	1.80	-2.28*	0.57	3.14**	2.35*	0.48
EMS 2.0%	3.04**	-1.10	-3.53**	-1.54	-4.71**	-1.50	-2.60**	3.00**	2.57*	-1.80

* significant at 5%

** significant at 1%

Table 31. Population variance and interfamily variance of pods per cluster in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	0.38	0.46	0.73	1.39
X-20 kR	0.44	0.28	1.29	0.89
X-30 kR	0.38	0.22	0.70	0.62
X-40 kR	0.27	0.32	0.27	0.44
γ- 10 kR	0.29	0.41	0.65	1.32
γ- 20 kR	0.40	0.28	0.89	0.61
γ- 30 kR	0.25	0.31	0.21	0.41
γ- 40 kR	0.27	0.32	0.39	0.44
EMS 0.5%	0.27	0.26	0.92	0.37
EMS 1.0%	0.34	0.26	0.96	1.08
EMS 1.5%	0.35	0.33	0.61	0.49
EMS 2.0%	0.21	0.41	0.53	0.88
Control	0.08	0.10		

Table 32. Intra-family variances for pods per cluster in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.580	0.370	0.275	0.440	0.075	0.110	0.110	0.440	0.610	0.780	0.379
X-20 kR	0.280	0.110	0.445	0.610	0.275	0.945	0.940	0.275	0.440	0.110	0.443
X-30 kR	0.370	0.075	0.775	0.185	0.410	0.275	0.220	0.460	0.275	0.800	0.384
X-40 kR	0.445	0.150	0.335	0.185	0.555	0.275	0.315	0.275	0.075	0.110	0.272
γ-10 kR	0.095	0.445	0.220	0.350	0.350	0.445	0.445	0.220	0.130	0.275	0.297
γ-20 kR	0.150	0.445	0.445	0.130	0.240	0.355	0.205	0.610	0.890	0.520	0.399
γ-30 kR	0.275	0.185	0.555	0.130	0.075	0.350	0.130	0.220	0.185	0.385	0.249
γ-40 kR	0.260	0.220	0.205	0.185	0.205	0.075	0.280	0.595	0.220	0.485	0.273
EMS 0.5%	0.240	0.575	0.130	0.130	0.445	0.220	0.220	0.130	0.350	0.295	0.273
EMS 1.0%	0.185	0.295	0.610	0.350	0.240	0.260	0.220	0.515	0.520	0.275	0.347
EMS 1.5%	0.130	0.610	0.350	0.575	0.295	0.185	0.295	0.185	0.355	0.575	0.355
EMS 2.0%	0.185	0.110	0.350	0.185	0.220	0.075	0.240	0.275	0.240	0.260	0.214
Control											0.08

contd.

Table 32 contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.580	0.185	0.185	0.445	0.220	0.630	1.440	0.185	0.410	0.315	0.459
X-20 kR	0.185	0.240	0.295	0.220	0.220	0.610	0.130	0.485	0.110	0.385	0.288
X-30 kR	0.520	0.110	0.220	0.275	0.130	0.220	0.075	0.295	0.205	0.185	0.223
X-40 kR	0.350	0.465	0.445	0.075	0.385	0.280	0.445	0.040	0.275	0.445	0.320
γ-10 kR	0.385	0.410	0.185	0.220	0.445	0.275	0.075	1.055	0.940	0.130	0.412
γ-20 kR	0.740	0.110	0.410	0.275	0.295	0.185	0.075	0.295	0.220	0.205	0.281
γ-30 kR	0.275	0.410	0.350	0.295	0.445	0.575	0.220	0.075	0.205	0.275	0.312
γ-40 kR	0.275	0.575	0.465	0.185	0.220	0.220	0.555	0.275	0.095	0.275	0.314
EMS 0.5%	0.445	0.075	0.275	0.295	0.040	0.110	0.275	0.220	0.610	0.275	0.262
EMS 1.0%	0.555	0.275	0.295	0.220	0.220	0.220	0.295	0.130	0.185	0.275	0.267
EMS 1.5%	0.430	0.295	0.240	0.440	0.185	0.445	0.075	0.075	0.450	0.630	0.326
EMS 2.0%	0.295	0.445	0.555	0.370	0.520	0.295	0.610	0.110	0.385	0.575	0.416
Control											0.10

Pod length.

Mean.

The family means of all the treatments of the two varieties are presented in Table 33. As indicated by the analysis of variance of the family means, the variety, treatment and variety x treatment was significant showing significantly different effect of treatments and real difference between the two varieties (Table 15). Different treatments also induced different magnitude of effects for different families as indicated from the 't'-tests (Table 34). The grouping of the families for each treatment (Table 17) showed that, majority of the families were shifted towards negative direction and only a small portion of the total families was shifted towards positive direction significantly. However, the two varieties responded some what differentially for this character. 12.5% families of T-9 and only 5% families of B-76 were shifted towards positive direction whereas, 58.33% families of T-9 and 53.33% of B-76 were shifted towards negative direction. In general, lower doses of physical mutagens caused positive shifting of means for both the genotypes.

Variance.

Within and between families variances and population variances for each treatment are presented in Tables 35 and 36. The population variance was increased for almost all the treatments in both the varieties as compared to controls indicating

Table 33. Family means of pod length in M_2 for T-9 and B-76

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	3.96	4.13	3.59	3.44	3.74	3.85	3.88	4.00	4.28	4.23	3.91
X-20 kR	4.31	4.37	4.03	3.22	3.80	3.63	3.67	3.49	3.50	3.67	3.77
X-30 kR	3.63	3.24	3.78	3.56	3.61	3.20	3.86	3.79	2.99	3.15	3.48
X-40 kR	3.14	3.29	3.33	3.53	2.95	2.88	2.90	3.06	3.63	3.02	3.17
♂-10 kR	4.16	3.92	4.29	4.55	4.10	3.59	4.39	3.84	4.15	3.81	4.08
♂-20 kR	4.16	4.33	4.60	4.36	4.30	4.10	3.73	3.90	4.47	3.99	4.20
♂-30 kR	3.78	3.70	3.71	3.52	3.77	2.91	2.85	3.59	3.75	3.52	3.51
♂-40 kR	2.93	3.93	2.54	3.36	3.32	3.31	3.91	3.53	3.30	3.29	3.34
EMS 0.5%	3.70	3.72	3.38	3.64	3.77	3.78	3.55	3.42	3.89	3.87	3.67
EMS 1.0%	3.87	3.66	3.66	2.96	3.45	3.51	3.52	3.45	3.74	3.68	3.55
EMS 1.5%	2.67	2.52	2.87	3.67	2.98	2.53	2.98	3.22	3.27	3.23	3.00
EMS 2.0%	3.34	3.31	2.88	2.78	3.36	3.41	2.95	2.70	2.69	2.79	3.02
Control											3.99

contd.

Table 33. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	3.77	3.69	3.44	3.57	3.62	3.59	3.78	3.77	3.57	3.45	3.63
X-20 kR	3.75	3.62	4.12	4.12	4.10	4.05	4.01	3.66	3.76	3.96	3.92
X-30 kR	3.56	3.74	3.68	3.17	3.53	3.56	3.15	3.27	3.26	3.24	3.42
X-40 kR	3.22	3.54	2.93	3.66	3.83	2.70	2.98	3.69	2.82	2.90	3.23
γ - 10 kR	4.19	3.82	3.92	3.41	3.33	3.65	3.29	3.05	3.93	3.43	3.60
γ - 20 kR	3.67	4.02	4.18	3.47	3.80	3.53	4.12	3.52	3.19	3.40	3.69
γ - 30 kR	3.36	3.13	3.25	3.79	3.83	3.40	3.49	3.40	3.51	3.50	3.47
γ - 40 kR	2.88	3.08	3.43	3.20	3.69	3.49	2.93	3.14	3.35	3.26	3.25
EMS 0.5%	3.71	3.39	3.43	3.96	3.60	3.49	3.54	3.18	3.13	3.66	3.51
EMS 1.0%	3.11	3.11	3.89	3.71	4.16	3.78	3.76	3.31	3.69	3.85	3.64
EMS 1.5%	3.68	3.53	3.06	3.50	3.85	3.65	4.08	3.58	3.26	3.18	3.54
EMS 2.0%	3.28	3.71	2.75	3.62	2.66	2.84	3.40	2.79	2.68	3.19	3.09
Control											3.83

Table 34. t-values of family means for pod length in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	-0.26	1.22	-3.49**	-4.79**	-2.26*	-1.22	-0.97	0.09	2.53*	2.12*
X-20 kR	2.75**	3.31**	0.35	-6.76**	-1.69	-3.17**	-2.79**	-4.31**	-4.27**	-2.81**
X-30 kR	-3.18**	-6.42**	-1.85	-3.75**	-3.36**	-6.89**	-1.12	-1.75	-8.50**	-6.94**
X-40 kR	-7.14**	-5.90**	-5.49**	-3.44*	-8.93**	-8.71**	-9.00**	-6.90**	-3.16**	-8.33**
γ-10 kR	1.47	-0.60	2.62**	4.97**	0.97	-3.49**	3.47**	-1.27	1.39	-1.59
γ-20 kR	1.47	2.92**	5.30**	3.21**	2.62**	0.94	-2.28*	-0.79	4.09**	0.04
γ-30 kR	-1.78	-2.56*	-2.48*	-4.10**	-1.90	-9.34**	-10.01**	-3.47**	-2.04*	-3.98**
γ-40 kR	-9.04**	-0.52	-12.73**	-5.53**	-5.80**	-5.95**	-0.67	-4.07**	-5.84**	-6.12**
EMS 0.5%	-2.55*	-2.35*	-5.20**	-3.08**	-1.92	-1.77	-3.85**	-4.90**	-0.86	-1.05
EMS 1.0%	-1.03	-2.86**	-2.89**	-9.01**	-4.62**	-4.11**	-4.14**	-4.62**	-2.20*	-2.66**
EMS 1.5%	-11.46**	-11.65**	-9.48**	-2.78**	-8.84**	-12.92**	-8.58**	-6.08**	-6.32**	-6.48**
EMS 2.0%	-5.64**	-5.73**	-9.60**	-10.67*	-5.18**	-4.95**	-8.77**	-11.33**	-11.42**	-10.46**

contd.

Table 34. contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	-0.43	-0.99	-2.80**	-1.85	-1.42	-1.71	-0.35	-0.43	-1.82	-2.57*
X-20 kR	-0.57	-1.51	2.09*	2.07*	1.91	1.57	1.25	-1.22	-0.50	0.93
X-30 kR	-1.93	-0.64	-1.06	-4.54**	-2.13*	-1.94	-4.75**	-4.02**	-3.92**	-4.21**
X-40 kR	-4.21**	-2.09*	-6.34**	-1.22	0.04	-8.11**	-5.95**	-0.98	-7.01**	-6.59**
γ-10 kR	2.52*	-0.07	0.65	-3.00**	-3.42**	-1.25	-3.76**	-5.50**	0.71	-2.87**
γ-20 kR	-1.14	1.37	2.44*	-2.48*	-0.21	-2.15*	2.02*	-2.18*	-4.54**	-2.94**
γ-30 kR	-3.35**	-5.01**	-4.12**	-0.28	-0.03	-3.06**	-2.44*	-2.92**	-2.24*	-2.35*
γ-40 kR	-6.73**	-5.25**	-2.86**	-4.27**	-1.01	-2.42*	-6.05**	-4.73**	-3.32**	-3.85**
EMS 0.5%	-0.86	-3.15**	-2.86**	0.92	-1.62	-2.42*	-2.09*	-4.55**	-1.99**	-1.21
EMS 1.0%	-5.12**	-5.15**	0.43	-0.85	2.38*	-0.35	-0.50	-3.70**	-1.00	0.14
EMS 1.5%	-1.08	-2.09*	-5.49**	-2.30*	0.14	-1.25	1.80	-1.74	-4.04**	-4.57**
EMS 2.0%	-3.78**	-0.85	-7.68**	-1.42	-8.37**	-6.77**	-3.05**	-7.31**	-8.18**	-4.52**

* Significant at 5%

** Significant at 1%

Table 35. Population variance and interfamily variance of pod length in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	0.032	0.066	0.44	0.09
X-20 kR	0.053	0.054	0.81	0.23
X-30 kR	0.067	0.088	0.57	0.29
X-40 kR	0.109	0.068	0.41	1.04
γ - 10 kR	0.056	0.080	0.51	0.76
γ - 20 kR	0.057	0.074	0.43	0.66
γ - 30 kR	0.055	0.057	0.72	0.28
γ - 40 kR	0.062	0.101	1.02	0.38
EMS 0.5%	0.064	0.062	0.18	0.37
EMS 1.0%	0.063	0.052	0.37	0.73
EMS 1.5%	0.075	0.063	0.80	0.57
EMS 2.0%	0.060	0.083	0.53	0.95
Control	0.037	0.057		

Table 36. Intra-family variances for pod length in M_2

T-9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.023	0.040	0.045	0.033	0.023	0.015	0.030	0.045	0.050	0.015	0.032
X-20 kR	0.045	0.077	0.060	0.050	0.004	0.040	0.070	0.070	0.075	0.045	0.053
X-30 kR	0.020	0.032	0.040	0.057	0.019	0.020	0.075	0.045	0.140	0.230	0.068
X-40 kR	0.170	0.027	0.074	0.225	0.025	0.250	0.055	0.155	0.055	0.060	0.109
γ - 10 kR	0.080	0.095	0.060	0.019	0.030	0.045	0.033	0.125	0.050	0.022	0.056
γ - 20 kR	0.060	0.075	0.070	0.030	0.095	0.085	0.045	0.025	0.040	0.050	0.057
γ - 30 kR	0.050	0.035	0.030	0.065	0.050	0.060	0.048	0.080	0.045	0.090	0.055
γ - 40 kR	0.095	0.040	0.045	0.050	0.085	0.040	0.145	0.025	0.040	0.060	0.062
EMS 0.5%	0.050	0.070	0.090	0.020	0.060	0.075	0.065	0.105	0.055	0.055	0.064
EMS 1.0%	0.085	0.060	0.045	0.057	0.075	0.050	0.040	0.105	0.035	0.080	0.063
EMS 1.5%	0.045	0.040	0.070	0.070	0.035	0.024	0.050	0.360	0.050	0.006	0.075
EMS 2.0%	0.060	0.065	0.075	0.035	0.120	0.112	0.050	0.017	0.030	0.040	0.060
Control											0.037

contd.

Table 36. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.060	0.085	0.033	0.065	0.080	0.055	0.055	0.085	0.075	0.065	0.066
X-20 kR	0.040	0.020	0.025	0.065	0.094	0.060	0.125	0.006	0.060	0.045	0.054
X-30 kR	0.045	0.055	0.085	0.220	0.085	0.027	0.135	0.035	0.145	0.055	0.089
X-40 kR	0.135	0.030	0.100	0.035	0.025	0.040	0.080	0.115	0.065	0.060	0.068
γ - 10 kR	0.115	0.035	0.026	0.052	0.245	0.145	0.055	0.045	0.065	0.019	0.080
γ - 20 kR	0.042	0.006	0.135	0.120	0.035	0.043	0.150	0.073	0.070	0.065	0.074
γ - 30 kR	0.065	0.035	0.085	0.035	0.075	0.055	0.040	0.065	0.040	0.065	0.057
γ - 40 kR	0.060	0.040	0.035	0.270	0.017	0.075	0.085	0.075	0.155	0.205	0.102
EMS 0.5%	0.045	0.029	0.055	0.080	0.110	0.045	0.031	0.135	0.050	0.045	0.062
EMS 1.0%	0.060	0.042	0.025	0.100	0.025	0.040	0.060	0.080	0.040	0.055	0.053
EMS 1.5%	0.035	0.014	0.060	0.045	0.030	0.085	0.030	0.160	0.080	0.092	0.063
EMS 2.0%	0.140	0.095	0.055	0.050	0.032	0.255	0.035	0.045	0.040	0.080	0.083
Control											0.057

release of variability by most of the treatments. The inter family variances were tested against within families variances (Table 20) for each treatment and they were significant for all the treatments except 10 kR X-ray in B-76, indicating heterogeneity of variances of different families.

Contrary to the present observations Rajput (1974) observed unchanged mean for pod length in green gram though the coefficient of variability was increased significantly. On the other hand, Khan (1983) observed shifting of mean in the positive direction for pod length in green gram.

Seeds per pod.

Mean.

The means of different families of different treatments of the two varieties are presented in Table 37. Analysis of variance (Table 15) showed that variety, treatment and variety x treatment interaction was significant indicating significant difference between the two varieties and also between the different treatments. Different mutagenic treatments induced different magnitude of effects to different families thereby changing the family means either towards positive or towards negative direction as indicated from 't'-tests (Table 38). Based on 't'-test, the family means were grouped into three categories viz., increased means, reduced means and unchanged means (Table 17). Majority of the family means were changed either towards

Table 37. Family means of seeds per pod in M_2 for T-9 and B-76

T-9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	4.62	5.37	3.87	3.41	4.08	4.37	5.08	4.66	6.00	5.00	4.65
X-20 kR	5.41	4.79	4.75	3.29	4.37	4.41	4.00	3.58	3.50	4.42	4.25
X-30 kR	4.29	3.46	3.66	3.75	4.41	4.16	3.37	3.50	3.71	3.21	3.75
X-40 kR	3.62	3.58	3.66	3.08	4.16	3.16	3.29	3.87	3.54	3.33	3.53
γ - 10 kR	5.16	4.54	4.91	5.70	3.75	5.20	4.47	4.54	4.79	5.16	4.82
γ - 20 kR	4.37	4.79	5.37	5.54	5.37	4.25	4.58	3.87	4.75	5.29	4.82
γ - 30 kR	4.41	4.21	4.92	3.83	4.54	3.08	3.00	3.62	3.91	3.41	3.90
γ - 40 kR	3.29	4.66	2.79	3.79	3.87	3.87	4.70	3.96	3.70	3.54	3.94
EMS 0.5%	4.54	4.87	4.58	4.12	3.83	3.58	4.75	4.45	3.87	3.92	4.25
EMS 1.0%	5.46	4.21	3.37	4.29	3.62	3.83	3.62	3.25	3.91	3.29	3.89
EMS 1.5%	3.62	3.50	3.70	3.66	2.70	2.91	2.62	3.12	3.62	3.75	3.32
EMS 2.0%	3.41	3.21	3.16	2.62	3.66	3.08	3.58	2.66	3.41	3.04	3.12
Control											4.11

contd.

Table 37. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	4.87	4.66	3.91	3.75	4.66	5.25	4.25	4.25	5.04	5.29	4.59
X-20 kR	3.75	3.87	4.62	4.87	4.41	4.37	3.91	4.91	4.25	3.62	4.26
X-30 kR	3.87	3.50	3.50	4.33	3.91	4.25	3.54	3.04	3.29	3.50	3.67
X-40 kR	3.41	2.87	3.41	3.87	3.75	3.12	2.75	4.12	2.66	2.87	3.29
γ - 10 kR	4.41	4.54	4.04	4.37	3.83	3.62	4.00	4.04	4.41	3.62	4.09
γ - 20 kR	3.75	3.62	4.08	3.91	4.58	4.41	4.04	3.87	4.12	3.25	3.97
γ - 30 kR	3.54	3.58	3.83	3.33	3.87	3.87	5.25	5.29	3.66	3.37	3.96
γ - 40 kR	3.16	3.95	4.08	3.50	3.50	3.75	3.87	3.67	3.04	3.37	3.59
EMS 0.5%	4.25	3.54	4.37	3.41	3.91	3.29	4.50	4.62	3.37	3.54	3.88
EMS 1.0%	4.62	4.37	3.87	3.75	4.25	3.91	3.50	4.25	3.37	3.66	3.96
EMS 1.5%	3.79	3.29	3.62	3.87	4.12	4.62	4.12	3.95	3.58	3.58	3.86
EMS 2.0%	4.12	3.50	2.87	3.58	4.29	3.00	2.70	3.79	3.87	3.41	3.52
Control											4.13

Table 38. t-values of family means for seeds per pod in M_2

T-9

Family

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	4.14**	9.88**	-1.95	-5.68**	-0.24	8.63**	7.93**	4.45**	15.08**	6.78**
X-20 kR	9.90**	9.08**	4.92**	-6.59**	2.08*	2.45*	-0.88	-4.36**	- 4.74**	2.39*
X-30 kR	8.44**	-5.37**	-3.50**	-2.87**	2.44*	0.40	-6.03**	-4.77**	-3.18**	-7.35**
X-40 kR	-3.92**	-4.16**	-3.60**	-8.56**	0.41	-7.82**	-0.65	-1.95	-4.61**	-6.18**
γ - 10 kR	8.64**	3.48**	6.40**	12.64**	-2.80**	9.00**	2.35*	3.48**	5.16**	8.49**
γ - 20 kR	2.08*	4.08**	9.10**	11.37**	10.26**	1.12	3.80**	-1.93	5.11**	9.38**
γ - 30 kR	2.35*	0.72	6.35**	- 2.26*	3.55**	-8.57**	-8.68**	-3.99**	-1.60	-5.70**
γ - 40 kR	-6.39**	4.36**	-10.12**	- 2.49*	-1.94	-1.89	4.75**	-1.19	-3.14**	-4.71**
EMS 0.5%	3.42**	6.08**	3.34**	0.08	-2.17*	-4.29**	5.10**	2.75**	-1.90	-1.54
EMS 1.0%	10.52**	0.82	- 6.15**	1.43	-3.99**	-2.28*	-3.99**	-6.93**	-1.60	-6.45**
EMS 1.5%	- 3.99**	-4.95**	- 3.14**	-3.63**	-10.99**	-9.87**	-12.13**	-7.92**	-3.78**	-2.87**
EMS 2.0%	- 5.76**	-6.83**	- 7.82**	-11.85**	- 3.38**	-8.08**	- 3.77**	-11.26**	-5.67**	-8.65**

contd.

Table 38. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	5.34**	3.84**	-1.56	2.64**	3.75**	8.13**	0.85	0.85	6.43**	8.03**
X-20 kR	-2.69**	-1.88	3.48**	5.34**	2.03*	1.72	-1.54	5.14**	0.83	-3.19**
X-30 kR	-1.88	-4.47**	-4.51**	1.43	-1.55	0.83	-4.14**	-7.82**	-6.12**	-4.58**
X-40 kR	-5.23**	-9.10**	-5.15**	-1.85	-2.76**	-6.97**	-9.58**	-0.07	-10.45**	-9.10**
γ - 10 kR	1.89	2.99**	-0.66	1.71	-2.15**	-3.68**	-0.92	-0.64	2.03*	-3.68**
γ - 20 kR	-2.69**	-3.68**	-0.35	-1.53	3.22**	1.99*	-0.63	-1.88	-0.07	-6.24**
γ - 30 kR	-4.23**	-3.82**	-2.15*	-5.64**	-1.88	-1.88	7.78**	8.45**	-3.34**	-5.49**
γ - 40 kR	-6.83**	-1.29	-0.35	-4.28**	-4.34**	-2.64**	-1.85	-3.16**	-7.44**	-5.17**
EMS 0.5%	0.86	-4.21**	1.69	-5.23**	-1.56	-5.94**	2.62**	3.54**	-5.49**	-4.21**
EMS 1.0%	3.54**	1.73	-1.83	-2.73**	0.83	-1.56	-4.60**	0.85	-5.30**	-3.39**
EMS 1.5%	-2.48**	-5.99**	-3.63**	-1.88	-0.07	3.48**	-0.07	-1.25	-3.85**	-3.97**
EMS 2.0%	-0.07	-4.47**	-9.10**	-3.97**	1.16	-8.01**	-10.26**	-2.48*	-1.88	-5.20**

* Significant at 5%

** Significant at 1%

Table 39. Population variance and inter family variance of seeds per pod in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	0.101	0.091	3.47	1.74
X-20 kR	0.115	0.143	2.63	1.27
X-30 kR	0.092	0.106	0.99	1.01
X-40 kR	0.085	0.088	0.65	1.56
γ - 10 kR	0.101	0.085	0.75	0.67
γ - 20 kR	0.098	0.120	1.89	0.87
γ - 30 kR	0.102	0.110	2.41	3.08
γ - 40 kR	0.135	0.184	1.96	0.69
EMS 0.5%	0.114	0.094	1.18	1.58
EMS 1.0%	0.082	0.104	2.61	0.98
EMS 1.5%	0.066	0.144	1.16	0.84
EMS 2.0%	0.135	0.060	0.74	1.69
Control	0.04	0.066		

Table 40. Intra-family variances for seeds per pod in M_2

T-9

Treatment	Family										Mean
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	
X-10 kR	0.060	0.155	0.085	0.040	0.135	0.150	0.070	0.105	0.060	0.150	0.101
X-20 kR	0.105	0.105	0.115	0.115	0.125	0.070	0.150	0.040	0.155	0.175	0.115
X-30 kR	0.105	0.040	0.200	0.155	0.040	0.070	0.085	0.050	0.105	0.070	0.092
X-40 kR	0.085	0.200	0.105	0.020	0.040	0.040	0.175	0.060	0.040	0.085	0.085
ɣ - 10 kR	0.040	0.105	0.105	0.150	0.250	0.020	0.040	0.040	0.195	0.070	0.101
ɣ - 20 kR	0.150	0.040	0.085	0.170	0.060	0.060	0.105	0.050	0.155	0.105	0.098
ɣ - 30 kR	0.195	0.195	0.210	0.105	0.040	0.020	0.050	0.060	0.105	0.040	0.102
ɣ - 40 kR	0.165	0.165	0.085	0.165	0.105	0.070	0.115	0.165	0.275	0.040	0.135
EMS 0.5%	0.040	0.145	0.325	0.060	0.150	0.105	0.060	0.085	0.155	0.020	0.114
EMS 1.0%	0.105	0.070	0.020	0.105	0.060	0.040	0.060	0.125	0.105	0.135	0.082
EMS 1.5%	0.060	0.085	0.085	0.105	0.020	0.040	0.060	0.085	0.060	0.060	0.066
EMS 2.0%	0.040	0.320	0.040	0.060	0.105	0.115	0.325	0.200	0.040	0.105	0.135
Control											0.04

contd.

Table 40 contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.060	0.040	0.105	0.155	0.135	0.060	0.060	0.060	0.040	0.200	0.091
X-20 kR	0.060	0.085	0.085	0.060	0.040	0.115	0.200	0.480	0.155	0.155	0.143
X-30 kR	0.060	0.155	0.155	0.105	0.105	0.085	0.200	0.105	0.040	0.060	0.106
X-40 kR	0.040	0.060	0.105	0.085	0.060	0.060	0.155	0.155	0.105	0.060	0.088
γ-10 kR	0.105	0.040	0.040	0.085	0.105	0.060	0.105	0.165	0.040	0.060	0.080
γ-20 kR	0.060	0.060	0.200	0.195	0.105	0.105	0.200	0.060	0.155	0.060	0.120
γ-30 kR	0.105	0.150	0.105	0.165	0.155	0.060	0.155	0.040	0.105	0.060	0.110
γ-40 kR	0.135	0.085	0.165	0.250	0.115	0.155	0.125	0.210	0.325	0.275	0.184
EMS 0.5%	0.085	0.135	0.155	0.040	0.105	0.105	0.060	0.060	0.060	0.135	0.094
EMS 1.0%	0.085	0.060	0.155	0.085	0.155	0.105	0.020	0.155	0.155	0.070	0.104
EMS 1.5%	0.040	0.135	0.085	0.085	0.060	0.085	0.155	0.210	0.200	0.085	0.114
EMS 2.0%	0.060	0.060	0.060	0.070	0.070	0.060	0.085	0.040	0.060	0.040	0.060
Control											0.066

positive or towards negative direction. 35.83% families of T-9 and 16.67% families of B-76 were shifted towards positive direction. On the other hand, 47.50% families of T-9 and 46.67% families of B-76 were shifted towards negative direction. Thus, more families from both the varieties were shifted towards negative direction than those shifted towards positive direction. The number of families shifted towards desirable direction was more in T-9 than in B-76, and in general, lower doses of treatments caused positive shifting of means and negative shifting was resulted from higher doses of treatments in both the varieties.

Similar observations were made by Lawrence (1975) in Arabidopsis thaliana (Heyn.) and Rajput (1974) in green gram when the mean for seeds per pod was shifted in either direction due to mutagenic treatments. Reduction in seeds per pod was reported in french bean by Sarafi et al. (1974). On the other hand, Khan (1983) in green gram observed an increase in mean due to treatment with gamma rays.

Variance.

The within families variance, population variance of each treatment and inter family variances of each treatment are presented in Tables 39 and 40. The population variance was increased for all the treatments of both the varieties except 2.0% EMS where, the same was decreased as compared to the controls in both the varieties. The inter family variances were tested against intra families variances and it was found that they were significant for all the treatments in both the varieties indicating heterogeneity of variances of the families (Table 20).

Pods per plant.

Mean.

The means of all the families of all treatments for two black gram genotypes are presented in Table 41. There was real difference between the two varieties and also between the different mutagenic treatments as indicated from the analysis of variance (Table 15). The family means were shifted mostly towards negative direction, particularly for B-76 as indicated by 't'-tests (Table 42). Based on 't'-test, the families were grouped into three categories viz., increased means, reduced means and similar means to that of the controls (Table 17). 75.00% families of T-9 and 86.67% families of B-76 exhibited reduced means whereas, only 14.17% families of T-9 and 0.83% families of B-76 showed shifting of the means in the positive direction. Only lower doses of physical mutagens (10 and 20 kR of X- and gamma) induced some significant effects in T-9. In B-76, only a single family from 20 kR gamma ray was found significantly exceeded the respective control. In general, number of pods per plant was reduced by all EMS treatments and higher doses of physical mutagens as well.

Variance.

The within (intra) and between (inter) families variances and population variances for each treatments are presented in Tables 43 and 44. To test the heterogeneity of variances of different families of each treatment, the inter family variances were tested against intra families variances and the results are shown in Table 20. Except 1.5% and 2.0% EMS in B-76, the families of all other treatments in both the genotypes were highly heterogeneous.

Our present investigations find support from similar works of some earlier authors e.g., Borojevic and Borojevic (1969) in

wheat, [redacted] Narasinghani and Kumar (1976) in cow pea, Rathinam (1983) in ground nut and Natarajan et al. (1983) in red gram where they also observed reduction in mean pod number. On the contrary, Nong et al. (1979) in soyabean, Vardanyan (1979) in french bean, vasileva (1975) in pea, Thakare et al. (1980) and Khan (1984) in green gram and Kundu and singh (1982) in black gram reported increased mean for pods per plant. However, shifting in mean for pods per plant in both the directions was reported in french bean by Mujeeb and Greig (1973), in green gram by Rajput (1974) and in black gram by Singh et al. (1979).

Seeds per plant.

Mean.

Mean of all the families of each treatment for two black gram varieties are presented in Table 45. Real difference between the two varieties and also between different treatments were observed from the analysis of variance (Table 15) where, variety, treatment and variety x treatment interactions were highly significant. From 't'-tests (Table 46) of the family means it was found that, most of the mutagenic treatments resulted reduced number of seeds per plant. Only few family means were shifted in the desirable positive direction. Following 't'- test the families were grouped into three categories, viz., reduced means, increased means and similar means as compared to the

Table 41. Family means of pods per plant in M_2 for T-9 and B-76

T - 9

Family

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	11.33	9.50	10.17	9.16	9.50	9.16	8.67	12.66	18.33	13.66	11.22
X-20 kR	14.66	15.16	9.83	7.00	8.00	11.00	8.00	8.83	10.83	11.00	10.43
X-30 kR	10.33	8.16	11.00	9.50	10.83	7.50	7.33	12.83	8.00	7.33	9.28
X-40 kR	9.83	8.00	7.83	8.00	8.16	5.50	8.00	7.66	6.00	7.50	7.65
γ-10 kR	12.50	12.00	9.66	9.83	13.16	9.00	14.50	11.83	8.50	11.00	11.20
γ-20 kR	15.00	16.33	13.83	16.16	14.16	14.16	10.00	10.33	13.66	13.33	13.70
γ-30 kR	9.17	10.67	9.50	9.16	9.33	5.83	9.00	6.66	9.50	8.50	8.73
γ-40 kR	8.00	8.33	6.33	7.17	7.66	7.50	9.83	8.50	6.33	6.33	7.60
EMS 0.5%	8.67	7.83	8.00	9.33	6.66	7.16	5.16	6.00	6.66	8.50	7.40
EMS 1.0%	4.83	7.33	6.16	7.16	7.16	7.66	6.83	5.50	3.83	3.66	6.32
EMS 1.5%	5.16	7.16	4.50	5.00	5.50	6.00	5.16	7.33	5.50	5.50	5.68
EMS 2.0%	5.50	6.00	4.17	5.16	4.83	5.67	5.16	6.83	4.66	5.00	5.30
Control											11.00

contd.

Table 41 contd.

B - 76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	8.16	8.50	11.00	8.33	6.50	9.33	10.66	11.16	9.50	6.83	9.00
X-20 kR	8.50	9.50	6.66	6.50	8.16	9.66	7.00	5.00	4.33	5.00	7.03
X-30 kR	7.16	6.83	6.33	5.83	6.16	5.50	4.00	5.66	7.33	7.50	6.23
X-40 kR	5.33	3.50	6.00	6.66	7.00	4.83	4.17	3.66	6.50	3.83	5.15
γ -10 kR	8.16	7.66	6.16	9.16	6.33	10.17	8.67	9.17	10.16	8.00	8.37
γ -20 kR	9.00	6.66	11.33	10.33	8.00	7.50	9.66	8.50	6.83	8.33	8.62
γ -30 kR	7.50	7.33	6.33	7.00	5.16	6.83	5.33	5.50	4.16	6.50	6.17
γ -40 kR	5.16	6.00	4.33	4.00	4.66	6.33	3.16	6.00	6.33	5.16	5.12
EMS 0.5%	7.00	6.00	4.83	4.50	5.16	7.66	4.83	5.33	4.67	6.00	5.60
EMS 1.0%	4.67	10.50	6.17	6.50	3.83	4.83	6.00	6.00	5.16	4.83	5.85
EMS 1.5%	5.16	6.00	5.66	5.66	3.67	5.16	4.83	5.67	5.33	6.16	5.33
EMS 2.0%	4.67	4.33	5.33	5.66	4.83	4.00	5.00	4.66	5.16	5.83	4.95
Control											9.96

Table 42. t-values of family means for pods per plant in M_2

T-9

Treatment	Family									
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	0.66	-3.02**	-1.68	-3.64**	-2.87**	-3.55**	-4.65**	3.34**	2.99**	2.36*
X-20 kR	7.12**	7.77**	-2.35*	-7.91**	-6.09**	-	-5.79**	-4.15**	-0.33	-
X-30 kR	-1.34	-5.81**	-	-2.99**	-0.33	-7.22**	-7.38**	3.59**	-6.14**	-7.38**
X-40 kR	-2.93**	-5.98**	-6.38**	-6.09**	-4.71**	-11.06**	-5.98**	-6.66**	-8.72**	-7.04**
♂ - 10 kR	2.94**	1.77	-2.61**	-2.18*	4.20**	- 3.76	6.92**	1.53	4.23**	-
♂ - 20 kR	6.15**	2.57*	4.93**	9.95**	6.35**	5.63**	-2.03*	-1.35	4.97**	4.57**
♂ - 30 kR	-3.68**	-0.66	-2.94**	-3.58**	-3.03**	-10.49**	-4.02**	-8.24**	-2.87**	-4.94**
♂ - 40 kR	-5.93**	-5.08**	-9.01**	-7.77**	-6.55**	- 6.92**	-2.29**	-4.90**	-8.93**	-8.93**
EMS 0.5%	-4.42**	-5.92**	-5.98**	-3.17**	-8.65**	-7.53**	-11.26**	-9.97**	-8.73**	-4.26**
EMS 1.0%	-12.63**	-7.32**	-8.50**	-7.59**	-7.79**	-6.49**	- 7.43**	-10.27**	-14.06**	-8.37**
EMS 1.5%	-11.45**	-7.53**	-13.07**	-12.07**	-10.52**	-9.97**	-11.95**	-6.96**	-10.79**	-10.88*
EMS 2.0%	-11.06**	-9.89**	-13.86**	-11.45**	-12.41**	-10.63**	-11.75**	-8.11**	-12.64**	-10.94*

contd.

Table 42. contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	-2.84**	-2.40*	1.68	-2.54*	-5.82**	-0.96	1.13	1.88	0.75	-5.11**
X-20 kR	-2.12*	-0.76	-5.47**	-5.54**	-2.90**	-0.48	-4.58**	-7.89**	-9.33**	-8.11**
X-30 kR	-4.64**	-5.05**	-6.06**	-6.80**	-6.12**	-7.39**	-9.95**	-7.13**	-4.39**	-3.88**
X-40 kR	-7.67**	-10.63**	-6.61**	-5.36**	-4.34**	-8.10**	-9.73**	-10.22**	-5.73**	-10.16**
γ - 10 kR	-2.92**	-3.81**	-6.17**	-1.30	-6.16**	0.33	-2.00*	- 1.27	0.31	- 3.25**
γ - 20 kR	-1.52	-5.36**	2.27*	-0.60	-3.03**	-3.99**	-0.49	- 2.23*	-4.94**	- 2.54*
γ - 30 kR	-3.86**	-4.36**	-6.06**	-4.80**	-8.01**	-5.08**	-7.67**	- 7.50**	-9.75**	- 5.65**
γ - 40 kR	-7.79**	-6.47**	-9.33**	-9.74**	-8.84**	-5.97**	-11.43**	-6.61**	-5.89**	-7.74**
EMS 0.5%	-4.91**	-6.52**	-8.44**	-8.99**	-7.79**	-3.78**	- 8.62**	-7.67**	-8.77**	-6.47**
EMS 1.0%	-8.77**	0.86	-6.37**	-5.73**	-10.30**	-8.62**	- 6.56**	-6.34**	-7.68**	-8.62**
EMS 1.5%	-7.74**	-6.47**	-7.13**	-6.53**	-10.28**	-8.07**	- 8.05**	-7.11**	-7.67**	-6.25**
EMS 2.0%	-8.64**	-9.07**	-7.73**	-7.13**	- 8.50**	-10.02**	-7.68**	-8.43**	-8.07**	-6.57**

* significant at 5%

** significant at 1%

Table 43. Population variance and inter-family variance of pods per plant in M_2 for each treatment

Treatment	Variance			
	Population		Inter-family	
	T-9	B-76	T-9	B-76
X-10 kR	1.63	2.00	53.21	16.10
X-20 kR	0.88	1.63	45.38	21.89
X-30 kR	0.65	1.08	22.29	7.00
X-40 kR	1.58	1.23	8.47	10.71
♂ - 10 kR	1.48	1.28	22.52	11.33
♂ - 20 kR	2.15	2.00	26.97	13.07
♂ - 30 kR	1.53	1.30	12.68	6.80
♂ - 40 kR	2.30	1.60	7.65	6.70
EMS 0.5%	2.20	1.45	10.09	6.70
EMS 1.0%	1.80	0.93	8.81	20.19
EMS 1.5%	1.11	1.56	5.24	3.28
EMS 2.0%	1.15	1.26	3.40	1.93
Control	1.23	1.28		

Table 44. Intra-family variances for pods per plant in M_2

T-9

Family

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	1.665	1.000	0.830	1.665	4.000	2.665	0.330	1.165	2.330	0.665	1.631
X-20 kR	2.665	0.665	1.330	1.000	0.330	0.330	0.330	0.830	0.330	1.000	0.881
X-30 kR	0.330	0.665	1.330	0.830	0.665	0.330	0.665	0.665	0.330	0.665	0.647
X-40 kR	0.330	1.830	1.665	0.830	1.665	1.000	1.830	1.665	4.000	1.000	1.581
γ - 10 kR	0.830	0.830	2.665	2.330	2.165	0.830	1.330	1.665	0.330	1.830	1.480
γ - 20 kR	3.330	2.665	5.165	2.665	0.665	1.665	0.330	1.165	1.665	2.165	2.148
γ -30 kR	1.330	0.330	2.500	1.165	0.830	0.830	0.830	4.165	1.000	2.330	1.531
γ - 40 kR	2.500	3.300	3.165	0.830	2.665	0.330	2.330	3.500	1.665	3.665	2.298
EMS 0.5%	3.330	2.330	1.330	0.665	1.665	0.665	2.665	1.830	0.665	6.830	2.200
EMS 1.0%	0.665	1.165	2.665	1.165	1.165	3.165	5.330	0.830	0.665	1.165	1.798
EMS 1.5%	0.665	0.665	1.000	1.330	1.000	1.330	0.665	0.665	2.500	1.330	1.115
EMS 2.0%	1.000	1.000	0.830	2.665	0.665	0.330	0.665	2.165	1.165	1.000	1.148
Control											1.230

contd.

Table 44• contd•

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0•665	1•330	2•500	2•165	0•330	4•665	3•165	1•165	3•330	0•665	1•998
X-20 kR	3•500	2•000	1•165	1•000	1•165	1•165	1•000	0•830	1•165	2•330	1•632
X-30 kR	1•665	1•665	0•665	1•165	2•665	1•000	0•330	0•665	0•665	0•330	1•081
X-40 kR	1•165	2•330	1•000	2•665	0•330	0•665	0•330	3•165	1•000	1•665	1•231
γ - 10 kR	1•165	1•165	1•165	2•165	0•665	1•330	1•330	0•330	2•665	0•830	1•281
γ - 20 kR	4•000	2•665	1•665	2•830	1•000	1•330	0•665	1•330	2•330	2•165	1•998
γ - 30 kR	2•500	1•665	0•665	2•300	1•165	2•165	0•665	0•330	0•665	0•830	1•298
γ - 40 kR	2•165	2•500	0•665	2•500	0•665	0•165	0•665	0•330	0•665	3•665	1•598
EMS 0•5%	1•330	2•500	0•665	2•830	2•665	2•165	0•665	0•330	0•330	1•000	1•448
EMS 1•0%	0•330	1•000	0•330	0•330	0•665	0•665	1•330	1•830	2•165	0•665	0•931
EMS 1•5%	2•665	1•830	1•665	0•665	2•830	0•665	1•165	1•330	1•665	1•165	1•564
EMS 2•0%	1•330	2•330	0•665	1•165	1•165	0•330	1•000	2•165	0•665	1•330	1•264
Control											1•280

control population means. 83.33% families of T-9 and 95.00% families of B-76 exhibited reduced means. On the other hand, only 5.83% families of T-9 showed increased mean i.e., shifting of mean towards desirable direction. The mentioned desirable families were obtained from lower doses (10 and 20 kR) of physical mutagens in T-9 only and such families with increased frequency were recorded for lower doses of gamma ray treatment.

Variance.

Population variance of each treatment, within families variance for each family and inter family variance for each treatment for both varieties are shown in Tables 47 and 48. To test the heterogeneity of variances of different families for each treatment, the inter family variance was tested against within families variance and are presented in Table 20. In T-9, the population variance was increased for all gamma ray treatments and for 10 and 40 kR X-ray only. This variety also exhibited increased population variance for 0.5% and 1.0% EMS treatments. Contrary to this B-76, showed greater population variance for 10 kR X-ray, 20 kR gamma ray and 0.5% EMS treatment as compared to control population. This then demonstrated the pronounced effect of gamma ray treatment in inducing increased variability for this character in T-9. Families of all the treatments of both the varieties were significantly heterogeneous for this character except 2.0% EMS in B-76.

Table 45. Family means of seeds per plant in M_2 for T-9 and B-76

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	50.50	49.33	40.83	37.00	41.66	39.66	41.83	50.33	79.33	50.66	48.12
X-20 kR	55.33	51.50	39.83	26.00	31.33	39.33	34.33	33.50	47.66	41.17	40.00
X-30 kR	44.00	25.50	32.33	31.00	40.33	30.00	26.33	45.00	30.33	25.66	35.05
X-40 kR	36.00	26.33	24.33	26.83	28.00	19.67	26.16	24.50	24.66	24.16	26.07
γ -10 kR	52.33	40.16	38.50	38.17	54.67	36.16	48.16	42.33	28.33	36.50	41.53
γ -20 kR	55.83	69.00	51.83	65.83	55.83	51.50	35.16	38.17	48.66	53.67	52.66
γ -30 kR	36.50	37.17	31.50	29.50	38.17	17.66	30.66	34.17	30.33	31.16	31.68
γ -40 kR	29.16	29.66	20.66	29.00	33.00	25.50	38.00	33.66	22.00	24.66	28.53
EMS 0.5%	31.16	25.66	32.50	29.67	22.16	23.66	22.33	18.16	28.00	26.16	25.95
EMS 1.0%	19.16	27.33	24.33	23.83	23.33	29.66	23.67	21.33	15.83	23.66	23.22
EMS 1.5%	18.33	25.67	18.50	17.66	20.50	20.16	19.66	24.50	21.66	20.00	20.67
EMS 2.0%	21.66	20.83	21.16	18.50	19.33	21.83	23.33	27.16	17.33	17.00	20.82
Control											49.37

contd.

Table 45 contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	25.00	28.83	39.67	33.16	24.50	34.66	43.83	43.83	34.66	28.83	33.70
X-20 kR	25.00	31.16	27.66	26.33	33.66	30.50	27.83	15.82	19.16	17.00	25.42
X-30 kR	23.16	25.50	22.00	22.83	22.17	23.00	17.67	21.00	25.66	24.50	22.75
X-40 kR	17.00	13.00	19.50	26.50	22.83	19.66	14.66	10.50	14.66	11.66	17.00
γ-10 kR	34.83	32.66	23.16	35.67	26.16	29.66	34.16	36.66	33.83	29.33	31.58
γ-20 kR	32.83	26.67	43.33	38.33	29.66	30.83	34.50	29.83	28.00	29.50	32.35
γ-30 kR	24.33	28.50	23.00	23.17	18.50	27.50	20.50	20.16	14.50	21.83	22.20
γ-40 kR	17.00	25.66	19.00	13.66	16.33	22.00	10.33	21.66	19.16	20.66	18.55
EMS 0.5%	27.00	24.66	20.50	15.33	22.33	30.50	18.50	20.00	17.66	21.83	21.83
EMS 1.0%	17.50	43.00	23.50	23.16	16.00	20.33	23.67	23.83	20.00	18.50	22.95
EMS 1.5%	21.33	19.33	17.33	21.50	14.66	19.83	15.66	19.33	21.16	24.00	19.42
EMS 2.0%	19.33	19.83	16.50	20.17	14.33	17.50	16.16	17.17	19.16	21.50	18.17
Control											44.12

Table 46. t-values of family means for seeds per plant in M_2

T-9

Family

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	0.51	-0.02	-3.92**	-5.31**	-3.28**	-4.35**	-3.26**	0.44	11.87**	0.55
X-20 kR	2.70**	0.94	-4.28**	-10.68**	-8.31**	-4.64**	-6.64**	-6.88**	-0.78	-3.70**
X-30 kR	-2.45*	-10.95**	-7.74**	- 8.27**	-3.96**	-8.87**	-10.49**	-1.98	-8.63**	-10.79**
X-40 kR	-6.12**	-10.35**	-11.42**	-10.20**	-8.90**	-13.57**	-10.48**	-11.08**	-10.50**	-11.54**
♂ - 10 kR	1.33	-3.64**	- 4.79**	-4.83**	2.19*	-5.58**	-0.55	-3.01**	-9.31**	-5.88**
♂ - 20 kR	2.64**	8.18**	0.94	7.34**	2.92**	0.87	-6.44**	-5.09**	-0.32	1.93
♂ - 30 kR	-5.87**	-5.51**	-7.98**	-8.94**	-5.11**	-14.46**	-8.63**	-6.24**	-8.73**	-8.15**
♂ - 40 kR	-9.08**	-8.75**	-12.72**	-9.29**	-7.26**	-10.93**	-5.06**	-7.03**	12.34**	-10.83**
EMS 0.5%	-8.10**	-10.63**	-7.55**	-8.86**	-12.46**	-11.66**	-11.74**	-14.21**	-9.82**	-9.65**
EMS 1.0%	-13.44**	-9.82**	-9.97**	-11.63**	-11.99**	-8.80**	-11.10**	-11.83**	-14.98**	-11.57**
EMS 1.5%	-14.13**	-10.85**	-14.13**	-14.38**	-12.75**	-13.37**	-13.68**	-10.94**	-12.47**	-13.37**
EMS 2.0%	-12.66**	-13.07**	-12.65**	-13.97**	-13.75**	-12.63**	-11.88**	-9.87**	-14.70**	-14.35**

contd.

Table 46. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	-7.10**	-5.64**	-1.64	-3.99**	-7.35**	-3.32**	-0.11	-0.10	-3.48**	-5.68**
X-20 kR	-6.94**	-4.73**	-6.05**	-6.37**	-3.85**	-4.92**	-5.75**	-10.37**	-9.21**	-9.99**
X-30 kR	-7.73**	-6.68**	-8.26**	-7.84**	-7.90**	-7.83**	-9.80**	-8.58**	-6.87**	-7.20**
X-40 kR	-10.02**	-11.57**	-9.14**	-6.46**	-7.84**	-8.54**	-10.95**	-12.38**	-10.97**	-12.09**
γ - 10 kR	-3.44**	-4.16**	-7.73**	-3.09**	-6.70**	-5.24**	-3.68**	-2.71**	-3.44**	-5.39**
γ - 20 kR	-4.04**	-6.30**	-0.29	-2.10	-5.38**	-4.84**	-3.52**	-5.01**	-5.70**	-5.19**
γ - 30 kR	-7.07**	-5.75**	-7.86**	-7.75**	-9.47**	-6.09**	-8.81**	-8.96**	-11.06**	-8.17**
γ - 40 kR	-10.05**	-6.78**	-9.38**	-11.25**	-10.30**	-8.16**	-12.62**	-8.30**	- 9.11**	-8.47**
EMS 0.5%	-6.32**	-7.14**	-8.63**	-10.65**	-8.19**	-5.00**	-9.56**	-8.95**	-9.85**	-8.17**
EMS 1.0%	-9.82**	-0.41	-7.71**	- 7.84**	-10.50**	-8.87**	-7.57**	-7.38**	-8.79**	-9.56**
EMS 1.5%	-8.21**	-9.19**	-9.93**	- 7.77**	-10.82**	-9.04**	-10.21**	-9.14**	-8.47**	-7.48**
EMS 2.0%	-9.19**	-8.90**	-10.25**	-8.49**	-11.11**	-9.94**	-10.27**	-9.91**	-9.28**	-8.41**

* significant at 5%

** significant at 1%

Table 47. Population variance and inter family variance of seeds per plant in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	23.58	22.56	881.46	300.52
X-20 kR	13.49	19.98	515.57	227.02
X-30 kR	15.31	14.80	329.27	32.73
X-40 kR	23.53	12.93	103.38	156.85
γ - 10 kR	21.76	16.96	389.75	116.66
γ - 20 kR	32.26	27.64	663.79	157.59
γ - 30 kR	29.66	18.99	204.11	102.71
γ - 40 kR	32.31	21.19	177.74	117.31
EMS 0.5%	25.23	23.38	121.07	124.00
EMS 1.0%	22.53	12.98	90.03	344.68
EMS 1.5%	14.29	20.83	41.10	48.88
EMS 2.0%	15.31	14.25	55.14	28.80
Control	17.01	23.20		

Table 48. Intra-family variances for seeds per plant in M_2

T-9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	12.830	18.165	12.665	17.330	73.665	16.165	14.330	21.330	43.665	5.665	23.58
X-20 kR	18.165	13.330	19.665	14.330	5.665	5.665	15.330	13.830	16.665	12.330	13.50
X-30 kR	15.500	13.330	14.165	21.830	18.665	13.000	13.665	22.000	11.330	9.665	15.31
X-40 kR	12.330	30.665	16.665	22.665	22.665	15.330	16.330	16.330	63.165	14.165	23.53
♂ - 10 kR	17.330	11.665	43.330	33.330	35.330	11.165	19.665	20.665	7.665	17.500	21.76
♂ - 20 kR	65.665	46.000	56.665	41.665	11.330	22.830	13.165	13.330	21.165	30.830	32.26
♂ - 30 kR	16.500	10.330	32.500	21.330	9.330	18.665	7.665	134.330	12.330	33.665	29.66
♂ - 40 kR	34.665	44.665	47.665	13.000	47.330	5.000	40.000	30.665	18.500	41.665	32.32
EMS 0.5%	44.165	29.165	23.830	8.830	12.665	7.665	29.665	19.165	11.500	65.665	25.23
EMS 1.0%	8.665	15.665	46.165	13.165	8.330	37.665	63.830	9.330	10.330	12.165	22.53
EMS 1.5%	9.665	8.330	12.500	23.165	12.330	7.665	9.165	11.500	30.665	19.000	14.40
EMS 2.0%	14.165	14.165	25.665	25.830	8.330	4.330	10.165	24.665	13.330	12.500	15.31
Control											

contd.

Table 48. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	8.330	6.665	22.330	26.665	4.330	64.165	41.330	12.330	31.165	8.330	22.56
X-20 kR	32.830	30.165	23.165	20.330	16.665	17.000	16.330	11.665	13.165	18.500	19.98
X-30 kR	26.665	27.500	8.330	11.330	23.330	16.000	6.830	11.330	11.665	5.000	14.80
X-40 kR	17.330	14.500	16.000	13.330	4.165	6.665	5.665	30.330	10.665	10.665	12.93
γ - 10 kR	16.165	14.330	15.665	30.330	9.665	12.665	11.165	13.665	30.330	15.665	16.96
γ - 20 kR	56.330	48.330	18.165	29.665	14.165	17.330	15.330	10.165	41.000	26.000	27.65
γ - 30 kR	47.165	24.830	11.500	21.330	21.500	28.000	8.330	12.275	9.500	11.665	19.61
γ - 40 kR	17.330	36.165	9.500	24.165	9.665	28.000	10.165	8.665	9.665	58.665	21.15
EMS 0.5%	24.330	36.165	11.500	18.665	65.165	35.500	11.500	5.000	5.665	20.330	23.38
EMS 1.0%	7.330	20.500	4.830	5.665	8.830	10.665	9.830	19.830	30.830	11.500	12.98
EMS 1.5%	44.165	12.165	16.165	10.000	34.665	12.665	12.165	28.665	23.665	14.000	20.83
EMS 2.0%	14.165	33.665	9.500	7.330	6.330	4.330	14.165	30.330	10.665	12.000	14.25
Control											23.20

Bhadra (1982) in black gram reported no significant change in mean for seeds per plant though the variance was enlarged. On the contrary, increase in seed number per plant was reported in broad bean by Vik (1975).

Yield per plant.

Mean.

The means of all the families of all the treatments for both the varieties are presented in Table 49. Variety, treatment and variety x treatment interaction were significant (Table 15) indicating real difference between the two varieties and also between the treatments for this character. The effects of the mutagenic treatments on different families were mostly negative in nature as indicated from 't'-tests (Table 50). The grouping of the family means on the basis of positive change, negative change and no change following 't'-tests indicated that 81.67% families of T-9 and 96.67% families of B-76 exhibited reduced means whereas, only 6.67% families of T-9 showed shifting in mean towards desirable positive direction. Not a single family of B-76 out yielded the control. However, the positive shifting of mean yield was observed for lower doses of physical mutagens (10 kR and 20 kR X-ray and gamma ray) in T-9 only. All EMS treatments and higher doses of physical mutagens resulted in decreased yield per plant for both the varieties.

Variance.

Population variance of each treatment, intra family variances for each family and inter family variences for each treatment are presented in Tables 51 and 52. The variance was increased for almost all the treatments in T-9. On the other hand, in B-76, the variance was increased for lower doses of physical mutagens but decreased for higher doses of physical mutagens. In case of chemical mutagen, it was increased very slightly for 0.5% EMS. The inter family variances were tested against within families variances and the results are presented in Table 20. Except 30 kR X-ray and 2.0% EMS in B-76, families of all the treatments of both the varieties were significantly heterogenous for this character.

Our present observation finds support from similar observations of some earlier authors where, the mean for yield per plant was shifted in the negative direction e.g., Rawlings et al. (1958) in soyabean, Narsinghani and Kumar (1976) in ground nut, Sharma and Sharma (1982) in lentil and Kundu and Singh (1981) in black gram. On the contrary, increase in mean pod yield was observed by Vasudevan et al. (1969) in barley, Vlk (1975) in broad bean, Glosan and Nicolae (1972) in soyabean, Rubaihayo (1975) in french bean, Chaturvedi and Singh (1980) in green gram and Kundu and Singh (1982) in black gram. However, Rajput (1974) observed in green gram positive or negative shift in mean for yield per plant which also recorded in the present study.

Table 49. Family means of yield per plant in M_2 for T-9 and B-76

T-9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	2.06	2.00	1.67	1.51	1.70	1.62	1.71	2.05	3.25	2.08	1.97
X-20 kR	2.25	2.10	1.63	1.05	1.28	1.61	1.41	1.37	1.95	1.68	1.63
X-30 kR	1.77	1.02	1.31	1.25	1.62	1.20	1.06	1.82	1.24	1.03	1.33
X-40 kR	1.43	1.04	0.95	1.06	1.12	0.78	1.03	0.96	0.98	0.96	1.03
γ - 10 kR	2.13	1.63	1.56	1.56	2.21	1.46	1.95	1.73	1.15	1.49	1.69
γ - 20 kR	2.26	2.82	2.10	2.68	2.28	2.10	1.45	1.56	1.98	2.18	2.14
γ - 30 kR	1.46	1.48	1.28	1.18	1.52	0.71	1.22	1.36	1.20	1.23	1.27
γ - 40 kR	1.15	1.16	0.81	1.13	1.29	0.99	1.49	1.31	0.86	0.97	1.12
EMS 0.5%	1.23	1.01	1.27	1.16	0.87	0.94	0.89	0.71	1.09	1.02	1.02
EMS 1.0%	0.76	1.08	0.96	0.94	0.93	1.17	0.94	0.85	0.63	0.95	0.92
EMS 1.5%	0.72	1.01	0.73	0.71	0.80	0.79	0.77	0.97	0.85	0.79	0.81
EMS 2.0%	0.85	0.81	0.82	0.70	0.76	0.85	0.92	1.06	0.68	0.66	0.81
Control											1.98

contd.

Table 40. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	1.04	1.17	1.61	1.35	0.99	1.41	1.76	1.66	1.39	1.15	1.35
X-20 kR	1.03	1.27	1.12	1.07	1.40	1.25	1.13	0.65	0.79	0.69	1.04
X-30 kR	0.93	1.02	0.89	0.89	0.89	0.93	0.73	0.85	1.02	0.98	0.92
X-40 kR	0.63	0.53	0.79	1.06	0.92	0.79	0.58	0.43	0.60	0.47	0.68
γ - 10 kR	1.45	1.34	0.96	1.46	1.06	1.17	1.37	1.46	1.36	1.20	1.28
γ - 20 kR	1.36	1.09	1.78	1.57	1.22	1.26	1.42	1.24	1.15	1.21	1.33
γ - 30 kR	0.98	1.14	0.90	0.93	0.72	1.13	0.83	0.80	0.60	0.89	0.89
γ - 40 kR	0.66	1.00	0.75	0.54	0.65	0.89	0.41	0.88	0.77	0.77	0.73
EMS 0.5%	1.11	0.99	0.81	0.61	0.90	1.23	0.75	0.80	0.71	0.86	0.88
EMS 1.0%	0.70	1.72	0.94	0.93	0.64	0.81	0.94	0.96	0.81	0.75	0.92
EMS 1.5%	0.84	0.75	0.69	0.85	0.59	0.79	0.62	0.76	0.84	0.95	0.77
EMS 2.0%	0.76	0.77	0.65	0.79	0.56	0.69	0.63	0.69	0.76	0.84	0.71
Control											1.79

Table 50. t-values of family means for yield per plant in M_2

T - 9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	0.91	0.23	-3.58**	-5.10**	-3.01**	-4.05**	-2.91**	0.80	12.45**	1.07
X-20 kR	3.08**	1.34	-3.92**	-10.68**	-0.81	-0.42	-6.33**	-6.68**	-0.34	-3.41**
X-30 kR	-2.41*	-11.07**	-7.69**	-8.30**	-4.00**	-9.00**	-10.56**	-1.81	-8.49**	-10.90**
X-40 kR	-6.34**	-10.69**	-11.82**	-10.51**	-8.95**	-13.77**	-10.75**	-11.48**	-10.70**	-11.76**
γ-10 kR	1.69	-3.47**	-4.66**	-4.77**	2.35*	-5.54**	-0.34	-2.69**	-9.21**	-5.62**
γ-20 kR	2.90**	8.86**	-1.17	7.88**	3.44**	1.24	-6.05**	-4.77**	0.06	2.27*
γ-30 kR	-6.00**	-5.74**	-7.52**	-9.14**	-5.28**	-14.65**	-8.81**	-6.37**	-8.91**	-8.44**
γ-40 kR	-9.44**	-9.23**	-13.11**	-9.75**	-7.73**	-11.48**	-5.49**	-7.58**	-12.79**	-11.21**
EMS 0.5%	-8.40**	-10.97**	-8.03**	-9.32**	-12.87**	-11.94**	-11.99**	-14.58**	-10.27**	-10.08**
EMS 1.0%	-14.07**	-10.13**	-10.35**	-12.00**	-12.17**	-9.16**	-11.38**	-12.09**	-15.27**	-11.71**
EMS 1.5%	-14.46**	-11.19**	-14.42**	-14.58**	-13.16**	-13.73**	-14.10**	-11.21**	-12.85**	-13.66**
EMS 2.0%	-13.03**	-12.08**	-13.12**	-14.55**	-14.07**	-13.10**	-12.23**	-10.31**	-15.07**	-14.79**

contd.

Table 50 contd.

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
X-10 kR	-7.09**	-5.84**	-1.69**	-4.09**	-7.65**	-3.39**	-0.28	-1.11	-3.75**	-6.07**
X-20 kR	-7.01**	-4.86**	-6.28**	-6.57**	-3.66**	-4.96**	-5.91**	-10.65**	-9.41**	-10.31**
X-30 kR	-8.09**	-7.05**	-8.61**	-8.47**	-8.27**	-8.13**	-10.02**	-8.92**	-7.31**	-7.59**
X-40 kR	-11.01**	-11.96**	-9.45**	-6.87**	-8.19**	-8.88**	-11.48**	-12.75**	-11.20**	-12.58**
♂-10 kR	-3.20**	-4.19**	-7.81**	-3.07**	-6.95**	-5.72**	-3.97**	-3.04**	-3.63**	-5.49**
♂-20 kR	-3.91**	-6.43**	-0.09	-2.03*	-5.41**	-4.95**	-3.44**	-4.90**	-5.77**	-5.19**
♂-30 kR	-7.39**	-6.12**	-8.48**	-8.13**	-10.11**	-6.19**	-9.15**	-9.47**	-11.34**	-8.37**
♂-40 kR	-10.72**	-7.41**	-9.95**	-11.81**	-10.77**	-8.47**	-13.15**	-8.57**	-9.49**	-9.64**
EMS 0.5%	-6.43**	-7.50**	-9.15**	-11.20**	-8.15**	-5.25**	-9.91**	-9.39**	-10.25**	-8.72**
EMS 1.0%	-10.30**	-0.66	-8.13**	-8.23**	-10.96**	-9.34**	-8.07**	-7.69**	-9.12**	-9.91**
EMS 1.5%	-8.76**	-9.87**	-10.44**	-8.28**	-11.21**	-9.45**	-10.75**	-9.70**	-8.94**	-8.00**
EMS 2.0%	-9.77**	-9.56**	-10.82**	-9.05**	-11.72**	-10.52**	-10.88**	-10.54**	-9.81**	-9.01**

* Significant at 5%

** Significant at 1%

Table 51. Population variance and inter family variance of yield per plant in M_2 for each treatment

Treatment	Variance			
	Population		Inter family	
	T-9	B-76	T-9	B-76
X-10 kR	0.041	0.046	1.49	0.42
X-20 kR	0.024	0.034	0.86	0.39
X-30 kR	0.026	0.024	0.54	0.04
X-40 kR	0.038	0.021	0.17	0.25
γ - 10 kR	0.037	0.031	0.64	0.187
γ - 20 kR	0.048	0.047	1.09	0.266
γ - 30 kR	0.048	0.030	0.32	0.170
γ -40 kR	0.048	0.028	0.27	0.183
EMS 0.5%	0.032	0.037	0.18	0.212
EMS 1.0%	0.034	0.019	0.14	0.55
EMS 1.5%	0.022	0.032	0.07	0.63
EMS 2.0%	0.023	0.021	0.09	0.044
Control	0.022	0.030		

Table 52. Intra-family variances for yield per plant in M_2

T-9

Treatment	Family F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.022	0.031	0.026	0.025	0.118	0.026	0.029	0.038	0.083	0.009	0.041
X-20 kR	0.031	0.020	0.044	0.025	0.008	0.010	0.026	0.024	0.029	0.021	0.024
X-30 kR	0.031	0.025	0.021	0.035	0.028	0.022	0.021	0.044	0.020	0.015	0.026
X-40 kR	0.019	0.045	0.025	0.034	0.024	0.027	0.049	0.027	0.109	0.022	0.038
γ - 10 kR	0.033	0.017	0.067	0.051	0.068	0.020	0.030	0.035	0.015	0.031	0.037
γ - 20 kR	0.096	0.066	0.085	0.062	0.012	0.041	0.019	0.026	0.037	0.042	0.049
γ - 30 kR	0.024	0.013	0.056	0.032	0.018	0.027	0.015	0.220	0.020	0.058	0.048
γ - 40 kR	0.052	0.065	0.071	0.022	0.064	0.007	0.065	0.046	0.025	0.058	0.047
EMS 0.5%	0.068	0.042	0.035	0.011	0.016	0.011	0.046	0.030	0.022	0.098	0.038
EMS 1.0%	0.018	0.027	0.065	0.017	0.058	0.052	0.097	0.014	0.016	0.019	0.038
EMS 1.5%	0.014	0.016	0.019	0.035	0.018	0.011	0.013	0.016	0.046	0.032	0.022
EMS 2.0%	0.020	0.019	0.040	0.046	0.011	0.006	0.013	0.035	0.019	0.017	0.023
Control											0.022

Table 52. contd.

B-76

Treatment	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	Mean
X-10 kR	0.014	0.008	0.037	0.044	0.010	0.107	0.069	0.105	0.057	0.015	0.047
X-20 kR	0.057	0.052	0.037	0.035	0.027	0.026	0.033	0.018	0.024	0.032	0.034
X-30 kR	0.044	0.044	0.012	0.018	0.038	0.028	0.012	0.018	0.023	0.007	0.024
X-40 kR	0.032	0.024	0.034	0.019	0.006	0.008	0.009	0.051	0.018	0.014	0.021
γ - 10 kR	0.029	0.024	0.030	0.055	0.014	0.025	0.018	0.026	0.064	0.026	0.031
γ - 20 kR	0.102	0.079	0.028	0.050	0.021	0.029	0.029	0.021	0.062	0.056	0.048
γ - 30 kR	0.073	0.039	0.017	0.035	0.031	0.043	0.015	0.009	0.018	0.017	0.030
γ - 40 kR	0.026	0.055	0.014	0.037	0.015	0.045	0.016	0.017	0.013	0.043	0.028
EMS 0.5%	0.040	0.054	0.018	0.028	0.103	0.058	0.018	0.006	0.013	0.031	0.037
EMS 1.0%	0.011	0.023	0.005	0.008	0.014	0.016	0.014	0.034	0.047	0.017	0.019
EMS 1.5%	0.066	0.017	0.026	0.013	0.064	0.019	0.017	0.046	0.037	0.019	0.032
EMS 2.0%	0.019	0.051	0.013	0.012	0.009	0.006	0.020	0.044	0.014	0.018	0.021
Control											0.030

One of the most important findings of the study is that, the families, means of which were shifted towards positive direction were mostly originated from the variety T-9. The contribution of B-76 towards such positive shifting was very less and some times even nil. Another significant finding of the present investigation is that, in all the characters, the shifting of means towards positive direction was observed mostly for lower doses of mutagenic treatments. However, irrespective of the shifting of means, the amount of variability was enlared for all the nine characters studied except plant height where the variability was reasonably decreased as compared to control in both T-9 and B-76.

Our present observations find support from similar observations made by Gaul (1965, 1966, 1969) from his extensive work with X-irradiation in barley where he concluded that irradiation results in a decrease in the mean and increase in the variance. Another supporting hypothesis of our present finding was formulated by Gaul (1965) and Aastveit (1966) where they stated that, "By random mutation a change in the mean value of almost any quantitative character of interest in plant breeding is to be expected in a direction associated with reduced vitality and the alteration of the mean is largely dependent on the genotypes used for the mutagenic treatment".

Irrespective of the shifting of means, increase in variance in M_2 generation after mutagenic treatments have been

reported by a number of authors for many quantitative characters in several crop plants e.g., Bhatia and Swaminathan (1963) in wheat, Vasudevan et al. (1969) in barley, Goud et al. (1971) in ragi, Nagl (1978/79) in broad bean, Natarajan et al. (1983) in red gram, Tickoo and Jain (1980) in green gram and Singh et al. (1979) in black gram. On the contrary, Ramanathan (1983) observed that the genotypic variability was lacking in M_2 generation in ground nut after treatment with gamma rays, EMS and combination of the two.

Variability, heritability and genetic advance.

The phenotypic (PCV), genotypic (GCV) and environmental (ECV) coefficients of variability, heritability, genetic advance and genetic advance as % of mean are presented in Table 53. Among the nine characters studied, yield per plant, seeds per plant, pods per plant and clusters per plant exhibited high phenotypic and genotypic coefficients of variation than other characters. Least coefficient of variation was observed for days to flowering at both phenotypic and genotypic levels. The heritability estimates were high for all the characters except pods per cluster. The highest genetic gain (GA % of mean) was also observed for yield per plant (55.26%) followed by seeds per plant (52.23%), pods per plant (47.49%) and clusters per plant (42.62%). Lowest genetic advance was observed for days to flowering (6.56%).

Significant amount of genetic variability for characters yield, plant height, maturity and seed size in soyabean was reported by Rawlings et al. (1958). Natarajan et al. (1983) recorded greatest variance for pods per plant and plant height in red gram. Tickoo and Jain (1980) reported increase in variance for yield and yield contributing characters in green gram. Khan (1982) in green gram also observed greatest variability in M_2 generation for yield, number of pods and 100-seed weight. Ramanathan (1983) reported increase in genotypic variance, heritability and genetic advance of yield attributes after mutagenic treatments in ground nut. The higher values of predicted heritability and genetic advance for yield and yield components in our present study suggested that the mutations have mostly occured at loci having additive effects.

Comparative study of the physical and chemical mutagens.

The success of a mutation breeding programme depends primarily upon the selection of proper mutagens and appropriate doses which are able to induce useful micromutations leading ultimately to yield improvement. It is recognized that ionizing radiations were highly effective in inducing chromosomal aberrations while chemical mutagens like ethyl methane sulphonate and diethyl sulphate, which are known to act primarily on base pairs in DNA molecule, give higher yield of gene mutations. The ionizing radiations

Table 53. Phenotypic and genotypic coefficients of variability (PCV and GCV), heritability and genetic advance of nine characters in M_2 generation

Characters	PCV	GCV	ECV	Heritability (%)	Genetic advance (GA)	Genetic gain (GA %)
1. Days to flowering	3.63	3.39	0.92	87.42	3.85	6.56
2. Height at first flowering	11.74	11.15	3.28	90.22	3.53	21.90
3. Clusters/ plant	22.28	21.40	3.94	92.19	1.53	42.62
4. Pods/ cluster	9.64	7.05	5.88	53.49	0.23	10.70
5. Pod length	7.71	7.00	2.37	82.43	0.46	13.03
6. Seeds/ pod	10.10	9.14	3.29	81.87	0.68	17.17
7. Pods/ plant	25.24	24.11	5.44	91.26	3.60	47.49
8. Seeds/ plant	27.52	26.35	5.30	91.67	14.76	52.23
9. Yield/ plant	28.83	27.74	4.80	92.59	0.63	55.26

with their known effect to induce higher frequency of chromosomal aberrations are expected to induce high amount of sterility and also produce more gross phenotypic alterations, which reduce chances of selection for yield improvement. Thus, it is expected that chemical mutagens like ethyl methane sulphonate may induce more quantitative variation than ionizing radiations. A number of authors reported better success with chemical mutagens compared to ionizing radiations in the course of studies on induced polygenic variability. Gaul and Aastveit (1966) in wheat and Brock (1970) in Arabidopsis thaliana reported that EMS was more effective than radiations in inducing polygenic variability.

Nevertheless, only 12 out of 151 commercialised varieties resulting from mutation were selected after application of mutagenic chemicals; the remaining 139 were produced by means of physical mutagens (Gottschalk, 1980). Indeed, a large number of studies suggested that as far as the overall production of variability is concerned, physical mutagens remain as a very powerful tool. In many studies the induced polygenic variability has been found to be greater with ionizing radiations (Rao, 1974 and Khamankar, 1974). However, Bhadra (1982) in black gram showed that, both EMS and gamma rays were equally effective in generating polygenic variability for yield and yield components. Gill et al. (1974), in a comparative study

of different mutagens in respect of induced polygenic variability in barley, found that, doses of mutagens have important role in determining the quantum and nature of induced variability. They observed that ingeneral, lower doses of EMS were effective for inducing positive micromutants, while the genetic variability released was much higher in the intermediate does of gamma rays and P^{32}.

The result of our present experiment shows that lower doses of ionizing radiations (X-ray and gamma ray) were effective in inducing useful micromutations in respect of yield and yield components. This can be further illustrated from the Table 54. Almost all characters except dwarfness in plant height, recovered families showing desirable positive shift in mean were obtained exclusively from lower doses of X-ray and gamma ray treatments. Of these two mutagens gamma ray treatments (lower dose) induced desirable families with the shift in mean at higher frequency. EMS was infact, found to be not very important in producing valuable micromutations, but the variability generated was very high for EMS treatments though most of them were towards negative direction. This might be due to the fact that, concentrations used for EMS treatments were sufficiently high to check the growth and vigour of plant leading to low productivity in M_2 generation itself. Thus, it can be suggested that, during the planning of any mutation breeding programme aimed to get valuable micromutations in black gram, lower doses of both X-ray and gamma ray may be of great

Table 54. Families with shift in mean towards desired direction at lower doses of physical mutagens for nine different characters in T-9 and B-76

T-9

Family

	Early flowering	Plant height		Clusters per plant	Pods per cluster	Pod length	Seeds per pod	Pods per plant	Seeds per plant	Yield per plant
		Tall	Dwarf							
X-10 kR	6	3	-	2	3	2	7	3	1	1
X-20 kR	8	1	4	2	2	2	6	2	1	1
Total	14	4	4	4	5	4	13	5	2	2
> - 10 kR	9	7	-	4	4	3	9	3	1	1
> - 20 kR	7	4	1	7	7	5	8	8	4	5
Total	16	11	1	11	11	8	17	11	5	6
Grand Total	30	15	5	15	16	12	30	16	7	8
Total families shifted in desirable direction	32	17	62	16	24	15	43	17	7	8
% contribution of lower doses of physical mutagens	93.75	88.23	8.06	93.75	66.67	80.00	69.77	94.12	100.00	100.00

contd.

Table 54. contd.

B-76

	Early flowering	Plant height		Clusters per plant	Pods per cluster	Pod length	Seeds per pod	Pods per plant	Seeds per plant	Yield per plant
		Tall	Dwarf							
X-10 kR	2	1	1	2	5	-	7	-	-	-
X-20 kR	1	1	1	-	2	2	4	-	-	-
Total	3	2	2	2	7	2	11	0	0	0
- 10 kR	1	2	-	1	6	1	2	-	-	-
- 20 kR	2	2	1	2	1	2	1	1	-	-
Total	3	4	1	3	7	3	3	1	0	0
Grand Total	6	6	3	5	14	5	14	1	0	0
Total families shifted in desirable direction	6	6	52	5	25	6	20	1	0	0
% contribution of lower doses of physical mutagens	100.00	100.00	5.77	100.00	56.00	83.3	70.00	100.00	0	0

significance, where gamma treatments (lower dose) may be of better choice. Further it appears that higher concentrations of EMS may not be very useful for inducing useful micromutants in black gram.

Varietal response to different mutagenic treatments.

A number of authors reported that different genotypes may respond differentially to mutagenic treatments inrespect of induced polygenic variability (Goud, 1967 ; Ojomo and Chheda, 1972; Sharma, 1975; Rao and Siddiq, 1977). Brock (1965) stated that mutations in a quantitatively inherited character would depend on the number of genes involved, relative proportion of genes with negative and positive effects and the degree to which the genes of the parental genome operate as a balanced set. Again it is well known that different genes differ in their mutability - some are more mutable than others (Stadler, 1946; Fahmy and Fahmy, 1957 and Jain and Raut, 1966).

In our own investigation it was found that, the two varieties used, responded almost in similar fashion for some treatments in respect of some characters, but for other treatments and some other characters they responded differentially. In general, the mean values were shifted towards negative direction for both the varieties for almost all the characters studied but the negative shifting was particularly high for B-76. Most of the promising

families selected in M_2 belongs to the variety T-9, where a considerable number of family means were shifted towards positive direction. From the analysis of variance it appears that, there was significant difference between the two varieties in respect of yield and components of yield. Significant variety x treatment interactions were also observed for all the characters studied which might indicates the differential response of the two varieties to different mutagenic treatments.

Macromutations.

The different macromutations isolated in M_2 generation and their percentage occurrence to the normal plants of the treatment to which it belongs are presented in Table 56. A brief description of the different macromutational types are given below :

(a) Trailing type.

The mutant was very tall with long internodes. The leaves were narrower and longer than the normal plants. The number of pods per plant and seeds per pod was less as compared to control. The seeds were relatively small.

(b) Sterile type.

The growth of this type of mutant was stunted, leaves was broad, compact and dark green in colour. The inflorescence were also compact and only few flowers were formed but no pod setting was observed (Fig. 1).

Table 56. Macromutations obtained in M_2 generation

B-76

Mutants	Dose	Number of plants		Percentage of mutants
		Normal	Mutant	
X-rays				
Trailing type	10 kR	212	23	10.85
Sterile type	30 kR	212	6	2.83
	40 kR	206	5	2.43
Semi sterile type	30 kR	212	12	5.66
	40 kR	206	8	3.88
Broad leaf type	30 kR	212	7	3.30
Dwarf type	40 kR	206	16	7.77
Gamma rays				
Sterile type	40 kR	206	7	3.40
Semi sterile type	40 kR	206	11	5.34
EMS				
Sterile type	1.5%	193	8	4.15
	2.0%	172	7	4.07
Semi sterile type	1.5%	193	9	4.66
	2.0%	172	12	6.98
Dwarf type	1.5%	293	14	7.25
	2.0%	172	23	13.37

contd.

Table 55. contd.

T-9

Mutants	Dose	Number of plants		Percentage of mutants
		Normal	Mutant	
X-rays				
Sterile type	30 kR	267	7	2.62
	40 kR	241	8	3.32
Semi sterile type	30 kR	267	6	2.25
	40 kR	241	8	3.32
Reduced and short pod type	40 kR	241	16	6.64
Dwarf type	40 kR	241	23	9.54
Gamma rays				
Sterile type	40 kR	246	4	1.63
Semi sterile type	40 kR	246	4	1.63
EMS				
Sterile type	1.5%	204	6	2.94
	2.0%	196	7	3.57
Semi sterile type	1.5%	204	4	1.96
	2.0%	196	6	3.06
Swarf type	1.5%	204	13	6.37
	2.0%	196	18	9.18

(c) Semi sterile type.

The growth of this type of mutant was also stunted having compact and dark green leaves. Branching was very few and sometimes nil due to bud compactness. Only few flowers were formed on the compact inflorescence and very few pods were formed. Pods contained very few number of seeds (1-3) (Fig. 2).

(d) Reduced and short pod type.

The mutants were having normal vegetative growth but number of pod formation was very less as compared to the control. The pods were short and having few number of seeds (Fig. 3).

(e) Broad leaf types.

The leaves of this type of mutant was abnormally broad, compact and dark green in colour. No branch formation was observed. Only one very compact inflorescence was formed which produced no flower or pod, i.e., the mutant was completely sterile.

(f) Dwarf type :

The mutants were extremely dwarf but having normal reproductive structures. Flower, pod and seed setting was just like normal plants (Fig. 4).

Normal plant : (Fig. 5).

From the analysis of the frequency of occurrence of the macromutants in M_2 generation (Table 55) it was found that, the sterile and semisterile mutants were formed at higher doses of all the three mutagens viz., X-ray, gamma ray and EMS. The

extreme dwarf mutants were resulted from higher doses of X-rays and EMS only. The number of dwarf mutants was the highest among all the mutants. The trailing type mutant and the broad leaf type mutant resulted from 10 kR and 30 kR X-rays in B-76 only. On the other hand, the reduced and short pod type mutant resulted from 40 kR X-rays in T-9 only. The family or families which segregated for macromutations in M_2 were not advanced to the M_3 generation except the trailing mutant type.

Induced variability in respect of macromutations, which are often associated with gross morphological changes may be very useful in crop like black gram where natural variability is very limited. This is primarily due to the fact that mutants appearing inferior to cultivated types, sometimes, proved to be very important source of germplasm when transferred to favourable idiotypes.

In our present investigation, among the morphological mutations the dwarf type mutants may have some practical value in respect of plant breeding purposes. The dwarf plant type with yielding capacity equal to or higher than control will be very useful if they respond to higher plant density and improved levels of agronomic managements.

Similar to the observations presented above Jana (1962) recorded trailing, semi-sterile, sterile and reduced pod type

mutants in black gram with different frequencies. In green gram, several of such macromutations were reported by Ganguli and Bhaduri (1980). Ramanathan and Rathinam (1983) also reported several such morphological mutants in ground nut.

Evaluation of mutagens.

The study on micromutations indicates the superiority of gamma treatments at lower doses. As oppose to this macromutations were recovered from high doses of mutagens tried. However, higher doses of X-rays were more effective in inducing macromutations. All types of mutants that isolated in M_2 generation were induced by X-rays while only three morphological mutants namely, sterile, semi-sterile and dwarf type mutants were isolated from higher doses of EMS. On the other hand, only sterile and semi-sterile mutations were induced by gamma rays. These observations of effectiveness of physical mutagen in inducing macromutations find support from similar observations made by D'Amato et al. (1962), Khan and Veeraswamy (1972) and Ashri and Levy (1974). However, the EMS exceeded gamma ray in respect of induction of macromutations which may be due to use of very high concentration of EMS that ultimately leads to morphological abnormalities.

Selection of promising lines for M_3.

The success of a mutation breeding programme depends not only on the quality and quantity of induced mutations, but equally

on our ability to pick up the desirable mutations. In fact, out of a large number of others that are of little value, the useful mutations occur with a very low frequency. In mutation breeding an important question arises, whether the selection for micromutations should be started in M_2 or later generations. Different selection techniques have been practised upon the induced polygenic variability by several authors (Gregory, 1955; Oka et al., 1958; Papa et al., 1961; Borojevic, 1965; Miah and Yamaguchi, 1956 b; Gaul et al., 1969; Ojomo and Chheda, 1972; Gill et al., 1974; Sinhamahapatra and Rakshit, 1981). Most common practice in many of the earlier studies has been to select a number of normal looking plants at random and raise M_3 families from them. Effective selection is practised mainly in M_3 generation. The main disadvantage of this procedure is that randomness by which selection is made makes the process highly uncertain.

As has been suggested by earlier workers (Jain and Tickoo, 1979; Bhadra, 1982; Kharkwal, 1983), selection for polygenic variability can be practised with definite advantage in M_2 generation. This selection according to these authors, should be applied only to the M_2 families not segregating for macromutations and promising progenies identified on the basis of high variance and mean shifted in the desired direction. Selection in M_2 generation has been practised by some earlier authors (Brock and Latter, 1961; Brock and Andrew, 1965; Bhatia and Van der Veen, 1965). But they studied characters having higher heritability like flowering

time mostly under controlled experimental conditions. Moreover, the selection techniques followed in such cases were not based on rigorous inter-family and intra-family selections following family mean and cv. analysis. It was Gupta and Swaminathen (1967) who suggested that different M_2 families should be analysed for their mean and variance in respect of the character for which selection is to be practised and to select the families showing significantly superior mean and varience over the control. Sharma (1986), reported that by applying selection seives early it is possible to reject a large part of the non-mutated or poorly mutated material, the volume of material can be reduced and the remaining material can be saturated with mutations to a greater extent.

In our present study, except a few, the population means of most of the treatments were shifted towards negative direction for most of the characters studied. However, the variance was increased for almost all the treatments for all the characters except plant height. Under this circumstances, it was felt appropriate to perform inter-family analysis. The heterogeneity test of family means indicated that, except a few, the families of almost all the treatments for most of the characters were significantly heterogeneous. Test of significance family means brought the most interesting finding to light is that, for almost all the characters, a small portion of the total M_2 families was shifted significantly towards positive direction. It became

essential, therefore, to focus attention on those selected number of M_2 families which showed significantly higher mean values than the corresponding control population means. Evidently, a family of this kind shows an obvious potential for selection that may ultimately lead to yield improvement.

The selection of promising families was performed based on three important characters viz., high pod number per plant, earliness and dwarfness. Instead of considering all the three characters at a time, we performed our selection considering the traits individually. However, families having the combination of all three traits or atleast two traits were present among the selected ones though their frequency was low. The families were selected irrespective of the treatment or variety to which it belongs. The seeds of the selected families were harvested and bulked familywise and were advanced by M_3 generation to see the effectiveness of M_2 selection in respect of different quantitative characters. Similar selection procedure was performed by Jana and Roy (1973) where they followed selection of M_2 families on the basis of significantly changed mean only. They took a random sample from the bulk seeds of individual selected M_2 families to raise M_3. However, Bhadra (1982) performed intra-family selection after identifying the promising M_2 families on the basis of higher means and variance or similar means to that of control and higher variance. The selection procedures followed by various authors while handling the mutagenic populations with an objective of isolation of micromutations is summarized in Table 56 .

Table 56. Selection procedures followed by some earlier authors

Authors	Crops	Characters	Selection in	
			M_2 generation	M_3 and/or late generations
1	2	3	4	5
1. Gregory 1955	Ground nut	Yield	In each group* a number of M_2 families were selected at random. A single normal looking plant for each of these selected families was advanced to M_3 generation.	From each group the 10 highest and the 10 lowest yielding M_3 families were selected and advanced to M_4 generation. A few normal looking plants with more vigour were also advanced to M_4 generation to see their yield performance.
2. Gaul et al. 1969	Barley	Yield	Randomly selected normal looking M_2 plants were advanced to raise M_3 families.	Variability experiments started in M_3 and selection was first done after M_3 results obtained. This selection was termed as early selection. Selection was conducted at between families level and this was continued through subsequent generations. In addition to early selection late selection was also done, where the first selection step was after M_4 results obtained.

*Grouping was done on the basis of degree of seedling injury in M_1 generation. Each group was maintained separately in subsequent generations. To avoid complexity it has not been described here.

Table 56. contd.

1	2	3	4	5
3. Gill et al., 1974	Barley	Selection for 100-seed weight. Data for other characters like yield, heading data and tiller number were also analysed.	M_2 plants were selected at random and advanced to raise M_3 progenies	From each treatment, top 5% M_3 progenies for 100-seed weight were selected and advanced to M_4 generation.
4. Miah and Yamaguchi, 1965 b	Rice	Yield	Randomly selected normal looking plants were advanced to raise M_3 progenies.	From each population the five highest yielding M_3 progenies were selected. Intra-family selection was done by taking two plants at random from each of these selected families.

contd.

Table 56. contd.

1	2	3	4	5
5. Ojomo and Chheda, 1972	Cow pea	Yield	M_2 generation was raised in the form of families. The test populations in M_3 were composed of approximately equal plant selections from each treatment level.	Observations were recorded in M_3 generation on different quantitative characters namely, yield of dry beans, time to flowering and number of pods per plant. Data were analysed for different statistical parameters. The best yielding 12 lines from each population were selected and advanced to M_4 generation, where a yield trail was performed .
6. Oka et al., 1958	Rice	Heading date and plant height	Bulk propagation (removal of only plants any recognizable change)	Similar procedures as adopted in M_2 generation was also followed in M_3 and M_4 generations. Selection was first practised in M_3 generation .

contd.

Table 56. contd.

1	2	3	4	5
7.	Papa et al., 1961	Soybean	Yield, seed weight, maturity, protein content and oil content.	M_2 generation was maintained and advanced to M_3 generation by Rawlings et al., 1959.	Selection was started from M_3 generation, from the genetic variance study conducted by Rawlings et al. (1958). The M_3 generation was subjected to selections for different characters independently. Selections were made for both + and - disections for all the characters except for yield where only a positive selection was done. For yield, 10 (10% of the population) of the highest yielding progenies from each treatment were selected within each variety. The similar procedure was followed for other character .

contd.

Table 56. contd.

1	2	3	4	5
8. Borojevic, 1965	Wheat	Number of kernels per spike	When analysis of variance showed an increase in growth variability in the M_2 generation, the selection was started. From each treatment 10 lines (random) were taken and from each of these lines the spike with the highest number of kernels per spike was selected for advancing to M_3 generation. The number of kernels of selected plants had to be at least 1.5 standard deviation higher than the main values of its lines.	In M_3, an essentially similar method was followed. In M_4, not just one spike with the highest number of kernels was selected, but 5 spikes were taken at random from each line, in order to see if the selected lines in the M_5 generation were homogygous or whether they would segregate.

contd.

Table 56. contd.

1	2	3	4	5
9. Bhatia and Vander Veen, 1965	Arabidopsis thaliana	Flowering time	M_2 generation was raised from bulk seeds of M_1 plants treatmentwise. Abnormal plants were discarded. Variance increased in M_2 generation. Earliest and latest plants were selected with 4.5 per cent selection intensively in both directions.	Within each M_3 line, among the normal type plants with good fertility, the plant was selected (with 2% selection intensity) which had the largest difference from the unselected control. Between families selection was not done. The same procedure was followed upto M_6 generation.
10. Gupta and Swaminathan, 1967	Brassica campestris var. toria	Number of secondary branches	M_2 families were analysed for plot mean and plot variance estimates. Families which were superior to control in plot mean and plot variance were advanced to M_3 generation.	Selection procedure in M_3 generation was same as in M_2 generation.

Table 56. contd.

1	2	3	4	5
11. Jana and Roy, 1973	Rice	Yield per plant, number of tillers, panicle length, number of sterile grains per panicle, number of filled grains per panicle and 100-filled grain weight.	Only those M_2 families were selected which showed significant deviations in mean values either in positive or negative direction from the control for any of the characters studied. Seeds from each of these M_2 families were bulked by taking an equal amount of seeds from 50 random plants from a single M_2 family (selected earlier for observation) and throughly mixed. A random sample from this bulk was sown to obtain M_3 progeny. Similar samples were made for all M_2 families	Response of M_2 selection was studied. M_4 generation was not raised.

Table 56. contd.

1	2	3	4	5
12. Bhadra, 1982	Black gram	Yield per plant, pod branches per plant, pods per plant and seeds per plant.	The M_2 families showing increased coefficients of variability (C.V.) associated with higher mean values were selected. Some M_2 families which combined an increased c.v. but similar means to control were also selected and advanced to M_3 generation. After selection of promising M_2 families an intra-family selection was also done.	A similar procedure of selection as done in M_2 was carried out in M_3 generation.

M_3 generation.

Based on the selection procedures discussed, 39 families from T-9 and 27 families from B-76 (Table 57) showing earliness in flowering, reduced height at flowering and more number of pods per plant than the respective controls were advanced to M_3 generation. Of the 39 families in T-9, 8, 19 and 12 families were for early flowering, reduced height and more pods per plant respectively. Similarly, 27 selected families of B-76 in M_2 were comprised of 6, 14 and 7 families for early flowering, reduced height and more pods per plant respectively. A few families however, combined either of the two characters and only one family showed combination of three. They were evaluated and the results are presented and discussed.

Micromutations.

To study the potentiality of M_2 selections and also to measure the amount of "additional variability" released if any, observations were recorded on nine quantitative characters in M_3 generation namely, days to flowering, days to maturity, plant height (cm), clusters per plant, pods per plant, pod length (cm), seeds per pod, seeds per plant and yield per plant (g). Following t-tests (Table 60) of individual family means of each treatment (Table 58), families were grouped for each character in three categories i.e., either no significant change, significant positive change or significant negative change as compared to control mean (Table 61). Analysis of variance was done to test the significance of means for each characters for the two varieties separately

Table 57. Selection of families at different treatments for M_3 in two black gram varieties

Variety	T-9	B-76	Total
Treatment	Family	Family	
X-10 kR	5	4	9
X-20 kR	6	2	8
X-30 kR	3	2	5
X-40 kR	2	-	2
γ-10 kR	5	3	8
γ-20 kR	4	5	9
γ-30 kR	3	2	5
γ-40 kR	3	2	5
EMS 0.5%	2	2	4
EMS 1.0%	2	3	5
EMS 1.5%	2	2	4
EMS 2.0%	2	-	2
Total	39	27	66

(Table 59). Variance of treated population (averaged over all families for each treatment) was compared against variance of control population (Table 62). Phenotypic and genotypic coefficients of variability and genetic advance were also calculated for each character. The phenotypic and genotypic correlation coefficients between all possible pairs of the nine characters were calculated for the two varieties separately following the analysis of covariances and variances (Tables 64 and 65).

Days to flowering.

Analysis of variance indicated that, the families were significantly different from each other for this character. t-tests of family means showed that a few families were significantly different for exhibiting earliness in flowering as compared to controls and majority of them showed significant delay in flowering. Family grouping based on t-tests also confirmed the above observation. In fact, altogether four families of X-10 and 20 kR showed significant deviation towards earliness in flowering in T-9. While, six families exhibited such behaviour in B-76 which were mostly derived from lower doses of mutagen treatments. Interesting enough, 1% EMS produced one early flowering family in B-76. However, in EMS treatments delayed flowering appeared in families with greater frequency. When the treated population variances were compared against control population variance, variances due to treatments were found to be higher

than that of control population variance indicating an increase in variability in M_3. However, higher doses of mutagen treatments in general, showed very high level of variability. This is not very much unexpected as higher doses of mutagen particularly all EMS treatments in general, induced lateness in flowering in M_3 which generated increased variability for lateness causing over all increased variability. This increase in variability in M_3 may be considered as the release of additional variability. Such increase in variance in M_3 for flowering was reported by Khan (1984) in green gram who observed that late flowering was of common occurrence. Similar observations were also recorded by Sharma (1986) in lentil.

Days to maturity.

Family means were significant for both variaties indicating families were significantly different from each other for this character (Table 59). t-tests of the family means showed that majority of the families in B-76 for different treatments exhibited significant earliness in maturity. While, this was not so in case of T-9. Grouping of families demonostrated that majority of the families in either of the varieties showing early maturity were derived from lower doses of mutagen treatments. However, around 44 per cent families in T-9 showed no change in maturity while it was about 19 per cent in B-76 suggesting the greater possibility of inducing early maturity lines in B-76 as compared to T-9. This is not very unusual as, B-76 is almost a week late in maturity

compared to T-9. In fact, T-9 has already been selected for earliness in which possibility of isolating further early matured lines is likely to be diminished. This by and large supports the early observation of Brock (1965). What is significant here is that, even in T-9 it is possible to induce earliness in maturity by as many as six days (Table 57).

In fact two lines matured around 85 days compared to 91 days of control (T-9). In case of B-76, one family matured by 87 days showing a reduction of almost 9 days as compared to control (B-76). These families/lines were obtained from the low doses (10 and 20 kR) of X-ray and gamma ray.

In conformity with our present observation, Bhadra (1982) in black gram and Verma and Singh (1984) in green gram also reported early matured M_3 families.

Treated populations in B-76 in general, showed increased variation as compared to control. Contrary to this 50 per cent of the treated populations in T-9 exhibited higher magnitude of variation. The increase in variance of the selected families as compared to controls indicates release of additional variability.

Plant height.

Families were significantly different for plant height (Table 58). 't'-tests of family means showed that larger number of families in T-9 were characterised by significantly reduced

plant height following mutagen treatments than B-76. This becomes very much evident when family means of both varieties were grouped. In fact, 69 per cent families of T-9 exhibited reduced plant height as a result of mutagen treatments while reduction in plant height was recorded for 41 per cent families in B-76. Height was reduced by 6 to 8 cm in some of the families of T-9 and B-76. On the other hand, around 30 per cent families of B-76 showed increase in height as against 10 per cent in T-9 though in both varieties shift in mean for plant height was more towards negative direction. This negative shift was more pronounced in T-9 in comparison to B-76. Treated population variances averaged over all families for each treatment on the other hand, indicated no change or less variability in majority of the cases for T-9. In other words, shift in mean for either directions may not necessarily cause increase in variation. However, variances of treated populations at increased doses of mutagens generally were found to be higher than controls in both varieties suggesting the release of additional variability in M_3 for plant height.

Our present observation of reduction in plant height in M_3 finds support from similar observations made by Borojevic and Borojevic (1968) in wheat, Mujeeb and Greig (1973) in french bean, Nimako *et al.* (1982) in soyabean, Sharma and Shama (1981) and Vasudevan *et al.* (1984) in lentil. On the contrary, increase in plant height was reported in M_3 by Vasileva (1975) in peas and Ravi *et al.* (1979) in lentil. Increase in variance in M_3 generation

after mutagenic treatments was reported by Borojevic and Borojevic (1969), Bhatia and Swaminathan (1963) and Bahl *et al.* (1968) in wheat; and Ramanathan (1983) in ground nut.

Clusters per plant.

Variable number of clusters per plant in different families of T-9 and B-76 were recorded showing higher or lower number or no change as compared to controls (Table 58). The analysis of variance showed the significant differences among families (Table 59) confirming observed differences as real. The grouping of families following 't'-tests of the individual means (Table 61) indicated that, 21 per cent family means of T-9 and 26 per cent family means of B-76 were shifted towards desirable direction i.e., towards positive direction. Such shift in mean for increased number of clusters per plant was in general recorded in families obtained from gamma ray treatments. On the other hand, 31 per cent families of T-9 and 30 per cent families of B-76 were shifted towards negative direction which were obtained more frequently in X-ray treated families. However, 49 per cent families of T-9 and 44 per cent families of B-76 showed no significant shift in mean from the control. In M_2 generation, most of the family means in both the genotypes for clusters per plant was shifted towards negative direction. But in M_3, a good number of family means in both genotypes were shifted towards positive direction thereby indicating recovery effect of the mutants in M_3 generation in respect of clusters per plant.

The population variances of all the treatments for both the varieties were increased sharfly as compared to controls. This indicates further release of variability in M_3 generation. In T-9, highest variance was observed for 30 kR X-ray followed by 20 kR gamma rays. On the other hand, in B-76 highest variance was observed for 1.5% EMS followed by 30 kR gamma ray. Such increased variations for treated populations are not entirely unexpected as no selection was practiced for clusters per plant in M_2. Parallel to our observations increase in variance in M_3 generation was reported by Bhadra (1982) in black gram. He also recorded increase in number of clusters per plant as reported earlier by Krishnaswamy et al. (1973) in green gram.

Pods per plant.

Following 't'-tests of the family means (Table 60), grouping of the families (Table 61) indicated that, 21 per cent families of T-9 and 26 per cent familiesof B-76 showed significantly increased means for this important yield component. Around 45 per cent of the families in both varieties showed no significant change in mean values. So, in comparison with M_2 where majority of the family means in both varieties were shifted in the negative direction (Table 17), more number of family means were shifted towards positive direction in M_3 generation. In other words, early selection in M_2 appears to be fruitful as it leads to recovery of mutants with increased pod number in M_3. Similar recovery of

mutants for pods were also reported by Bhadra (1982) in black gram and by Sharma (1986) in lentil.

The population variance for pods per plant was increased for all the treatments in both the varieties. In T-9, highest variance was observed for 40 kR gamma ray while in B-76, highest variance was observed for 1.0 per cent EMS. It was found that in general, the variance in M_3 was increased sharply for higher doses of gamma ray and EMS treatments (Table 62). Increase in variance in M_3 due to mutagenic treatments compared to control was reported by Khan (1984) in green gram and Kundu and Singh (1982) in black gram.

Pod length (cm.).

The results of 't'-tests (Table 60) and subsequently grouping of family means (Table 61) for pod length showed that, the mean pod length of only one family was shifted in the positive direction for T-9. Not a single family of B-76 showed increase in pod length in B-76. Instead, 31 per cent families of T-9 and 56 per cent families of B-76 showed reduction in mean pod length. In general, the treated population variance was decreased as compared to control in M_3 generation. The variance was decreased for all treatments in both varieties except for 10 kR gamma ray in T-9 and 20 kR gamma ray in B-76. Thus, it can be suggested that, selection for pod length should be performed in M_2 generation where families with increased mean pod length together with high range of variation were available (Tables 33 and 36).

seeds per pod.

The 't'-tests of family means was done separately for the two varieties (Table 60) and subsequently grouping of the family means (Table 61) indicated that, 5 per cent families of T-9 and 22 per cent families of B-76 showed significantly increased number of seeds per pod compared to control. Thus, the two varieties responded differentially in respect of shifting of means towards positive direction. Interesting enough, fewer number of families in B-76 showed positive shift in M_2 and M_2 was grown in winter, while M_3 was raised in Kharif. This prompts us to suggest that seasonal effect may play an important role for realizing useful mutants and different genotypes may react differentially to seasonal variations. This type of seasonal effects on genotypes for recovering micromutants were also encountered earlier by Bhadra (1982) in black gram.

The treated population variance was increased in both the varieties. In T-9, highest variance was observed for 30 kR X-ray and in B-76 highest variance was observed for 40 kR gamma ray suggesting release of variability at higher doses of physical mutagens. Similar increase in variance in M_3 generation was reported by Khan (1983) in green gram.

Seeds per plant .

Different families exhibited variable number of seeds per plant. The analysis of variance showed that families were

significantly different. 't'-tests of the individual family means confirmed significant deviation of family means for this characters either positive or negative direction in comparison to control means. From the grouping of the family means it was found that, 28 per cent families of T-9 and 26 per cent families of B-76 were shifted significantly towards positive direction showing parallel behaviour of both varieties for positive shift in mean for seeds per plant. However, more than 50 per cent families of both the varieties did not show any significant deviation from the controls. It is interesting that, a considerable number of families in either varieties shifted towards positive direction as compared to M_2 generation where 6 per cent families of T-9 only showed such shift. It would thus indicate the possibility of isolating families of increased number of seeds per plant in M_3 generation. Similar increase in number of seeds per plant was reported earlier by Ravi et al. (1979) in lentil.

The population variance for this character in M_3 was increased for all treatments in both the varieties with the exception of 20 kR and 30 kR X-ray in B-76. In T-9, highest variance was observed for 40 kR gamma ray, but it was so for 20 kR gamma ray in B-76. In general, higher doses of mutagen treatments released higher variability.

Yield per plant.

Seed yield per plant in M_3 generation was different for different families. The families were significantly different

from each other as indicated from analysis of variance. The 't'-tests of the individual family means confirmed significant deviation of family means for seed yield per plant. From the grouping of family means it was found that, 33 per cent families of T-9 and 26 per cent families of B-76 out yielded the respective controls in M_3 generation indicating similar behaviour of both the varieties for shifting of means towards positive direction. Around 54 per cent families of both the varieties did not show any significant deviation from the control for yield per plant. The result of M_3 regarding seed yield is promising because, a good number of families in both the varieties out yielded the controls. Similar increase in seed yield per plant was reported earlier by Vlk (1975) in broad bean, Ravi et al. (1979) in lentil, Chaturvedi and Singh (1980) in green gram and Kundu and Singh (1980) in black gram.

The population variance for yield per plant in M_3 was increased for all the treatments in both the varieties except 30 kR X-ray in B-76. The highest variance in T-9 was observed for 40 kR gamma ray and in B-76 for 20 kR gamma ray. Thus, gamma ray treatments appear to be very effective in generating variation for seed yield per plant. Similar increase in variance in M_3 generation by gamma ray was reported in green gram by Khan (1983) and in black gram by Kundu and Singh (1982).

Variability and genetic advance.

The phenotypic and genotypic coefficients of variability (PCV and GCV), genetic advance (GA) and genetic advance expressed

as percentage of mean (GA %) were calculated for each of the nine characters for the two varieties separately and are presented in Table 63. A general trend was observed of the nine characters studied namely, plant height, clusters per plant, pods per plant, seeds per plant and yield per plant in both varieties showed relatively high GCV. Correspondingly, these characters exhibited high genetic advance, expressed as percentage of mean. In T-9, GA% was found to be highest for pods per plant followed by seeds per plant and yield per plant. On the other hand, in B-76 plant height showed highest GA% of mean followed by pods per plant and clusters per plant. In other words, high genetic advance expressed as per cent of mean was realised for pods per plant in either of the varieties. Days to flowering and days to maturity showed very limited genetic advance expressed as percentage of mean in both varieties. The trend recorded in M_3 for these genetic parameters more or less confirms the earlier observations reported for M_2.

Krishnaswamy and Rathinam (1982) in green gram reported increased genetic advance in yield and yield contributing characters. In lentil, Dixit and Dubey (1985) reported highest genetic advance for grain yield per plant followed by pods per plant.

Correlations.

As in other crops, yield in black gram is a complex character and may involve several related characters. Various

Table 58. Family means of nine characters in M_3 for T-9 and B-76

T - 9

Families/ Lines	Days to flower-ing	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
1	37.08	86.42	30.42	11.42	28.00	3.89	6.00	125.75	5.00
2	37.83	85.50	27.75	12.42	29.25	4.01	6.25	133.17	4.77
3	35.08	86.17	25.99	9.83	23.42	3.87	5.83	106.68	4.31
4	36.17	85.58	29.47	10.67	24.08	3.69	5.57	105.75	4.16
5	35.05	86.50	23.47	8.17	22.67	3.88	6.07	138.00	5.84
6	38.33	92.00	31.04	11.75	28.42	3.80	5.62	127.67	4.77
7	37.92	92.50	36.16	16.50	36.50	4.12	6.33	168.17	6.18
8	36.92	90.83	32.13	13.25	31.92	3.95	5.90	145.92	5.73
9	37.42	92.42	32.50	13.00	29.75	3.91	5.87	133.75	5.39
10	36.00	84.83	25.11	9.67	21.08	3.90	6.03	108.17	4.19
11	35.50	87.25	27.25	10.42	22.67	3.87	6.13	110.50	4.52
12	37.42	90.58	30.84	10.83	27.42	3.83	5.85	136.42	5.44
13	39.08	89.75	27.74	10.17	22.58	3.84	6.63	106.00	4.13

contd.

Table 58. contd.

T - 9

Families/ Lines	Days to flower-ing	Days to matu-rity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
14	35.17	85.50	28.11	8.08	19.50	3.38	4.83	84.00	3.37
15	34.67	85.42	25.25	10.25	24.50	3.54	5.78	111.75	4.41
16	37.42	93.58	30.91	12.08	31.75	3.84	5.95	166.00	6.17
17	36.17	84.92	27.48	9.58	21.17	3.72	5.55	100.50	3.76
18	36.50	90.00	26.71	10.67	25.50	3.68	5.79	117.83	4.49
19	36.00	89.67	25.41	9.92	23.75	3.79	5.60	118.50	4.49
20	37.92	89.33	24.62	10.17	24.08	3.91	6.17	122.58	4.60
21	37.50	91.75	24.15	8.33	21.33	3.71	5.73	102.00	3.83
22	37.08	90.58	23.80	9.67	22.25	3.87	6.01	115.08	4.38
23	38.50	93.00	26.41	11.75	23.42	3.86	5.98	128.33	5.27
24	42.92	92.67	25.37	10.58	24.42	3.55	5.60	135.50	4.91
25	37.17	89.58	24.97	9.33	20.83	3.90	5.73	89.58	3.54
26	40.08	91.17	25.82	7.58	17.75	3.68	5.58	79.33	3.27

contd.

Table 58. contd.

T - 9

Families/ Lines	Days to flower-ing	Days to matu-rity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
27	35.33	91.17	27.01	10.75	28.17	3.76	5.82	125.25	4.75
28	38.50	93.42	27.78	13.75	30.83	3.96	5.92	159.92	6.21
29	37.92	92.67	29.36	12.67	31.25	3.98	6.07	148.92	5.97
30	38.50	93.75	40.02	15.50	37.42	3.89	6.07	191.58	7.16
31	40.42	92.33	30.48	11.17	26.58	3.97	6.03	137.33	5.43
32	39.50	91.17	27.45	9.92	24.83	3.68	5.91	132.75	5.44
33	40.75	89.08	26.61	10.67	21.92	3.66	5.55	120.08	5.12
34	42.42	95.17	26.69	11.08	26.25	3.82	5.95	146.06	5.75
35	39.08	92.75	22.55	8.83	22.25	3.77	5.83	117.67	4.60
36	39.25	95.00	35.91	14.25	32.83	3.68	6.15	154.08	6.18
37	41.42	91.67	41.53	17.00	38.08	3.85	6.12	183.17	7.12
38	37.08	86.00	23.93	10.00	23.33	3.88	6.05	128.42	4.93
39	40.17	92.08	25.75	11.75	28.00	3.93	5.98	158.67	6.80
Control	36.25	91.00	31.02	11.17	26.50	3.92	6.03	121.92	4.67

contd.

Table 58. contd.

B - 76

Families/ Lines	Days to flower-ing	Days to matu-rity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
1	39.33	94.08	47.65	14.42	34.67	3.98	6.35	172.08	6.63
2	41.17	94.08	46.18	12.50	23.92	3.84	5.98	137.00	5.61
3	43.42	94.00	27.57	12.00	30.58	3.89	5.97	139.75	5.75
4	42.42	95.08	25.21	11.17	20.25	3.94	6.12	82.58	3.54
5	43.42	91.08	28.35	13.00	26.92	4.06	6.32	155.67	6.21
6	39.08	89.42	25.48	9.93	17.33	3.72	5.77	96.50	3.92
7	37.50	88.58	20.54	9.00	21.58	3.77	5.84	97.00	3.72
8	37.67	88.92	24.47	10.17	22.42	3.78	5.88	118.75	4.63
9	41.92	93.08	29.44	13.83	36.00	3.97	5.98	167.75	6.82
10	40.83	94.17	31.25	11.75	26.17	4.09	6.25	138.08	5.67
11	40.08	92.33	25.47	10.17	24.75	3.98	6.15	143.42	5.88
12	40.33	90.42	38.99	15.42	32.67	4.06	6.60	180.50	6.83
13	39.17	94.83	35.56	14.08	31.33	3.99	5.73	160.67	6.61
14	38.33	87.00	23.67	10.42	21.58	3.82	5.93	109.58	4.14

contd.

Table 58. contd.

Families/ Lines	Days to flower-ing	Days to matu-rity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
14									
15	40.00	90.83	23.39	10.42	20.08	3.69	5.81	116.58	4.75
16	39.75	91.25	24.42	11.17	24.17	3.80	5.97	122.58	4.94
17	39.92	89.42	29.86	11.58	27.00	3.95	6.05	154.50	5.79
18	39.42	94.33	24.86	10.08	22.17	3.71	5.42	123.58	5.07
19	44.33	102.50	38.24	16.00	35.67	3.79	5.60	153.50	6.61
20	42.67	39.75	35.20	17.25	34.92	3.80	5.65	175.00	6.52
21	38.33	93.75	33.33	14.75	32.25	3.74	5.87	160.42	5.91
22	40.42	94.33	27.24	11.67	27.17	3.75	5.73	146.83	5.76
23	42.33	93.67	22.01	9.00	21.83	3.72	5.67	106.17	4.33
24	44.75	95.42	27.67	9.33	25.00	3.97	5.96	141.83	5.49
25	41.50	93.25	29.48	11.92	25.92	3.98	5.82	132.33	5.23
26	40.42	89.25	26.32	11.25	25.50	3.71	5.68	129.42	5.10
27	43.33	92.50	27.28	12.92	29.00	4.00	6.17	165.50	6.28
Control	41.00	96.00	28.30	11.67	26.58	4.02	5.98	133.92	5.22

Table 59. Analysis of variance of nine characters in M_3 for T-9 and B-76

T - 9

Source	DF	Mean sum of squares								
		Days to flowering	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
Replication (R)	2	51.54**	25.49^{NS}	163.29**	65.20**	343.41**	0.22**	0.78**	6584.31**	9.22**
Family (F)	39	12.33**	27.48*	55.05**	13.70**	71.17**	0.06**	0.21**	1877.58**	2.82**
Error (E)	78	6.02	10.22	27.68	7.80	28.75	0.02	0.09	933.49	1.40
Total (T)	119	8.85	16.13	38.93	10.70	47.94	0.037	0.14	1337.87	2.00

B - 76

Replication (R)	2	41.75**	113.52**	73.85**	4.68^{NS}	43.08^{NS}	0.055*	0.055^{NS}	1883.75^{NS}	1.89^{NS}
Family (F)	27	11.94**	30.77**	136.00**	14.32**	79.91**	0.05**	0.20**	1877.45*	2.73*
Error (E)	54	4.97	9.29	21.03	6.18	30.69	0.017	0.07	1212.95	1.90
Total (T)	83	8.12	18.79	59.70	8.79	47.00	0.028	0.11	1445.28	2.17

* Significant at 1%

** Significant at 5%

Table 60. 't' - values of family means for nine characters in M_3 for T-9 and B-76

T - 9

Families/ Lines	Characters								
	Days to flowering	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
1	1.38	-5.42**	-0.61	0.44	1.22	-0.47	-0.31	0.71	1.62
2	3.55**	-8.32**	-3.44**	2.30**	1.64	1.43	2.45*	1.55	0.37
3	-2.96**	-5.63**	-4.62**	-2.34*	-2.15*	-0.92	-2.72*	-2.52*	-1.45
4	-0.13	-6.88**	-1.34	-0.77	-1.47	-4.47**	-5.12**	-2.17*	-1.81
5	-2.14*	-4.41**	-8.77**	-4.18**	-2.47*	-0.69	0.35	2.32*	3.98**
6	3.98**	1.15	0.01	0.58	0.81	-1.65	-3.72**	0.55	0.26
7	3.22**	2.00	3.96**	5.51**	4.10**	3.47**	3.34**	4.11**	3.43**
8	1.71	-0.25	0.86	2.74*	2.38*	0.38	-1.59	2.41*	2.85**
9	2.56*	1.26	1.55	1.89	1.56	-0.15	-1.56	1.28	1.92
10	0.81	-6.84**	-6.41**	-2.30*	-3.29**	0.30	0	-1.67	-1.53
11	-1.61	-4.55**	-4.11**	-0.98	-2.32*	0.84	1.84	-1.45	-0.49
12	1.95	-0.46	-0.17	-0.42	0.43	-1.36	-2.09*	1.36	1.94
13	3.69**	-1.26	-2.81*	-1.41	-2.07*	-1.10	0	-1.89	-1.65

contd.

Table 60. contd.

T - 9

Families/ Lines	Days to flower-ing	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
14	-3.11**	-6.98**	-2.28*	-5.69**	-4.17**	-9.95**	-18.61**	-5.06**	-2.65*
15	-2.42*	-7.16**	-6.70**	-1.40	-0.081	-5.75**	- 3.17**	-1.21	-0.84
16	2.54*	4.10**	-0.17	1.55	3.46**	-1.21	- 0.83	5.69**	5.18**
17	-0.19	-7.92**	-3.18	-2.29*	-3.16**	-2.75*	- 4.58**	-2.79*	-3.14**
18	0.43	1.25	-3.88**	-1.18	0.49	-3.30**	- 1.84	-0.47	-0.46
19	0.52	-1.47	-6.61**	-2.07*	-1.28	-1.79	- 4.97**	-0.34	-0.47
20	3.22**	-1.85	-6.08**	-2.13*	-1.73	-0.17	-1.27	0.10	-0.30
21	2.00	0.87	-5.86**	-4.73**	-3.55**	-3.78**	- 3.34**	-3.06**	-3.27**
22	1.65	0.56	-7.93**	-2.53*	-2.40*	-0.69	- 0.06	-0.73	-0.77
23	3.00**	2.55*	-4.50**	0.93	-2.38*	-0.83	- 0.50	0.97	2.19*
24	11.67**	2.45*	-5.79**	-0.87	-1.03	-6.43**	-4.92**	1.32	0.62
25	1.26	-1.41	-6.28**	-2.58*	-3.48**	-0.42	-2.62*	-4.46**	-3.95**
26	5.33**	0.21	-5.64**	-6.66**	-5.40**	-5.20**	-7.93**	-6.19**	-5.20**

Contd.

Table 60. contd.

T - 9

Families/ Lines	Days to flower-ing	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
27	-1.61	0.14	-3.91**	-0.51	0.92	-2.42*	-2.35*	0.42	0.28
28	3.83**	2.80*	-3.28**	3.21**	2.08*	0.60	-1.33	3.60**	3.97**
29	2.73*	2.25*	-1.97	2.63*	2.60*	0.91	0.40	3.26**	3.93**
30	4.41**	3.42**	5.68**	6.35**	3.39**	-0.58	0.46	4.52**	4.49**
31	6.27**	1.65	-0.53	0	0.03	0.87	0	1.28	1.72
32	3.33**	0.18	-3.25**	-1.37	-1.16	-3.50**	-1.51	1.55	2.82**
33	5.86**	-2.25*	-4.66**	-0.80	-3.62**	-3.93**	-5.14**	-0.29	1.78
34	9.27**	4.94**	-4.28**	-0.14	-0.12	-1.51	-0.96	2.23*	2.62*
35	4.28**	2.46*	-7.31**	-4.78**	-3.04**	-2.42*	-2.23*	-0.61	-0.27
36	6.62**	5.13**	3.22**	3.93**	3.28**	-0.97	1.19	3.78**	4.46**
37	8.62**	0.60	4.79**	7.14**	5.28**	-1.16	1.30	5.86**	6.32**
38	1.20	-6.62**	-6.89**	-1.98	-1.78	-0.60	0.21	0.74	0.80
39	6.45**	1.10	-4.33**	0.80	0.77	0.18	-0.68	3.66**	5.38**

contd.

Table 60. contd.

Families/ Lines	Days to flower-ing	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
1	-1.69	-2.70*	16.93**	2.38**	3.28**	-0.58	4.38**	3.01**	3.14**
2	0.25	-2.32*	7.10**	1.58	-1.41	-2.74*	0	0.30	1.00
3	2.30*	-2.87**	- 0.78	0.51	2.74*	-2.23*	-0.08	0.83	2.03
4	2.32*	-1.32	- 3.98**	-0.54	-2.54*	-1.44	1.58	-0.46**	-3.52**
5	2.70*	-5.26**	0.04	1.52	0.13	0.53	3.31**	1.56	1.78
6	-2.70*	-9.26**	- 3.47**	-2.36*	-5.86**	-4.25**	-2.32*	-4.42**	-4.03**
7	-5.10**	-6.20**	- 9.65**	-3.78**	-2.27*	-4.14**	-1.63	-3.64**	-3.95**
8	-7.42**	-8.18**	- 3.64**	-2.30*	-2.36*	-5.76**	-1.05	-1.72	-1.76
9	1.51	-4.90**	1.38	2.47*	5.14**	-0.75	0	4.02**	4.96**
10	-0.28	-2.50*	2.20**	0.13	- 0.18	1.16	2.94**	0.82	0.97
11	-1.68	-7.37**	- 3.09**	-2.78*	- 1.10	-0.73	1.85	1.05	1.38
12	-0.82	-10.44**	8.26**	4.76**	2.48*	0.80	7.00**	3.60**	3.40**
13	-2.93**	-1.55	5.28**	3.01**	1.98	-0.50	-3.56**	2.21*	2.94**
14	-3.70**	-11.54**	-5.94**	-2.32*	- 3.48**	-3.12**	-0.46	-3.19**	-3.95**
15	-1.17	- 6.33**	-6.65**	-2.92**	- 4.86**	-6.62**	-1.98	-2.41*	-1.69

contd.

Table 61. Grouping of families for nine characters in M_3 for T-9 and B-76

T - 9

Characters / Treatment	Days to flowering			Days to maturity			Plant height			Clusters per plant		
	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change
X-10 kR	2	2	1	1	4	-	-	4	1	1	2	2
X-20 kR	1	2	3	1	3	2	-	6	-	-	3	3
X-30 kR	2	-	1	2	-	1	-	2	1	-	1	2
X-40 kR	2	-	-	1	-	1	-	1	1	-	1	1
γ-10 kR	1	-	4	-	1	4	1	3	1	2	1	2
γ-20 kR	2	-	2	1	2	1	-	3	1	1	1	2
γ-30 kR	1	-	2	1	-	2	-	1	2	1	1	1
γ-40 kR	3	-	-	1	-	2	1	1	1	1	1	1
EMS 0.5%	2	-	-	-	1	1	-	2	-	-	-	2
EMS 1.0%	2	-	-	2	-	-	-	2	-	-	1	1
EMS 1.5%	2	-	-	1	-	1	2	-	-	2	-	-
EMS 2.0%	1	-	1	-	1	1	-	2	-	-	-	2
Total	21	4	14	11	12	16	4	27	8	8	12	19
Per cent	53.85	10.26	35.90	28.21	28.21	43.58	10.26	69.23	20.51	20.51	30.77	48.72

contd.

Table 61 • contd•

B - 76

Characters	Days to flowering			Days to maturity			Plant height			Clusters per plant		
Treatment	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Charge	No Change	+ Change	- Change	No Change
X-10 kR	-	1	3	-	4	-	2	1	1	2	1	1
X-20 kR	-	1	1	-	2	-	1	1	-	-	1	1
X-30 kR	-	-	2	-	2	-	-	2	-	-	1	1
γ - 10 kR	2	-	1	-	2	1	-	2	1	-	1	2
γ - 20 kR	1	2	2	-	4	1	2	1	2	2	1	2
γ - 30 kR	1	-	1	1	1	-	1	1	-	1	-	1
γ - 40 kR	1	1	-	-	1	1	2	-	-	2	1	1
EMS 0•5%	-	-	2	-	1	1	-	1	1	-	1	1
EMS 1•0%	1	1	1	-	2	1	-	1	2	-	2	1
EMS 1•5%	1	-	1	-	2	-	-	1	1	-	-	2
Total	7	6	14	1	21	5	8	11	8	7	8	12
Per cent	25•93	22•22	51•85	3•70	77•78	18•52	29•63	40•74	29•63	25•93	29•63	44•44

contd•

Table 61. contd.

T - 9

Characters	Pods per plant			Pod length			Seeds per pod			Seeds per plant			Yield per plant		
Treatment	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change
X-10 kR	-	3	2	-	1	4	1	2	2	-	2	3	-	1	4
X-20 kR	-	4	2	-	3	3	-	3	3	1	2	3	2	1	3
X-30 kR	-	1	2	-	1	2	-	3	-	-	1	2	-	1	2
X-40 kR	1	1	-	-	1	1	-	1	1	1	1	-	1	1	-
γ -10 kR	2	1	2	1	3	1	1	2	2	2	1	2	2	1	2
γ -20 kR	1	2	1	-	-	4	-	-	4	1	-	3	1	-	3
γ -30 kR	1	-	2	-	-	3	-	2	1	1	-	2	1	-	2
γ -40 kR	1	-	2	-	-	3	-	-	3	1	-	2	1	-	2
EMS 0.5%	-	1	1	-	2	-	-	1	1	-	-	2	1	-	1
EMS 1.0%	-	1	1	-	1	1	-	1	1	1	-	1	1	-	1
EMS 1.5%	2	-	-	-	-	2	-	-	2	2	-	-	2	-	-
EMS 2.0%	-	-	2	-	-	2	-	-	2	1	-	1	1	-	1
Total	8	14	17	1	12	26	2	15	22	11	7	21	13	5	21
Per cent	20.51	35.90	43.59	2.56	30.77	66.67	5.13	38.46	56.41	28.21	17.95	53.85	33.33	12.82	53.85

contd.

Table 61. contd.

Characters	Pods per plant			Pod length			Seeds per pod			Seeds per plant			Yield per plant		
Treatment	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change	+ Change	- Change	No Change
X-10 kR	2	1	1	-	2	2	1	-	3	2	-	2	2	-	2
X-20 kR	-	1	1	-	1	1	1	-	1	-	1	1	-	1	1
X-30 kR	-	1	1	-	2	-	-	-	2	-	1	1	-	-	2
X-40 kR															
ɣ -10 kR	1	1	1	-	1	2	-	-	3	-	1	2	-	1	2
ɣ -20 kR	1	1	3	-	1	4	3	2	-	2	1	2	2	1	2
ɣ -30 kR	1	1	-	-	2	-	-	2	-	-	-	2	1	-	1
ɣ -40 kR	2	-	-	-	2	-	-	1	1	2	-	-	1	-	1
EMS 0.5%	-	1	1	-	2	-	-	2	-	-	1	1	-	1	1
EMS 1.0%	-	1	2	-	1	2	-	-	3	-	1	2	-	1	2
EMS 1.5%	-	-	2	-	1	1	1	1	-	1	-	1	1	-	1
EMS 2.0%															
Total	7	8	12	0	15	12	6	8	13	7	6	14	7	5	15
Per cent	25.93	29.63	44.44	0	55.56	44.44	22.22	29.63	48.15	25.93	22.22	51.85	25.93	18.52	55.55

Table 62. Population variance of different treatments of nine characters for T-9 and B-76 in M_3

T - 9

Treatments	Characters								
	Days to flowering	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
X-10 kR	2.89	4.44	6.44	3.59	20.24	0.016	0.08	370.34	0.56
X-20 kR	4.21	4.44	4.43	4.60	27.64	0.02	0.13	480.01	0.79
X-30 kR	4.19	5.10	7.14	8.98	43.78	0.014	0.14	967.81	1.37
X-40 kR	4.05	2.54	13.64	3.11	18.55	0.01	0.06	414.25	0.61
γ - 10 kR	2.28	5.34	8.34	7.53	46.82	0.03	0.13	888.23	1.42
γ - 20 kR	1.78	6.83	3.05	8.78	34.19	0.02	0.07	829.43	1.25
γ - 30 kR	3.26	4.83	2.62	5.38	44.16	0.023	0.09	1047.92	1.53
γ - 40 kR	3.28	4.43	11.11	4.43	78.71	0.008	0.12	1896.17	2.43
EMS 0.5%	11.04	5.51	4.60	8.12	10.54	0.02	0.08	297.36	0.48
EMS 1.0%	5.14	3.37	6.01	3.13	29.22	0.02	0.08	866.48	1.24
EMS 1.5%	2.69	7.67	41.33	8.54	45.21	0.014	0.08	972.51	1.43
EMS 2.0%	4.90	5.35	7.02	5.01	33.16	0.013	0.08	934.65	1.42
Control	0.97	4.06	8.33	1.00	11.50	0.03	0.02	243.75	0.35

contd.

Table 62. contd.

B - 76

Treatments	Characters								
	Days to flowering	Days to maturity	Plant height	Clusters per plant	Pods per plant	Pod length	Seeds per pod	Seeds per plant	Yield per plant
X - 10 kR	4.59	4.49	32.20	9.63	36.75	0.02	0.09	966.67	1.35
X - 20 kR	3.44	5.50	4.25	3.42	33.71	0.02	0.104	176.20	1.47
X - 30 kR	6.90	5.52	2.35	4.38	8.23	0.022	0.07	226.30	0.37
γ - 10 kR	6.07	3.21	4.78	6.45	33.34	0.01	0.113	743.14	1.90
γ - 20 kR	8.07	5.25	13.03	7.53	50.97	0.03	0.09	1586.84	2.43
γ - 30 kR	10.27	3.53	11.06	10.01	45.80	0.02	0.12	1131.40	1.96
γ - 40 kR	5.00	4.86	10.54	8.78	53.14	0.015	0.16	1292.36	1.78
EMS 0.5%	4.90	11.64	3.35	5.89	33.30	0.02	0.11	852.25	1.44
EMS 1.0%	7.29	5.28	4.70	4.35	62.07	0.007	0.08	1488.86	2.17
EMS 1.5%	5.21	2.74	6.37	11.28	43.22	0.008	0.07	1129.57	1.51
Control	2.00	1.84	4.60	1.11	14.64	0.03	0.03	375.75	0.49

Table 63. Variability and genetic advance of nine characters in M_3 for T-9 and B-76

T - 9

Sl. No.	Characters	PCV	GCV	ECV	GA	GA%
1	Days to flowering	7.53	3.83	6.49	1.52	4.02
2	Days to maturity	4.43	2.66	3.53	2.96	3.28
3	Plant height	21.38	10.64	18.54	3.10	10.93
4	Clusters per plant	28.06	12.60	25.07	1.30	11.67
5	Pods per plant	25.00	14.35	20.47	4.45	16.98
6	Pods length	4.53	2.62	3.70	0.12	3.14
7	Seeds per pod	6.13	3.40	5.10	0.23	3.91
8	Seeds per plant	27.44	13.78	23.73	18.35	14.25
9	Yield per plant	27.19	13.63	23.52	0.71	14.12

contd.

Table 63. contd.

B - 76

Sl. No.	Characters	PCV	GCV	ECV	GA	GA%
1	Days to flowering	6.61	3.73	5.46	1.77	4.33
2	Days to maturity	4.36	2.88	3.28	3.64	3.92
3	Plant height	26.07	20.95	15.82	10.25	34.69
4	Clusters per plant	24.74	13.66	20.63	1.87	15.52
5	Pods per plant	25.67	15.15	20.72	4.93	18.44
6	Pod length	4.46	2.58	3.36	0.12	3.09
7	Seeds per pod	5.59	3.37	4.46	0.25	4.22
8	Seeds per plant	27.34	10.74	25.14	12.05	8.70
9	Yield per plant	26.94	9.66	25.15	0.39	7.12

PCV = Phenotypic coefficient of variability
GCV = Genotypic coefficient of veritability
ECV = Environmental coefficient of variability
GA = Genetic advance
GA% = Genetic advance % of mean

relationships between yield components have been observed. There is a substantial body of data that demonstrate pod as the classical yield component in grain legumes (Adams, 1974). Unfortunately, many characters on the other hand, show negative association with seed yield and its components. For example, early or late flowering and maturity, either early or late influence seed yield through different yield components and often their influence is known to reduce seed yield (Dasgupta, 1983).

Mutation may prove to be useful to break such undesirable relationships. With this in view, we examined correlation coefficients of different characters in our mutagen treated populations in two black gram varieties and the results are given in Tables 64 and 65. As expected in either varieties, pods per plant appeared to be important determinant of plant yield as they showed significantly positive phenotypic correlations and very high genotypic correlation with yield. Similarly, characters like days to flowering, days to maturity, seeds per pod etc. showed significantly positive phenotypic correlations and high genotypic correlations with seed yield. What is more significant here is that, days to flowering and days to maturity in case of mutagen treated populations of T-9 registered significant negative association with seeds per pod indicating thereby earliness in flowering and maturity may lead to increase in seed number in pod. However, such trend was not entirely recored in mutagen treated populations of B-76. Nevertheless, in this case also a high and strong negative correlation at

Table 64. Phenotypic (upper values) and genotypic (lower values) correlation coefficients in T-9 between various character pairs in M_3

Characters	Days to flowering	Days to maturity	Plant height	Cluster per plant	Pods per plant	Pod length	Seeds per pod	Yield per plant
Days to flowering		0.51**	0.05	0.08	0.08	-0.06	-0.65**	0.18*
		0.84	0.36	0.77	0.69	0.10	-0.89	0.86
Days to maturity			0.23**	0.21**	0.42**	0.14	-0.37**	0.42**
			0.58	0.93	0.88	0.42	-0.79	0.79
Plant height				0.71**	0.67**	0.18*	0.14	0.51**
				0.96	0.97	0.57	0.50	0.41
Clusters per plant					0.87**	0.41**	0.33**	0.79**
					0.83	0.93	0.86	0.80
Pods per plant						0.53**	0.38**	0.85**
						0.96	0.99	0.95
Pod length							1.00**	0.42**
							1.00	0.71
Seeds per pod								0.43**
								0.79

* Significant at 5% level
** Significant at 1% level

Table 65. Phenotypic (upper values) and genotypic (lower values) correlation coefficients in B-76 between various character pairs in M_3

Characters	Days to flowering	Days to maturity	Plant height	Cluster per plant	Pod per plant	Pod length	Seeds per pod	Yield per plant
Days to flowering		0.46**	0.14	0.09	0.13	0.21	0.11	0.17
		0.78	0.11	0.53	0.58	0.53	0.06	0.81
Days to maturity			0.41**	0.46**	0.44**	0.20	-0.06	0.36**
			0.49	0.59	0.63	0.01	-0.50	0.68
Plant height				0.66**	0.58**	0.27*	0.25*	0.54**
				0.98	0.72	0.40	0.40	0.99
Clusters per plant					0.84**	0.33**	0.25*	0.75**
					0.94	0.24	0.09	0.95
Pods per plant						0.34**	0.24*	0.88**
						0.40	1.12	0.99
Pod length							0.67**	0.38**
							0.50	0.60
Seeds per plant								0.33**
								0.27

* significant at 5% level

** significant at 1% level

genotypic level between days to maturity and seeds per plant was recorded. This is indeed a well come situation.

It thus can be argued that through mutagen treatments in our case it is possible to induce favourable association between seeds per pod and early flowering and early maturity. There is hence, a good ground to suggest, through mutagenesis in the present study it may possible to induce a change in plant genetic make up which has a significant bearing in plant improvement of a crop like black gram.

Macromutations.

No family of M_2 belonging to 40 kR X-ray and 2.0% EMS for B-76 was advanced to M_3. Thus, other than these treatments macromutants recovered from T-9 and B-76 in M_3 generation are presented in Table 66. Different macromutants namely, trailing type, dwarf type, broad leaf type, compact inflorescence type (fertile), sterile type and semi-sterite type in different frequencies were obtained and their descriptions were already given earlier in M_2.

From the percentage occurrence of different mutant types it was found that, the dwarf type mutants were more frequent as compared to other mutants in both varieties. The least frequent was the broad leaf type. In M_3, the dwarf mutant was found to segregate from 30 kR X-ray in B-76. Whereas, this mutant was segregated from 40 kR X-ray in T-9 indicating differential

treatment dose response. The sterile mutants were isolated from 30 kR X-ray and 1.5% EMS in B-76. In T-9, it was isolated from 1.5% EMS only. In both B-76 and T-9, the semi-sterile mutants were isolated from 30 kR X-ray and 40 kR gamma ray. These observations would thus suggest treatment and dose specificity of genotypes for recovering macromutations.

Our present findings about the macromutations find support from similar observations made by some earlier authors. The twining and tall mutant in M_3 was reported by Jana (1962) in black gram and Bandyopadhyay and Bose (1979) in green gram. The broad leaf type unifoliate mutant was reported by Jana (1962), Rao and Jana (1976) in black gram and Kasprzyk (1970) in broad bean. The dwarf type mutant was reported by Ramanathan and Rathinam (1983) in ground nut and by Chowdhury (1983) in cow pea. Sterile type mutant was isolated by Ganguli (1973) in green gram and Ganguli and Bhaduri (1980) in green gram. The semi-sterile mutants were reported by Ganguli and Bhaduri (1980) in green gram.

Comparative evaluation.

Mutagens.

Higher doses of all the mutagens were effective in inducing one or more types of macromutations in M_3 generation (Table 66). Most of the macromutants in both the varieties were found to segregate from higher doses of mutagenic treatments. The most effective doses were 30 and 40 kR X-rays, 40 kR gamma rays, 1.0%

Table 66. Different macromutants recovered in M_3

B - 76

Mutants	Dose	Number of plants		Percentage of mutants
		Normal	Mutant	
X-ray				
Trailing type	10 kR	168	13	7.74
Dwarf type	20 kR	87	10	11.49
Broad leaf type	30 kR	87	2	2.30
Sterile type	30 kR	87	7	8.05
Semi-sterile type	30 kR	87	8	9.19
	Total	516	40	63.49 %
Gamma ray				
Semi-sterile type	40 kR	85	5	5.88
	Total	85	5	7.94%
EMS				
Sterile type	1.5%	76	4	5.26
	1.0%	79	3	3.80
Dwarf type	1.5%	76	11	14.47
	Total	231	18	28.57%
	Grand Total		63	

Table 66. contd.

T - 9

Mutants	Dose	Number of plants		Percentage of mutants
		Normal	Mutant	
X-rays				
Compact inflorescence type	40 kR	81	7	8.64
Dwarf type	40 kR	81	9	11.11
Semi-sterile type	30 kR	123	5	4.06
	Total	285	21	55.26%
Gamma rays				
Semi-sterile type	40 kR	131	3	2.29
	Total	131	3	7.89%
EMS				
Dwarf type	1.5%	89	8	8.99
Sterile type	1.5%	89	6	6.74
	Total	178	14	36.84%
	Grand Total		38	

and 1.5% EMS. In both the varieties, X-ray was found to be the most potent mutagen in inducing macromutations. Of the total macromutants observed in M_3 for B-76, 63 per cent was resulted from X-rays, 29 per cent from EMS and only 8 per cent from gamma rays. On the other hand, in T-9, out of 38 macromutations 55 per cent from (X) rays. Thus, the result corresponds with that of M_2 generation where, one of the physical mutagen (X-ray) was found to be more effective than the chemical mutagen (EMS).

Varieties.

When the two varieties viz., T-9 and B-76 were compared in respect of macromutations, it was found that both the varieties responded in more or less similar fashion as the M_2 generation. The broad simple leaf type mutant and the trailing mutants were induced by X-ray only in B-76, whereas, the compact inflorescence type mutant was induced by X-ray in T-9. Sixty three macromutants were induced for B-76 and thirty eight for T-9. Thus, B-76 was more mutable than T-9 in respect of macromutations. The differential response of different varieties to mutagenic treatments in inducing macromutations were reported by a number of earlier authors which has been reported earlier in M_2 generation.

Nodule development

Nutman (1959, 1967) has made an intensive study of the host-Rhizobial interaction of different species of clover and

different strains of Rhizobium trifoli from the genetical stand point. He has established that the presence or absence of nodules, number of nodules produced on a host, the rate at which nodules appear and the effectiveness of the nodules are considerably influenced by host genome. Sen and Bhaduri (1968) have studied the mode of inheritance of the distribution pattern of nodulation in different species of Vigna and related genera and they concluded that distribution pattern of nodules in this species was controlled by a single pair of genes. It is therefore, considered that, change in genetic make up of the black gram genotype induced by the mutagen treatments tried in the present study may lead to a change in host by which nodule development may likely to be influenced. Keeping this in view six mutant lines showing relatively high yield compared to their respective controls were studied for nodule development at pre-flowering (Stage I), first flowering (Stage II), peak flowering (Stage III) and early pod maturity (Stage IV) stage of plant growth. They were grown during kharif crop and at each stage 9 normal looking healthy plants (three from each replication) were sampled. Observations on nodule number in tap and lateral roots are given in Table 67. In general, lateral roots formed more nodules than tap roots. However, T-9 produced conspicuously higher number of nodules at tap root than others at pre-flowering stage. A distinct difference for nodule development was noticed among mutant lines. Averaging over all stages, mean number of nodules in L-1, L-10 and L-29 was higher than other mutant lines and than T-9 and B-76. But L-1 and L-10 as well as L-2

showed a peak in nodule formation at first flowering and thereafter they registered decline. On the other hand, L-22, L-24 and L-29 exhibited maximum nodule formation at peak flowering stage (Fig. 6) which was more comparable to the observations recorded for T-9 and B-76 (Fig. 7). Another interesting observation is that other than L-24, mutant lines continued to produce more number of nodules at early pod maturity stage as compared to respective controls. Results thus indicate that it is possible to induce variability for nodule formation in hosts through mutagen treatments. What is more significant here is the persistance of nodules in more number in most of the mutant lines. This character is often considered to be useful parameter since, this would favourably influence not only seed yield alone, but also protein content as well (Dasgupta, 1983).

Table 67. Nodules at different stages of plant growth in few selected mutant lines of T-9 and B-76 in M_3

Treatment	Families/ Lines	Stage I			Stage II			Stage III			Stage IV			Mean
		Tap	Lateral	Total	Tap	Lateral	Total	Tap	Lateral	Total	Tap	Lateral	Total	
(T_9) X-10 kR	L-1	4.08	16.42	20.50	6.50	32.50	39.00	9.42	27.33	36.75	8.67	19.00	27.67	30.98
(T_9) X-10 kR	L-2	5.83	8.50	14.33	6.83	34.42	41.25	8.33	20.33	28.26	7.33	18.00	25.33	27.39
(T_9) γ-20 kR	L-10	3.92	16.00	19.92	9.17	31.75	40.92	10.67	23.50	34.17	10.67	17.42	28.09	30.78
(T_9) X-20 kR	L-22	4.25	6.00	10.25	10.83	12.92	23.75	11.67	19.92	31.59	9.17	17.33	26.50	22.95
(T_9) γ-10 kR	L-24	4.92	12.08	17.00	6.92	24.75	31.67	8.92	25.50	34.42	7.92	16.75	24.67	26.94
(B_{76}) X-10 kR	L-29	4.00	9.58	13.58	9.83	28.17	38.00	11.83	25.33	37.21	10.50	22.50	33.00	30.43
	T-9	8.00	10.33	18.33	10.08	24.75	34.83	10.25	22.42	32.67	8.75	15.25	24.00	28.21
	B-76	5.92	11.50	16.40	9.92	18.83	28.75	9.58	19.42	29.00	9.33	14.25	23.58	24.69

Stage I = pre-flowering stage, Stage II = first flowering stage
Stage III = peak-flowering state, Stage IV = early maturity stage

Fig. 6. Variation in nodule development in two mutant lines and their respective controls at peak flowering stage of plant growth.

Note. Figs. 1 and 5 = L-29 (from B-76)
2 and 6 = L-10 (from T-9)
3 and 7 = B-76
4 and 8 = T-9

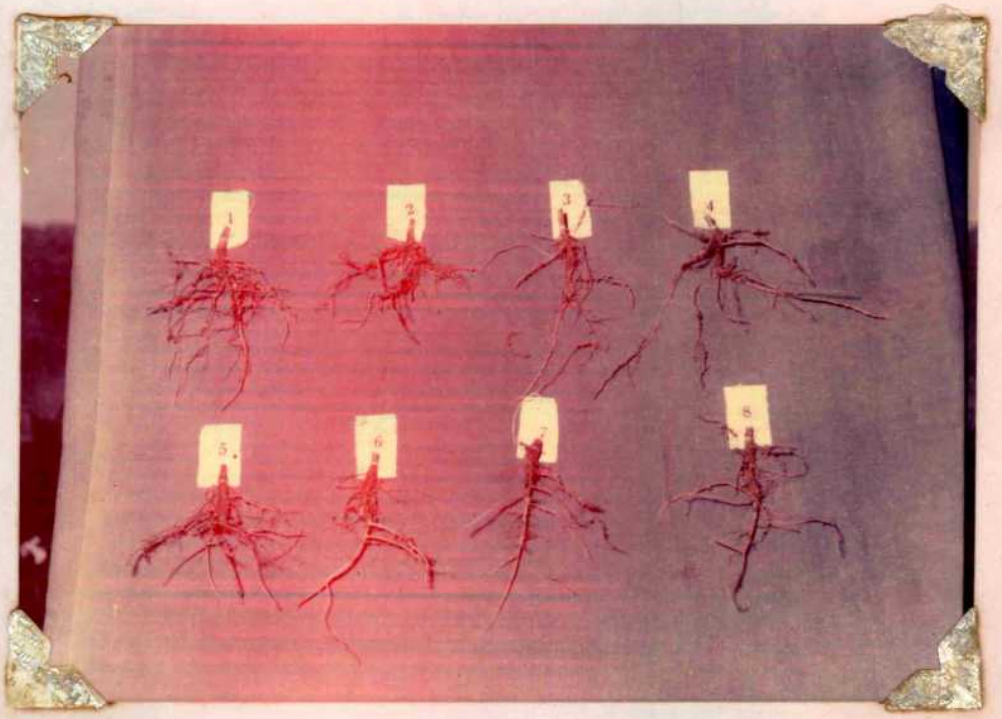


Fig. - 6

Fig. 7. Nodule formation of different mutant lines along with their respective controls (T-9 and B-76) at different stages of plant growth. Note that L-1, L-2 and L-10 show maximum nodule formation at stage - II (first flowering) while, L-22, L-24 and L-29 exhibit peak in nodule number at stage-III (peak flowering).

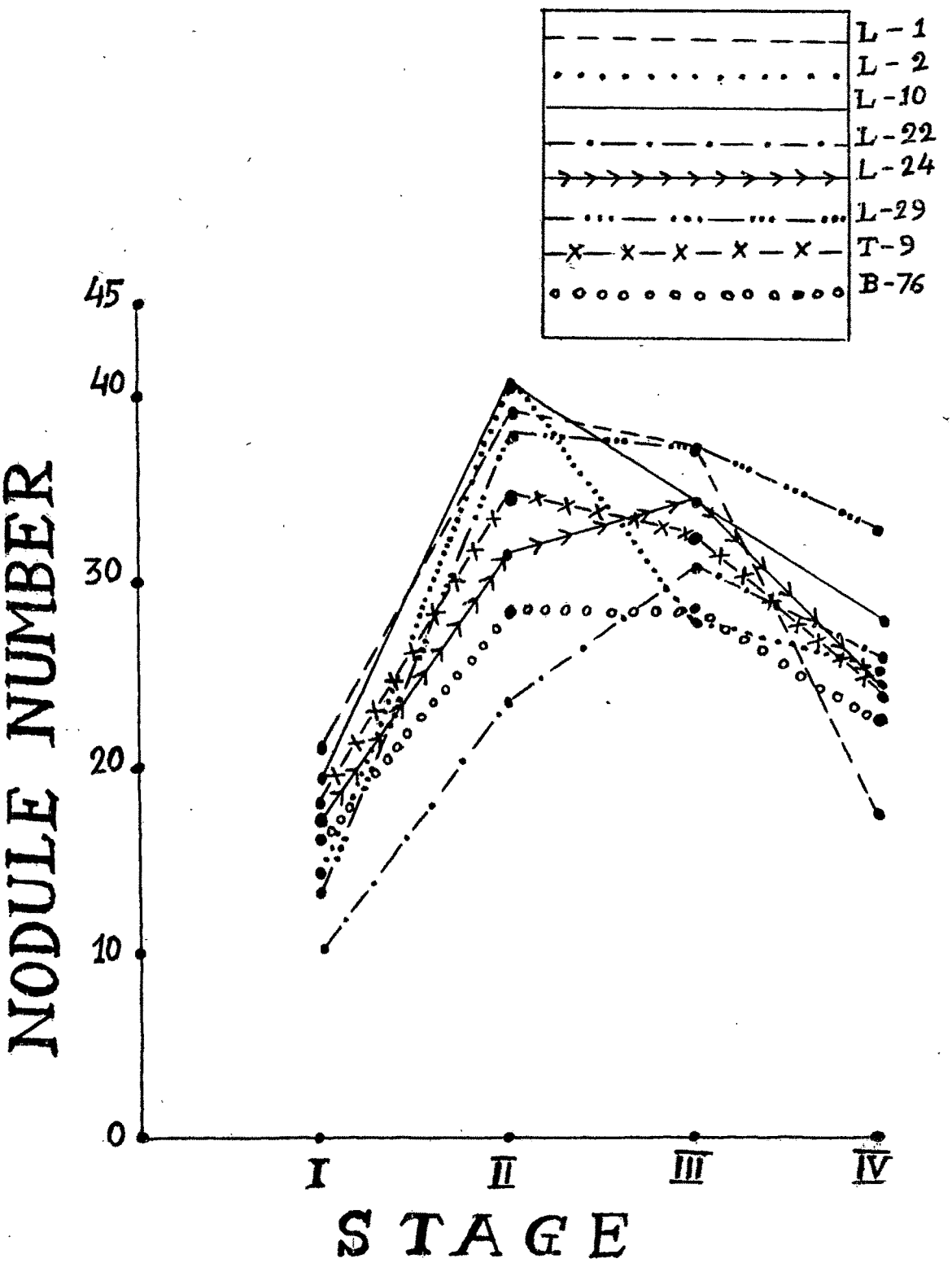

L - 1
L - 2
L - 10
L - 22
L - 24
L - 29
T - 9
B - 76
45
40
30
20
10
0
NODULE NUMBER
I
II
III
IV
STAGE

FIG. 7.

selection of promising families/lines.

Altogether 31 families/lines were selected in M_3 generation on the basis of reduced height, early flowering/maturity and more number of pods per plant. Of these families 13, 12 and 6 families were from different treatments of X-ray, gamma rays and EMS respectively. However, majority of the families were isolated from either 10 or 20 kR dose of X-ray and gamma ray (Table 68). In M_2 generation also majority of the families were derived from lower doses of X-ray and gamma ray. This is however, one may expect as, in the present study lower doses of these two mutagens were more effective in generating variability and inducing shift of mean in desired direction.

Effectiveness of mutagens.

In recent years, the relative effectiveness of the physical and chemical mutagens for mutation breeding programme has received a great deal of attention. A number of authors reported better success with chemical mutagens compare to ionizing radiations for inducing polygenic variability. Gaul and Aastviet (1966) in wheat, Brock (1970) in Arabidopsis thaliana, Kharkwal (1978) in Bengal gram reported that chemical mutagens like EMS were more effective than radiations in inducing polygenic variability. On the other hand, in many studies the induced polygenic variability has been found to be greater with ionizing radiations (Rao, 1974 and Khamankar, 1974)

Table 68. Selection of families at different treatments in M_3 of two black gram varieties

Variety Treatment	T - 9 Family	B-76 Family	Total
X - 10 kR	3	2	5
X - 20 kR	4	1	5
X - 30 kR	1	1	2
X - 40 kR	1	-	1
γ - 10 kR	3	-	3
γ - 20 kR	4	2	6
γ - 30 kR	1	-	1
γ - 40 kR	1	1	2
EMS 0.5%	-	-	-
EMS 1.0%	1	1	2
EMS 1.5%	1	2	4
EMS 2.0%	-	-	-
Total	21	10	31

suggesting physical mutagens as powerful tool in generating polygenic variability. It thus, becomes increasingly difficult to arive at any definite conclusion which prompts us to examine closely our own analysis for quantitative characters in M_2 and M_3 generations. We tried 4 doses of two physical mutagens, X-ray and gamma-ray and also 4 concentrations of EMS, a very known potent chemical mutagen in two black gram genotypes, T-9 and B-76. Alongwith the study on micromutations of the nature discussed earlier we also attempted to score several macromutants for different morphological characters.

From the analysis a few significant points emerge. Either in M_2 or M_3, 10 and 20 kR of X-ray and gamma ray in general induced a shift in mean for most of the characters towards desired direction. Similarly, these two doses of X-ray and gamma ray generated large amount of variability in either of the mutant generations for most of the characters. These would therefore, suggest that lower doses of ionizing radiations like X-ray and gamma ray are very effective in generating polygenic variability for different quantitative characters in two black gram genotypes though T-9 appears to be more sensitive .

However, from our study it is difficult to ascertain the superiority of either of the two physical mutagens over the other as, they showed almost parallel reactions. On the other hand, analysis of macromutations reveals conspicuously different picture.

Macromutants were scored with high frequency at higher doses of physical and chemical mutagens where higher doses of X-ray induced macromutations more frequently in B-76 followed by EMS and gamma ray. From the above discussion, there is a good ground to suggest that doses of mutagens have important role in determining the quantum and nature of induced variability. It is well recognised that ionizing radiations like X-ray and gamma ray are highly effective in inducing chromosomal aberrations while, mutagens like EMS and DES (diethyl sulphate) which are known to act primarily on base pairs of DNA molecule, results higher yield of gene mutations. Because of this basic difference between these two groups of mutagens it is offen suggested that, chemical mutagens may have a superiority over physical mutagens for the purpose of mutation breeding.

Our present study, on the contrary indicates the superiority of physical mutagens where dose of the treatment appears to be principal determining factor in inducing either micro or macromutations. If doses of physical mutagens are fixed at lower level as in our case 10 and 20 kR X-ray and gamma ray which may not cause drastic effects on chromosomes and thereby, may effecively release polygenic variability. In fact, majority of the families/lines selected by us in M_2 and M_3 generations have been derived from 10 and 20 kR treatments of X-ray and gamma ray. Such dose specificity for inducing polygenic variability has been reported by Gill et al. (1974) in barley .

Our study does not entirely agree with the earlier observation of Bhadra (1982) in black gram who observed that EMS and gamma rays were equally effective in generating polygenic variability. Perhaps, concentrations of EMS used in our study were too high which was reflected even in M_1 generation where very drastic effects were recorded following EMS treatments. However, the same physical mutagens induced macromutations at higher doses. From the above discussions it is reasonable to suggest that ionizing radiations like X-ray and gamma ray would continue to play an important role if the experiments are planned with proper selection of the doses in generating useful micromutations.

Efficiency of early generation selection.

It is a common practice to advance only normal looking M_2 plants at random to M_3 generation and apply the first dose of selection at M_3. This necessarily results in increase in volume of materials to be handled and delay in isolation of promising variants. Moreover, one may suspect that, many a time promising families may have been lost during the process of random selection. Therefore, we have attempted to explore the possibility of selecting for polygenic variability right from M_2 which is the first segregating generation where one may expect to have the release of genetic variability due to treatments on which selection can effectively be practised. Furthermore, selection of promising variants from early generation is is possible to reject the

unmutated "roughage" in M_2 itself. Our analysis presented earlier and discussed clearly domonstrates the release of sufficient amount of variability in M_2 generation for all the characters other than plant height. subsequently, in M_3 we observed further release of variability. We present our observations in summarised form for variability in M_2 and M_3 generations for different characters where doses of different treatments were pooled together (Table 69). It is evident from the table that, other than pod length and seeds per pod the induced variability was increased further by a great margin in M_3 generation over M_2. This phenomenon is often been termed as the release of additional variability. The question arises as to where from this additional variability is being released. Obviously the mutagenic treatment is the only cause in increase in variability as similar increase in variability was not observed in the controls and much of these induced variability was recorded in M_2 generation. Further segregation for the polygenic system in M_3 is expressed as release of additional variability. This being the mechanism of induction and inheritance of micromutations. Selection in M_2 can certainly help in identifying progenies that are likely to show more variability and better response to selection .

We found some characters revealed greater variability in later generations than others. These results demonstrate that some characters have a tendency to stabilise sooner than others. This may be partly related with the number of polygene controlling them. For the present discussion it can be accepted that for some

Table 69. Variability in M_2 and M_3 generations for different characters of the two blackgram varieties T-9 and B-76 (pooled over treatments)

Treatments	Days to flowering		Plant height		Cluster per plant		Pods per plant	
	M_2 generation	M_3 generation	M_2 generation	M_3 generation	M_2 generation	M_3 generation	M_2 generation	M_3 generation
				T - 9				
Control	2.66	0.97	3.98	8.33	0.73	1.00	1.23	11.50
X-ray	2.43	4.33	1.33	7.91	0.81	5.07	1.18	27.55
γ-ray	3.20	2.65	1.85	6.28	1.00	6.53	1.86	50.97
EMS	2.67	5.94	1.39	14.94	0.73	6.20	1.56	29.53
				B - 76				
Control	2.20	2.00	3.60	4.60	0.58	1.11	1.28	14.64
X-ray	2.34	4.98	1.24	12.93	0.74	5.81	1.48	26.23
γ-ray	2.17	7.35	1.77	9.85	0.65	8.19	1.54	45.81
EMS	1.46	5.80	1.52	4.80	0.59	7.17	1.30	46.19

Table 69. contd.

T - 9

Treatments	Pod length (cm)		Seeds per pod		Seeds per plant		Yield per plant(g)	
	M_2 generation	M_3 generation	M_2 generation	M_3 generation	M_2 generation	M_3 generation	M_2 generation	M_2 generation
Control	0.04	0.03	0.04	0.02	17.21	243.75	0.02	0.35
X-ray	0.07	0.02	0.10	0.10	18.98	780.10	0.03	0.83
γ-ray	0.06	0.02	0.11	0.10	29.00	1166.88	0.05	1.66
EMS	0.07	0.02	0.10	0.08	19.34	767.75	0.03	1.14

B - 76

Control	0.06	0.03	0.07	0.03	23.20	375.75	0.03	0.49
X-ray	0.07	0.02	0.11	0.09	17.57	456.39	0.03	1.06
γ-ray	0.08	0.02	0.13	0.12	21.19	1188.43	0.03	2.02
EMS	0.07	0.02	0.10	0.09	17.86	1158.93	0.04	1.71

characters such as pod length and seeds per pod selection could be confined to M_2 alone. Atleast for such characters both time and effort can be economized and only M_2 selections can be advanced to M_3 confirmation, further selection, preliminary testing and multiplication.

The same principle can also be applied to other characters as well, even though their variance increased in M_3 over M_2 appreciably. The M_2 progenies can be classified into different categories as significant positive or negative shift for mean and variance which has already been described in our study for selecting promising variants and only the more promising ones may be advanced for second cycle of selection.

However, a question is asked whether on the basis of the scheme i.e., selection of promising progenies in M_2 and subsequently second dose of selection in M_3 for the superior progenies it is possible to achieve substantial gain. The rigorous selection at early generation as in random selection may also lead to the loss of desirable progenies. Thus, we have examined the relative advantage of early generation selection. We carried out selection for three traits in M_2 and M_3 generations. The Table 70 shows the frequency of promising micromutations over the entire experimental material in the two generations. Per cent of promising selections are increased in all treatments in M_3 over M_2 except in gamma treatment in B-76. Increase in per cent of selection in M_3 may be due to the addition

Table 70. selection efficiency for micromutation in M_2 and M_3 generations of two black gram varieties (pooled for three characters)

T - 9

Mutagen	M_2 generation		M_3 generation	
	Total progenies	Promising selections (%)	Total progenies	Promising selections (%)
X-ray	1175	8.17	945	11.43
γ-ray	1179	7.63	865	12.33
EMS	1168	4.11	469	7.68

B - 76

X-ray	1156	4.15	472	10.17
γ-ray	1167	6.17	696	5.17
EMS	1142	3.68	407	8.85

of new mutated progenies to the total number of selections in M_3. By and large such analysis points to the fact that by exercising rigorous selection even at M_2 it is possible to recover superior M_3 selections with certain advantages. With greater perfection of the selection of the selection technique the precision and contribution of early generation selection can be increased so that, a majority of the promising variants can be identified one generation earlier.

Performance of mutant lines in advanced generation.

We carried out promising mutant lines selected in M_3 upto M_6 generation and made a preliminary trail with 4 such mutant lines during summer season. Results obtained from the trail are given in Table 71. It was observed that L-13 gave highest plant yield followed by L-5. In thesetwo,harvest index was improved marginally as compared to respective controls. They showed however, a good improvement in number of pods per plant. Of these two lines, L-13 appears to be outstanding as it not only produced exceptionally higher number of pods (53 against 28 of B-76 and 36 of T-9) but it also formed very high clusters per plant. Moreover, it was more synchronous in flowering and completed its flowering period in 18 days as compared to 22 days of B-76 and T-9. These promising results need to be confirmed through multilocation trail in different seasons over number of years.

Table 71. Plant yield, harvest index and other plant characters of few selected lines in advanced mutant generation

Variety/ Lines	Characters						
	Height (cm)	Clusters/ plant	Pods/ plant	Seeds/ pod	100-seed wt.(g)	Plant yield(g)	HI (%)
B - 76	17.3	11.8	28.0	5.5	4.3	6.2	35.4
T - 9	20.4	13.4	36.4	5.7	4.5	7.9	36.7
$(T_9 \gamma_{10})$ L-5	21.5	13.2	38.7	5.6	4.8	9.4	37.4
$(T_9 \gamma_{20})$ L-7	21.4	13.0	34.0	5.4	4.6	8.2	34.8
$(T_9 \gamma_{20})$ L-8	16.5	11.0	30.9	5.2	4.4	7.4	35.8
$(B_{76} X_{10})$ L-13	18.4	16.3	52.7	5.0	4.7	11.5	37.5

N.B. Each figure is average of 15 plants

HI = Harvest index

SUMMARY AND CONCLUSION

The aims of our present investigation were to study and establish the following points :

1. Radio- and chemosensitivity of the two varieties of black gram (T-9 and B-76) in M_1 generation after mutagenic treatments with X-ray, gamma-ray and EMS.

2. Amount and nature of variability created in M_1 generation as immediate effect of mutagenesis.

3. Selection of the promising families in early segregating generation (M_2) on the basis of significant shift in mean towards desired direction and quantum of variability generated for some important polygenic characters.

4. Isolation of the macromutants with gross morphological changes in M_3 generations.

5. Assesment of the performance of the selected M_2 families/lines in M_3 and also to measure the amount and nature of "additional variability" released in M_3.

6. Observation on the nature of association between yield and different components of yield in M_3 generation.

7. Observation on the variation in nodule development following mutagenic treatments in M_3 generation.

8. Assessment of the relative effectiveness of different mutagens used in M_2 and M_3 generations in inducing macro- and micro-mutations.

9. Relative response of the two varieties, T-9 and B-76 to different mutagenic treatments.

10. Assessment of the performance of few selected lines in advanced generation.

The observations recorded from the present investigation are summarised below.

Twelve characters namely, germination per cent, survival per cent (at 6th day, at first flowering and at maturity), plant height (at flowering and maturity), pollen fertility (%), seeds per pod, days to flowering, days to first pod maturity, pods per plant and pod length were analysed to see the immediate effect of mutagen treatment in M_1 generation. Of the twelve characters, the treatment effects were significant for eight characters in both T - 9 and B - 76 indicating the potentiality of mutagen treatments for inducing variability in M_1 generation. No significant treatment effects were recorded for seeds per pod and pod length in either varieties. For rest of the characters, varieties showed differential response to different mutagenic treatments. The mutagen treatments caused a shift in the mean values of different characters in negative direction and the magnitude of decrease was not the same for all the characters. In few instances however, the mean was shifted towards

positive direction particularly for 10 and 20 kR X-ray and gamma-ray treatments. In general, pronounced effects were recorded at increased doses of mutagenic treatments. However, very drastic effects were recorded for almost all the characters following EMS treatments. The standard deviation of almost all the treatments in both the varieties increased compared to control indicating release of variability in M_1 generation due to mutagenic treatments.

To study the effectiveness of physical and chemical mutagens in inducing polygenic mutations in M_2 generation, observations were recorded on days to flowering, height at flowering, clusters per plant, pods per cluster, pod length, seeds per pod, pods per plant, seeds per plant and yield per plant. In our present study, except a few, the population means of most of the treatments were shifted towards negative direction for most of the characters studied. The families, means of which were shifted towards positive direction were mostly originated from the variety T-9. The contribution of B-76 towards such positive shifting was less compared to T-9. In all the characters, the shifting of means towards positive direction was observed mostly for lower doses of mutagenic treatments. However, irrespective of the shifting of means, the amount of variability was enlarged for all the nine characters studied except plant height.

Among the nine characters studied in M_2, yield per plant, seeds per plant, pods per plant and clusters per plant exhibited high phenotypic and genotypic coefficients of variation than other character. The heritability estimates were high for all the characters

except pods per cluster. The highest genetic gain in M_2 was also observed for yield per plant (55.26%) followed by seeds per plant (52.23%), pods per plant (47.49%) and clusters per plant (42.62%). The higher values of predicted heritability and genetic advance for yield and yield components in our present study suggested that the mutations have mostly occured at loci having additive effects.

Lower doses (10 and 20 kR) of ionizing radiations (X-ray and gamma-ray) were effective in inducing useful micro-mutations in respect of yield and yield components. Of these two mutagens gamma-ray treatment (lower dose) induced desirable families with the shift in mean at higher frequency. EMS was infact, found to be not very important in producing valuable micromutations may be due to its high concentration. The population variance of each treatment in general, increased with high magnitude for lower doses of treatments in M_2 generation. In M_2 the two varieties used, responded almost in similar fashion for some treatments in respect of some characters, but for other treatments and some other characters they responded differentially. Analysis of variance indicated significant difference between the two varieties for most of the characters studied.

Different macromutants isolated in M_2 were, trailing type, sterile type, semi-sterile type, reduced and short pod type, broad leaf type and dwarf type. In our present investigation, among the morphological mutations, the dwarf type mutants may have some practical value in respect of plant breeding purposes. The dwarf

plant type with yielding capacity equal to or higher than control will be very useful if they respond to higher plant density and improved levels of agronomic managements. Macromutations were recovered from high doses of mutagens tried. However, high doses of X-rays were more effective in inducing macromutations. The selection of promising families in M_2 for M_3 was performed based on three important characters viz., high pod number, earliness and dwarfness. The families which showed significantly higher mean values than the control population means were selected and advanced to M_3 generation.

To study the potentiality of M_2 selections and also to measure the amount of "additional variability" released if any, observations were recorded on days to flowering, days to maturity, plant height, clusters per plant, pods per plant, pod length, seeds per pod, seeds per plant and yield per plant in M_3 generation.

Like M_2, in M_3 generation, 10 and 20 kR X-ray and gamma ray ingeneral, induced a shift in mean for most of the characters towards desired direction. Similarly these two doses of X-ray and gamma ray generated large amount of variability in ether of the mutant generations for most of the characters. Thus, lower doses of ionizing radiations like X-ray and gamma ray are very effective in generating polygenic variability for different quantitative characters though, T-9 appears to be more sensitive.

A general trend was observed of the nine characters studied namely, plant height, clusters per plant, pods per plant, seeds

per plant and yield per plant in both varieties showed relatively high GCV. Correspondingly, these characters exhibited high genetic advance, expressed as percentage of mean. The trend recorded in M_3 for these genetic parameters more or less confirms the earlier observations reported for M_2.

As expected, in either varieties, pods per plant appeared to be important determinant of plant yield as they, showed significantly positive phenotypic correlations and very high genotypic correlation with yield. Similarly, characters like days to flowering, days to maturity, seeds per pod etc. showed significantly positive phenotypic correlations and high genotypic correlations with seed yield. Interestingly, days to flowering and days to maturity in case of mutagen treated populations of T-9 registered significant negative association with seeds per pod indicating thereby earliness in flowering and maturity may lead to increase in seed number per pod. Similarly, a high and strong negative correlation at genotypic level between days to maturity and seeds per plant was recorded. Thus, through mutagen treatments, it is possible to induce favourable association between seeds per pod and early flowering and early maturity.

Like M_2 in M_3 generation also, macromutations were scored with high frequency at higher doses of physical and chemical mutagens where, higher doses of X-ray induced macromutations more frequently in B-76 followed by EMS and gamma ray. Most of the macromutants in both the varieties were found to segregate from higher

doses of mutagenic treatments. The most effective doses of mutagenic treatments were 30 and 40 kR X-rays, 40 kR gamma ray and 1.0% and 1.5% EMS. In both the varieties, X-ray was found to be the most potent mutagen in inducing macromutations. The variety B-76 was found to be more mutable than T-9 in respect of macromutations.

Nodule development was studied at pre-flowering, first flowering, peak flowering and early pod maturity stages in M_3. In general, lateral roots formed more nodules than tap roots. A distinct difference for nodule development was noticed among mutant lines. Averaging over all stages, mean number of nodules in L-1, L-10 and L-29 was higher than other mutant lines and than T-9 and B-76. But L-1 and L-10 as well as L-2 showed a peak in nodule formation at first flowering and thereafter they registered decline. On the other hand, L-22, L-24 and L-29 exhibited maximum nodule formation at peak flowering stage which was more comparable to the observation recorded for T-9 and B-76. Except L-24, all mutant lines continued to produce more number of nodules at early pod maturity stage as compared to respective controls. Thus, it is possible to induce variability for nodule formation in hosts through mutagen treatments.

Examination of the relative advantage of early generation selection reveals that, by rigorous selection even at M_2 it is possible to recover superior M_3 selections with certain advantages though the per cent of promising selections increased in all treatments in M_3 over M_2. Our preliminary yield trail in M_6 generation with few selected lines shows that, L-13 (from 10 kR X-ray of B-76)

and L-5 (from 10 kR gamma ray of T-9) gave high plant yield. Though their harvest index was improved marginally, the two lines showed a good improvement in number of pods per plant. Of these two lines, L-13 appears to be out standing as it not only produced high number of pods but it also formed very high clusters per plant. Moreover, it was more synchronous in flowering which is a vital trait to improve a crop like black gram.

Our present study thus indicates the superiority of physical mutagens where dose of the treatments appears to be principal determining factor in inducing either micro- or macromutations. If doses of physical mutagens are fixed at lower level as in our case 10 and 20 kR X-ray and gamma ray which may not cause drastic effects on chromosomes and thereby, may effectively release polygenic variability. In fact, majority of the families/ lines selected by us in M_2 and M_3 generations have been derived from 10 and 20 kR treatment of X-ray and gamma ray.

FUTURE SCOPE OF RESEARCH

A few mutant lines selected from advanced mutant generations showed high seed yield potentiality in our preliminary yield trail experiment. Through multilocation trails over number of years they need to be further tested. Protein content and its quality study would be of great significance for promising mutant lines. Further, mutant lines which appears to be relatively inferior in respect of seed yield but superior for some other character or characters like earliness, reduced height, etc. could be used successfully for hybridization programmes. As a very preliminary study was made for nodule development which showed conspicuous variation in nodulation, a detailed analysis in this line could be very much useful. We selected few macromutants in M_2 and M_3 generations. Their detailed genetics has to be worked out and understood, so as to utilise them effectively in future breeding. Finally, lower concentrations of EMS (lower than used here) may be tried for evaluating effectiveness of EMS in inducing polygenic variability in black gram.

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