GENETIC VARIABILITY IN GREEN GRAM (VIGNA RADIATA L. WILCZEK) FOLLOWING IRRADIATION AND HYBRIDIZATION

BY

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Dissertation submitted to the Haryana Agricultural University in partial fulfilment of the requirements for the degree of:

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IN

GENETICS

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Haryana Agricultural Univesity

HISAR

1989

IN THE MEMORY

OF MY

GRAND FATHER

CERTIFICATE I

This is to certify that this dissertation entitled: "Genetic variability in green gram (Vigna radiata L. Wilczek) following irradiation and hybridization" submitted for the degree of Ph.D. in the subject of Genetics of the Haryana Agricultural University, is a bonafide research work carried out by Shri Raj Kumar Mittal under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE II

This is to certify that this dissertation entitled: "Genetic variability in green gram (Vigna radiata L. Wilczek) following irradiation and hybridization" submitted by Shri Raj Kumar Mittal to the Haryana Agricultural University in partial fulfilment of the requirements for the degree of Ph.D., in the subject of Genetics, has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

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CONTENTS

INTRODUCTION

Since long hybridization has been used as a mechanism to create genetic variability. Discovery of the techniques to induce mutations provided a new opportunity for repatterning the genetic architecture of crop plants. The induction of mutations has now been accepted as a useful tool in plant breeding programmes One of the most important applications of mutation breeding is for the creation of variability in quantitative characters. The variability thus created enhances the scope of crop improvement. The improvement in agronomic characters through mutation breeding has been achieved in different field crops. Useful mutants from economic point of view have been obtained by ionizing radiations in peanuts (Gregory, 1955), barley (Gaul, 1961), wheat (Bhatia and Swaminathan, 1962; Borojevic, 1965), maize (Scossiroli, 1962), French bean (Swarup and Gill, 1968), Mungbean (Santos, 1969), beans (Moh, 1972), rice (Reddy and Reddy, 1973) and many other crop plants.

It has been demonstrated in many crop species that mutagenesis is as effective as hybridization in supplying the genetic variability for polygenic traits (Gregory, 1956; Gustafsson, 1954; Williams, 1959; Krull and Frey, 1961; Gupta and Virk, 1977). Variability for quantitative characters from mutagen treatment approximated half that from hybridization, and the variability sources were additive in mutagen treated hybrids. Variability from either source was heritable (Frey, 1965). This enlarged variability could be fixed by proper selection procedure and an over all improvement in the variety could be achieved.

It has been demonstrated that when heterozygous material is exposed to mutagen treatment, there is increased release of genetic variability (Krull, 1960; Jalil Miah and Yamaguchi, 1965; Saini and Sharma, 1970; Sharma et al., 1982). However, reports are not available for comparing the effect of irradiation alone with hybridization when either or both the parents have been irradiated prior to their involvement in crossing programme.

Mungbean (*Vigna radiata* L. Wilczek) is an important grain pulse in Indian diet because of its high nutritive value and easily digestible protein. The yields in mungbean are generally low and exploitation of natural variability through hybridization has not led to any break through in grain yields. Thus there is need for exploring unconventional methods for improvement.

Keeping these aspects in view the present study with gamma radiation was planned with the following objectives.

1. To assess the magnitude and direction of gamma irradiation induced mutations in quantitative traits of mungbean as compared with hybridization.
2. To compare the effectiveness of direction of irradiated parents (♀ is irradiated, ♂ is irradiated or both are irradiated).
3. The expected use of this induced variability in mungbean breeding.

REVIEW OF LITERATURE

The idea of producing artificial mutations and their utilization for breeding cultivated plants is almost three quarters of the century old. Muller (1927) for the first time induced mutations in Drosophila using X-rays. In barley and maize similar possibility was searched by Stadler (1928a, 1928b). At the same time, Goodspeed (1929) also induced mutations in Datura and Nicotiana. These experiments opened up a new field for creating variability and from that time onward the induced mutations have been used frequently for changing the characteristics of crop plants.

Gamma radiations are commonly employed for mutation studies because of their ease in availability. Shorter wave length of ionizing radiation and deep penetration are other advantages. Since gamma rays have been frequently used in mutation studies with higher plants, they serve as a good check for comparison with other mutagens.

Ever since the discovery of mutagens, efforts have been made for inducing mutations in nearly all the plant species which are of any use to human beings such as food, textile, medicinal, ornamental value etc. Generally the frequency of undesirable mutations far exceeds the desirable ones. The type of mutations desired also vary from species to species and the problems peculiar to the specific situations. For example, in some cases dwarfness or increased branching etc. may be desired, where as disease resistance or yield or salt tolerance may be the objective in other cases.

Factors such as metabolic state of the plant (cell), ploidy level, water content, oxygen level, temperature and light influence the mutation frequency. However, these relations are complicated by the fact that numerous biological and physico-chemical factors are superimposed. Often different tissue and cell types of the same plant may exhibit quite different sensitivity (Nilan, 1956; Bacq and Alexander, 1959 and Nilan and Konzak, 1961). Meiotic cells are generally more sensitive than somatic cells (Sax and Swanson, 1941 and Sparrow and Singleton, 1953). In barley, Mericle and Mericle (1961) reported that the shoot in the early and middle proembryo stage of development was more sensitive to X-ray treatment than the roots. Even the same cell has a different sensitivity depending on the stage of nuclear division. For example, in *Trillium erectum* there was a 60 fold difference in the frequency of radiation induced fragments between the meiosis stage with the lowest(early post meiotic interphase) and that with the highest sensitivity (diplotene and metaphase 1) (Sparrow, 1951 and Evans, 1962).

Besides the biological factors, many chemical and physical factors are also influential. There are numerous protective substances, e.g., cysteine, which reduce the radiation effect (Nybom, 1954) and intensifying agents such as oxygen (Nilan and Konzak, 1961 and Nilan *et al*.,1961) which is biologically the most important.

Water content also varied the radiation sensitivity of the seeds. It has long been known that presoaked seeds, which have a correspondingly high water content and whose physiological activity has started are much more sensitive to radiation than seeds of normal water contents of about 11-14% (Stadler, 1928; Wertz, 1940; Gustafsson, 1947 and Kaplan, 1951).

Gaul (1963) showed that chlorophyll mutations in barley can be very variable, and depend particularly on temperature and light. Low temperature often intensified the expression of the chlorophyll deficiency, while warmth could lead to considerable or complete normality.

For modulating the character complex of mutation, the genetic milleu can be of more importance in breeding than the environment. Timofeeff- Ressovsky (1934) was apparently the first to conclusively prove the genotypic modification of the expression of mutations with Drosophila (after earlier investigations by Gonzalez, 1923). The interaction of the mutation with new genes can cause a change in dominance. Such cases have been described in barley for chlorophyll mutations (Hallqvist, 1953) and for a gigas mutant (Gustafsson, 1954). The interaction with foreign alleles can even go so far that dominant as well as recessive behaviour of the mutation is annulled i.e. the mutated gene leads to heterozygosity as well as homozygosity to the original phenotype, and a back mutation is stimulated. These reversions are due to the suppressor gene effect. These reversions were observed in Drosophila by Bridges (1932), in Neurospora by Giles et al. (1955) and in barley by Caldescott and North (1961). The reverse case is also known where mutations first become effective through foreign genotypic factors. After x-ray treatment of Epibolium parviflorum, Michaelis and Kaplan (1950) found a mutation which could not manifest itself in the original genotypic milleu. Only crossing with E. hirsutum led to its manifestation.

Frequency of desirable induced mutations would be greater in polyploids than in diploids, since the tetra and hexaploids have two or three times as many genes as do the diploids.

There are possibilities of combining hybridization and mutations in a breeding procedure. Induction of mutations in F_2 seeds of a variety may prove more useful. Apparently the genetic variability released by crossing is basically not different from that induced by radiation. Mutagenic treatment of hybrid seed would, therefore mean the production of additional variability and thus greater chances of success in selection. An example supporting this assumption is provided by the investigations of Krull (1960) in oat.

2.1 Morphological mutants.

Mutations induced by ionizing radiations may be sufficiently drastic to alter the normal plant characteristics such as leaves, roots, stems, floral parts etc. The reports of such induced mutations in literature are numerous. In the following table some of such references have been summarized on leguminous crops to illustrate the types of drastic mutations encountered.

Crop	Mutagenic agent	Morphological variants	Reference
Melilotus alba	EMS, hydroxylamine (HA), 5-bromouracil (BU), and 2-Aminopurine (AP).	Short internode, curled leaf, multifoliate leaf, and cotyledonary branching	Gengenbach *et al*., 1969
Pigeon pea	Thermal and fast neutrons	Bold seed	Pawar *et al*.,1979
Cicer arietinum	X-rays	Flat stemmed and flat podded	Athwal, 1963
Cicer arietinum	Pile Neutrons	Early, high yielding free from different disease	Bhatnagar *et al*., 1979
Phaseolus mungo	X-rays and EMS	Tall mutant which was early maturing with bigger flowers and lesser seeds	Jana, 1963
Phaseolus mungo	X-rays and EMS	Crinkled leaf, Waxy leaf, narrow leaf and unifoliate leaf	Appa Rao and Jana, 1976
Black bean	X-rays and EMS	Brown, yellow or white seed coat colour	Moh , 1971 and 1972
Vigna radiata	X-rays	Reduction in days to flowering	Seth *et al*., 1985
Vigna radiata	X-rays	Reduction in seedling height which was associated with an increase in chlorophyll content	Mustaque and Qureshi, 1973
Vigna radiata	X-rays	Albino infertile and dwarf	Athwal *et al*., 1970

(Contd. . .)

Crop	Mutagenic agent	Morphological variants	Reference
Vigna radiata	X-rays, EMS, N-methyl N-Nitro N-Nitrosoguanidine (MNNG), Hydroxylamine (HA)	Chlorophyll and Morphological mutations	Grover and Virk, 1984
Phaseolus aureus	X-rays	Stunted plant growth, rough, leathery and crinkled leaves. Formation of clusters of leaves in floral position	Rajput, 1971
Vigna radiata	X-rays and EMS	Unifoliate sterile leaf and multifoliate leaf	Santos, 1969
Phaseolus vulgaris	X-rays	i) Semidwarfs (SDM-1 and SDM-2): Short and trailing with foliage variability, germinated, bloomed and matured later than the parent blue lake. ii) Late flowering/high yielding (LfHy) :delayed flowering, early, profused plant growth and increased plant height iii) Pod shape/high yielding (PsHy): flattened pods and oval seeds with greater yield	Mujeeb and Greig, 1973.
Vigna radiata	X-rays	Various types of chlorophyll (albino, xantha, virescent, lutescent, chlorina, striata, viridis and maculata) and morphological (Tiny leaf, leathery long leaf, long leaf, variegated, tribulate, Bushy, pyramid shape and sterile).	Subramaniam, 1980

Crop	Mutagenic agent	Morphological Variants	Reference
Vigna radiata	X-rays	Mutant with yellow testa, green stem, branches and leaves and increased yields,	Singh and Yadava, 1982.

2.2 Mutations in quantitative characters

The induction of mutations for quantitative characters is a sound source of genetic variability for the improvement of crop plants. Induction of polymeric variation has been the subject of intensive study by a number of workers (Bhatia and Swaminathan, 1962; Borojevic, 1965; Brock, 1965, 1966, 1967; Gaul, 1964; Goud, 1967; Oka et al., 1958 and Scossiroli et al., 1961).

According to Gaul (1965), the micromutations are useful in plant breeding for two reasons.

i) They might occur more frequently than macromutations.

ii) They often do not affect vitality adversely as do the macromutations because the minute changes of physiological nature are less drastic.

Various workers have reported a change in mean value and an increase in variance after mutagenic treatment. It has been suggested that the mutations with small phenotypic effects have high occurrence frequency and have equal probability of being negative or positive in their phenotypic effects (Gregory 1955; Oka et al., 1958; Jalil Miah and Yamaguchi, 1965). In the following table are summarized the key references of mutation studies for quantitative characters in various crops.

Crop	Mutagenic agents	Quantitative characters: Increase in mean	Quantitative characters: Decrease in mean	Quantitative characters: Increase in variance	References
Oryza sativa	γ-rays	Plant height			Abifarin and Rutger, 1982.
Rye	Neutron treatment		Straw length and seed set	Straw length and seed set	Aastveit, 1967
Arabidopsis thaliana	γ-rays		Number of seeds/pod		Lawrence, 1968
Soybean	Irradiation			Yield, plant height, maturity and seed size	Rawlings *et al*., 1958
Flax	Irradiation	Plant height, yield and number of primary bran-ches	Number of seeds/capsule	Yield	Bari, 1971
Pea	γ-rays		Plant height, pod fertility and pollen abortion		Monti and Donini, 1968
Cowpea	γ-rays and Neutron		Yield and time to flowering	Yield, pods/plant and time to flowering	Ojomo and Chheda, 1972
Cowpea	γ-rays	branches, pods/plant, pod length and seeds/pod			Choulwar and Borikar, 1986

(Contd...)

Crop	Mutagenic agents	Quantitative characters			References
		Increase in mean	Decrease in mean	Increase in variance	
Broad bean	γ-rays	Number of seeds/pod			Samsi and Sofjy, 1980
Vigna radiata	γ-rays	Plant height, pods/cluster and 100-seed weight	Days to maturity	Days to maturity, plant height, pods/cluster and 100-seed weight	Verma and Singh, 1984
Vigna radiata	EMS	number of pods and yield		Number of pods and yield	Prasad, 1976
Vigna radiata	γ-rays		Plant height, pod length, number of pods/plant, number of grains/pod and yield/plant		Shakoor *et al.*, 1978
Vigna radiata	γ-rays	Number of pods and pod length			Seth *et al.*, 1986

(Contd...)

Crop	Mutagenic agents	Quantitative characters			References
		Increase in mean	Decrease in mean	Increase in variance	
Vigna radiata	γ-rays		Yield/plant, grain size, number of pods/ plant and protein content	Yield/plant, grain size, number of pods/ plant and protein content	Dahiya, 1973
Phaseolus aureus	γ-rays		Number of seeds/ pod and grain yield		Yaha Ashraf _et al._, 1975
Vigna radiata	γ-rays	Days to flowering, pods/plant, grain/pod, yield and 100-seed weight	Plant height	Plant height, pod length, days to flowering, pods/plant, grain/pod, yield and 100-seed weight	Rajput, 1974
Vigna radiata	γ-rays and sodium azide	Yield			Avila and Murty, 1983
Vigna radiata	γ-rays and EMS	Number of pods and yield		Number of pods and yield	Bahl and Gupta, 1982
Vigna radiata	γ-rays			Yield, number of fertile branches, number of pods and 100-seed weight	Khan, 1981, 1982 a[illegible] 1984

Brock (1967) treated early flowering race of *Arabidopsis thaliana* with gamma rays and thermal neutrons and obtained visible mutations and variation in flowering time and plant weight. There were negative phenotypic and genotypic correlations between the induced flowering time and plant weight variations. His results supported the hypothesis that random mutation results in an increase in variance for quantitative charactes which can be utilized by selection. He also indicated that mean of character not subjected to selection after the induction of mutation will be determined by its previous history and its genetic correlation existing between it and a character under selection. Brock (1976) selected the most extreme mutants for lateness after EMS treatment, for earliness after thermal neutrons treatment and for increased plant weight after EMS and gamma rays treatment. Their results supported the previously proposed hypothesis.

Kumar and Das (1969), reported earliness in flowering after exposing the seeds of brown sarson with gamma rays and thermal neutrons. Higher values of heritability, gentic coefficient of variation and genetic advance obtained in the irradiated material were indicative of mutations at additive gene loci.

Shaikh and Ahmed (1982) isolated some putative mutants in *Cicer arietinum* on the basis of leaf characters, flowering time, plant type and seed yield. They also isolated a mutant with the highest protein content and also a considerable higher seed yield.

A depressing effect of gamma irradiations was observed by Shakoor *et al*. (1978) on all the characters studied in mungbean

The magnitude of broad sense heritability estimates for plant height appeared to be related to the radiation exposure and were usually of high order indicating the possibility of effective selection in M_2 generation.

Gardner (1961) suggested the use of irradiations (Neutrons) in maize to induce beneficial changes in genes affecting yield for those populations that have reached a plateau or in which genetic variation is rather limited. He argued that no particular advantage of irradiation is achievable in highly heterozygous and heterogeneous populations. Nevertheless, irradiation increased mean yield in subsequent generations.

Ojomo and Chheda (1972) observed no change in mean but a higher value of variance for number of pods per plant after x-rays and neutrons treatments in cowpea. They suggested that by using pods per plant as selection index, it is possible to make selection from irradiated populations which on the average yielded higher than similar selections from the control populations.

Khan (1982) studied variation in quantitative characters of mungbean (Phaseolus aureus Roxb.) after seed irradiation with gamma rays. The greatest variability was generated in the M_2 for yield, number of fertile branches, number of pods and 100-seed weight. Khan (1984) further studied the quantitative variations induced by gamma rays, ethyl methane sulfonate and hydrazine and reported higher values for the genotypic coefficient of variation heritability and genetic advance of the character in M_3 than in the M_2 indicating that the gain could be achieved by selection in the M_3.

He also observed higher variances in the M_2 indicating the effectiveness of these treatments in inducing mutations in polygenic characters.

Thakarl et al. (1981) reported the variation in some physiological components of yield viz-rate of dry matter accumulation and its partitioning, leaf area, specific leaf weight, number of cells per lamina and their size, seed yield and its components, and protein content, in induced mutants of mungbean. They got five true breeding mutants showing variation in leaf size.

Pai and Gaur (1983, 1987) observed quantitative and qualitative changes in mitochondrial proteins isolated from irradiated kidney bean hypocotyl segments. They observed reduction in protein content and qualitative alteration in these proteins. These changes were attributed to radiated induced enhancement of protease activity.

2.3 Hybridization and Mutagenesis

Hybridization has since long been used as a mechanism to create genetic variability. However, the use of induced mutation has not only provided an effective supplement to the conventional approach of plant breeding but also acted as an important means for repatterning the genetic architecture of the crop plants. It serves as an important source of variability to be used for recombination (Razzaque, 1971).

Gregory (1956,1961) proposed that mutation offered an alternative to hybridization since quantitative variation generated by both the methods were equally heritable. He also emphasised that there was no experimental evidence to contradict the hypothesis that the radiation treatment might destroy some of the latent variance in the F_1 generation.

Krull and Frey (1961) evaluated pure line and hybrid populations of oat for the effect of an acute dose of thermal neutron irradiation on the genetic variability of three quantitatively inherited characters heading date, height and 100-seed weight. They observed that radiation increased the variance both between and within families in Clintland, Beede and hybrid backgrounds. No consistent positive or negative shifts in skewness value were induced by radiation. The results from selection experiment and heritability percentages indicated that the variability created by radiation was equally as heritable as that due to hybridization.

Jalil Miah and Yamaguchi (1965) made a comparative assessment of irradition effects on the amount of induced variability in several quantitative characters of two rice varieties (Kinmage and Gasastigue) and their hybrids. They noticed significantly higher variation in hybrids than their parents in X_3 and later generations. According to them selection for plant yield in the irradiated hybrid progenies should be continued in subsequent generation as in cross breeding. They realized the importance of genotypic background favourable for mutagenesis and suggested the use of mutagenising F_1 hybrids. Similar observations were also made by Emergy _et al_. (1964) and Loesch (1964).

Pinchinat and Adams (1966) studied the effect of intercrossing and neutron irradiation on yield components in beans. The correlation coefficient between mean number of pods per plant and mean number of seeds per pod showed a tendency to decrease with both intercrossing and irradiation.

Saini and Sharma (1970) observed that in two rice varieties and F_2 hybrids gamma radiations did not change the mean value but the genetic variance in the hybrid material was greater in magnitude than that in controls for most of the characters. It further increased showing a supplementary effect to the variance normally released by hybridization. The heritability estimates and genetic gains also followed the same trend. It was concluded that hybridization followed by irradiation may be better than hybridization alone.

Khadr (1970) reported that both irradiation and EMS produced significant variability in seed weight and its components in two wheat varieties whereas in the hybrid the expression of irradiation induced variability was somewhat depressed. The variations resulting from EMS and hybridization were to a great extent independent and cumulative. Neither EMS nor irradiation caused any significant shift in the means of seed weight, width and length.

Further, Khadr and Shukry (1972) found that both gamma irradiation and EMS seed treatments induced significant genetic variability for heading date, plant height, spike length and kernel weight in two pure wheat cultivars, but neither was effective in increasing the genetic variation in the hybrid background. The relative magnitude of induced variation compared with that from hybridization depended on the particular mutagen, and attribute and averaged less than 50% of that from hybridization. Heritability and expected genetic gains were not much lower in mutagenic populations than in hybrid populations. They indicated that induced mutations were some what similar in nature to the variation released from hybridization. The induced variation was not accompanied by any shift in the population mean and, in most cases, variation was equally distributed around the population mean.

Virk et al. (1978) studied gamma radiation induced polygenic variation in pure breeding and segregating genotypes of wheat and rice. The magnitude of induced variation in pure breeding lines of wheat for grain number and grain yield was equal to or greater than the conventional segregation following hybridization. For rice, the two types of variations were almost the same for yield but the hybridization segregation was greater for plant height and tiller number. They also reported that variations from hybridization and irradiation were generally not cumulative. In wheat, similar non-cumulative variations were also observed by Gupta and Virk (1977). The latter found an increase in additive and non-additive component of variance following irradiation. They recommended the use of irradiation as a supplement to hybridization.

Avakyan et al. (1977) observed that in the F_1 hybrids of wheat, mutation frequency in F_2M_2 exceeded the sum of the frequencies of the irradiated parents.

Wheat hybrids and their parents were compared by Kassem et al. (1976) before and after mutagenic treatment. Mutational effects on heritability value of particular traits were specific and unique for each parent. EMS mutagenized population had higher heritability value as compared to irradiated populations in both the varieties. Although untreated population of hybrid origin had higher heritability than the irradiated populations of either parent for all traits except grain yield, the mutagen treatment increased heritability in hybrids.

Like the parent varieties, differential response of different hybrids has also been reported in relation to mutagenesis (Avakyan, 1974). He found that inter-varietal tobacco hybrids were more radio resistant than either of the parents. However, in wheat, different hybrids had varying degree of resistance to ionizing radiations. The hybrids exceeded their parent varieties in frequency and spectrum of mutations (Gupta and Virk, 1977).

Quantitative variations were induced in an F_2 population of Nicotiana rustica by gamma irradiation. Using triple cross and a hierarchial inbreeding design (Virk et al., 1981), they noticed an increase in the additive genetic variance for four characters, viz., leaf width, flowering time, height at flowering time and final height. Increase in the dominance components of variation was also noticed. They concluded that some of the mutations might have induced the loci at which the F_2 was already segregating, thus creating three or more alleles at these loci.

Sharma et al. (1982) studied variations in polygenic traits induced by treating the F_1 seeds with EMS in some spring wheat crosses. They observed that ranges and variances increased with mutagen treatment in most of the cases, suggesting the efficiency of mutagen treatment of F_1 seeds in increasing the F_2 variability. As regard mean, it was either lower or higher in treated F_2 populations. The character association among grain yield and quality traits altered in direction or magnitude or both due to intermating/or mutagen treatment or both. In some cases the direction was unaltered in desirable manner. They suggested the biparental mating of mutagen treatment/or both to break undesirable linkage between desirable traits.

Sharma et al. (1986) estimated additive and dominance genetic variance by NCD II (Normal and mutagen treated populations) and NCD III (normal populations) biparental mating designs for protein and tryptophan content in wheat. Both additive and dominance genetic variance were important for controlling the traits. The estimates of the additive genetic variances increased in the mutagen treated populations, whereas the dominance genetic variance decreased for both the traits. The mean of the NCDII and NCD III progenies (B_1P_5) were higher than those of the F_2 and F_3 selfs. The mean performance of both traits increased in the second cycle of biparental matings over the first. They suggested the recurrent biparental matings in the early generation to exploit both additive and non-additive genetic variances, to break undesirable linkage and to release latent genetic variability and ultimately to improve the populations.

Virk et al. (1986) compared the mean performance of F_6 and F_7 generations of pea produced from control and irradiated F_2 seeds together with the parental lines for ten metric traits and the variability was partitioned by weighted least square analysis. irradiation induced both additive and dominance gene effects for three characters namely height of first pod bearing node, number of days to flowering and seed yield and only the additive effects for seed number. No variation could be induced for height at flowering, height at maturity, number of secondary branches and total number of pods. Variation neither existed nor could be induced in number of primary branches and number of nodes.

MATERIALS AND METHODS

This study was carried out at Haryana Agricultural University, Hisar. The experimental material constituted two recommended varieties of green gram (Vigna radiata L. Wilczek) K-851 and ML-9. Variety K-851 is from Kanpur and is characterized by profuse branching, medium maturity, shining green medium seeded, wider adaptability, susceptible to yellow mosaic virus and ML-9 is from Ludhiana and is characterized by profuse branching, late maturity, small seeded, tolerant to yellow mosaic virus.

Dry seeds of these two varieties were irradiated with 20kR gamma rays (^{60}Co source) in the Department of Genetics, Haryana Agricultural University, Hisar. The irradiated seeds were sown to have the M_1 generation. Unirradiated seeds were also sown. Normal looking fertile M_1 plants selected at random were involved in hybridization programme so that either both or one of the parents happened to be irradiated.

The material including parents, M_2, F_1 and M_2F_1 was sown in the following year for evaluation and consisted of the following parents and their crosses.

ML-9
"ML-9"

K-851
"K-851"

ML-9 x K-851
ML-9 x "K-851"
"ML-9" x K-851
"ML-9" x "K-851"

K-851 x ML-9
"K-851" x ML-9
K-851 x "ML-9"
"K-851" x "ML-9"

The irradiated parent is enclosed within inverted commas.

Mutants for gross morphological features were harvested and evaluated separately in M_2,F_1 and M_2F_1. Other plants too were harvested individually. Single plant progeny of M_2, F_1 and M_2F_1 were again grown in the following year in Randomized Block Design with a view to assess the variability in morphological and quantitative traits in M_3, F_2 and M_3 F_2.

Quantitative Characters

Observations on the following quantitative characters were recorded on normal looking plants.

i) Plant height: The plant height was measured in cm. from ground level to the tip of the plant.

ii) Number of pod/plant : Total number of pods on a plant were counted at maturity.

iii) Pod length : The pod length (cm) was worked out by taking mean of five randomly selected pods for each plant.

iv) Number of seeds/pod : The number of seeds per pod was worked out by averaging the total seeds of a random sample of five pods for each plant.

v) 100-seed weight : 100 seeds were counted at maturity at random for individual plant and weighted in grams.

vi) Seed yield per plant : The weight (g) for all the seeds produced by each plant was recorded.

Number of plants in each of the genetic groupings for M_2, F_1 and M_2F_1 and M_3,F_2 and M_3F_2 generation are presented in table 1 and table 2.

Morphological mutants

The morphological mutants which appeared in the M_2, F_1 and M_2F_1 populations were sown separately to study their behaviour in M_3, F_2 and M_3F_2 generation.

The frequency of the mutants for a particular character was also calculated.

$$\text{Percentage of the plant for a particular morphological variant} = \frac{\text{Total number of plants showing particular morphological variants}}{\text{Total number of plants showing different morphological variants}} \times 100$$

Statistical analysis

Data collected for the six quantitative characters in M_2, F_1 and M_2F_1 and M_3,F_2 and M_3F_2 generations were analysed. The details of statistical methods employed are given below.

Mean : $$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}$$

(x = variate value of the character
n = number of values)

Variance : $$S^2 = \frac{1}{n-1}\left[\sum_{i=1}^{n} (x_i)^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}\right]$$

Standard error : $$S.E. = \sqrt{S^2/n}$$

Coefficient of variation : $$C.V. = \frac{\sqrt{S^2}}{\bar{X}} \times 100$$

Table 1: Number of plants of M_2 and M_2F_1 on which data were recorded.

	R_1	R_2	R_3
ML - 9	6	6	6
"ML-9"	250	250	250
K - 851	7	6	7
"K-851"	250	250	250
ML - 9 x K-851	20	23	16
ML - 9 x "K-851"	23	19	16
"ML-9" x K-851	30	26	31
"ML-9" x "K-851"	32	40	25
K-851 x ML-9	25	25	21
"K-851"x ML-9	61	57	46
K - 851x "ML-9"	16	12	12
"K-851"x "ML-9"	73	46	46

" " indicates the irradiated parent

Table 2: Number of progeny rows of M_3 and M_3 F_2 on which data were recorded.

		R_1	R_2	R_3
ML - 9		18	18	18
"ML -9"		30	30	30
K -851		15	15	15
"K-851"		30	30	30
ML -9	x K-851	30	30	30
ML -9	x"K-851"	30	30	30
"ML-9"	x K-851	30	30	30
"ML-9"	x"K-851"	30	30	30
K - 851	x ML - 9	30	30	30
"K-851"	x ML-9	30	30	30
K-851	x "ML-9"	30	30	30
"K-851"	x "ML-9"	30	30	30

" " indicates the irradiated parent

Genotypic coefficient of variation : $G.C.V. = \frac{\sqrt{\sigma^2 g}}{\bar{x}} x 100$

($\sigma^2 g$ = genotypic variance)

Phenotypic coefficient of variation : $P.C.V. = \frac{\sqrt{\sigma^2 p}}{\bar{x}} x\ 100$

[$\sigma^2 p$ (phenotypic variance) = $\sigma^2 g + \sigma^2 e$]

Heretability : $H = \sigma^2 g / \sigma^2 p$

(broad sense)

Genetic advance : G.A. $\frac{K.\ \sigma p.\ H}{\bar{x}.} x\ 100$

(%age of mean)

(K = Selection differential in standard unit 2.06 at 5% selection for large sample)

Test of homogeneity of variance

To test the homogeneity of variance a method given by Bartlett in 1937 is used. When the degree of freedoms are different, the test criterion is

$$M = (2.3026)[(\Sigma fi) \log \bar{S}^2 - \Sigma fi \log Si^2]$$

($\bar{S}^2 = \Sigma fiSi^2 / \Sigma fi$

Si^2 = variances)

$$C = 1 + \frac{1}{3(a-1)} \left[\Sigma \frac{1}{fi} - \frac{1}{\Sigma fi} \right]$$

(a = genetic groups)

χ^2 = M/c with (a-1) degree of freedom.

When some or all of the Si^2 are less than 1, it is worth noting that χ^2 is unchanged if all Si^2, $\bar{S}^2$ are multiplied by the same number (say 10 or 100).

RESULTS

Gamma radiations affect cytoplasmic organelles as well as cause mutations. While the direct effects on the cytoplasmic organelles find immediate expression, genetic effects may not be properly expressed due to altered physiology of the plant or, if the genetic effects are of recessive nature these will not be detected.

Plants in M_1 generation were, therefore, used only for making crosses and no data were recorded on them. Detailed observations on quantitative characters were recorded in M_2,F_1 and M_2F_1. These generations were carried further in the following year and data were recorded on M_3,F_2 and M_3F_2 generations.

4.1 Quantitative characters in M_2,F_1 and M_2F_1 generations

4.1.1 Plant height

With irradiation, no significant change in mean was observed in both the varieties. However, a significant increase in variance and coefficient of variation was recorded in irradiated ML-9. Crosses (ML-9 x "K-851" and "K-851" x ML-9) where irradiated K-851 was used either as male or as female parent, a decrease in mean was observed. "ML-9" x "K-851" also showed decrease in mean plant height. An increase in variance was observed in K-851 x "ML-9" cross. When irradiated ML-9 was used as either male or female parent, an increase in coefficient of variation was observed. Increase in coefficient of variation was also observed in ML-9 x "K-851" and "K-851" x "ML-9" crosses (Table 3).

4.1.2 Number of pods per plant

Irradiated ML-9 showed an increase in mean, variance and coefficient of variation. On the other hand, no change in mean, and

Table 3: Mean and variance for plant height in M_2 and M_2F_1 progenies.

	Mean(cm)	Variance	Coefficient of variation
ML -9	39.65 ± 1.60	46.36	17.17
"ML-9"	42.14 ± 0.64	306.36	41.54
K-851	35.64 ± 1.22	29.92	15.35
"K-851"	34.25 ± 0.22	36.70	17.76
ML-9 x K-851	35.81 ± 0.87	44.92	18.71
ML-9 x "K-851"	31.85 ± 0.96	53.07	22.87
"ML-9"x K-851	35.43 ± 0.88	67.84	23.24
"ML-9"x "K-851"	32.04 ± 0.60	34.95	18.45
K-851 x ML -9	33.99 ± 0.76	40.65	18.77
"K-851x ML-9	30.29 ± 0.46	35.10	19.56
K-851 x"ML-9"	35.47 ± 1.34	72.18	23.95
"K-851"x"ML-9"	34.05 ± 0.60	59.32	22.62

" " indicates the irradiated parent.

variance and an increase in coefficient of variation was observed in irradiated K-851 (Table 4). Decrease in mean and variance was observed in "ML-9" x "K-851" cross. An increase in variance and coefficient of variation was recorded in the crosses where irradiated K-851 was used as female parent. But, reverse was true when it was used as the male parent. Reciprocal differences for variance were observed.

4.1.3 Pod length

Table 5 shows the mean, variance and coefficient of variation for pod length. A significant change was not found in mean, variance, and coefficient of variation in both the varieties when irradiated. Irradiation followed by hybridization caused a decrease in the mean which was more pronounced when irradiated ML-9 was used as either parent. The use of irradiated K-851 as male parent resulted in an increase in variance and coefficient of variation. The cross, "K-851" x "ML-9", also showed significantly higher values of variance and coefficient of variation. Among crosses reciprocal differences for variance were observed.

4.1.4 Number of seeds per pod

No change in mean and variance was observed upon irradiation in both the varieties. Irradiated K-851 showed an increase in coefficient of variation. Irradiation followed by hybridization resulted in a decrease in mean which was maximum in the crosses where both the parents happened to be irradiated. An additive increase in variance and coefficient of variation was observed in M_2F_1 generation (Table 6).

Table 4: Mean and variance for number of pods per plant in M_2 and M_2F_1 progenies.

	Mean	Variance	Coefficient of variation
ML - 9	16.11 ± 1.48	39.67	39.10
"ML-9"	20.11 ± 0.40	119.72	54.41
K-851	17.40 ± 1.36	36.77	34.85
"K-851"	15.15 ± 0.30	66.77	53.94
ML - 9 x K - 851	20.63 ± 1.91	216.15	71.26
ML - 9 x "K - 851"	21 24 ± 1.45	121.63	51.92
"ML- 9" x K - 851	17 10 ± 1.34	155.49	72.92
"ML- 9" x "K - 851"	11.71 ± 0.78	59.12	65.66
K - 851 x ML - 9	14 42 ± 1.01	71.90	58.80
"K-851" x ML - 9	17.76 ± 1.06	184.45	76.47
K-851 x "ML-9"	15.35 ± 1.48	87.66	60.99
"K-851" x "ML-9"	15 87 ± 0.90	124.83	70.44

" " indicates the irradiated parent

Table 5: Mean and variance for pod length in M_2 and M_2F_1 progenies

			Mean (cm)	Variance	Coefficient of variation
ML - 9			6.25 ± 0.11	0.23	7.67
"ML-9"			6.18 ± 0.02	0.28	8.56
K-851			7.39 ± 0.15	0.45	9.08
"K-851"			7.32 ± 0.03	0.51	9.76
ML - 9	x	K-851	6.60 ± 0.08	0.34	8.83
ML - 9	x	"K-851"	6.55 ± 0.19	2.04	21.81
"ML-9"	x	K-851	6.28 ± 0.05	0.20	7.12
"ML-8"	x	"K-851"	6.03 ± 0.08	0.64	13.27
K-851	x	ML-9	6.98 ± 0.11	0.85	13.21
"K-851"	x	ML-9	6.59 ± 0.07	0.91	14.47
K - 851	x	"ML-9"	5.93 ± 0.14	0.79	15.01
"K-851"	x	"ML-9"	6.31 ± 0.11	2.15	23.24

" " indicates the irradiated parent

Table 6: Mean and variance for number of seeds per pod in M_2 and M_2F_1 progenies.

	Mean	Variance	Coefficient of variation
ML-9	9.12 ± 0.38	2.58	17.61
"ML-9"	8.30 ± 0.06	2.49	19.01
K-851	10.16 ± 0.27	1.50	12.05
"K-851"	9.60 ± 0.05	2.23	15.55
ML - 9 x K-851	9.49 ± 0.16	1.44	12.64
ML - 9 x "K-851"	8.50 ± 0.29	5.03	27.08
"ML-9" x K-851	8.35 ± 0.18	2.40	20.39
"ML-9" x "K-851"	8.16 ± 0.19	3.56	23.12
K - 851 x ML - 9	9.51 ± 0.16	1.74	13.87
"K-851" x ML - 9	8.13 ± 0.02	4.35	25.65
K - 851 x "ML - 9"	8.20 ± 0.36	5.18	27.75
"K - 851" x "ML - 9"	7.94 ± 0.20	6.65	32.48

" " indicates the irradiated parent

4.1.5 100-seed weight

Results of mean, variance and coefficient of variation for 100-seed weight are presented in Table 7. The mean value of 100-seed weight increased in irradiated ML-9. Both the irradiated varieties showed a increase in variance and coefficient of variation. Increase in variance and coefficient of variation was also observed in ML-9 x "K-851", "K-851" x ML-9 and "K-851" x "ML-9" crosses. K-851 x "ML-9" showed increased value of coefficient of variation only.

4.1.6 Seed yield per plant

No change in mean, variance and coefficient of variation for seed yield per plant was observed in irradiated ML-9. Irradiated K-851 showed increase in variance and coefficient of variation while the mean remained unaffected (Table 8). ML-9 x "K-851" showed an increase in mean. Decrease in mean and variance was observed in "ML-9" x "K-851". An increase in variance was observed in "K-851"x ML-9. In "ML-9" x K-851, "ML-9" x "K-851", "K-851" x ML-9 and "K-851" x "ML-9" coefficient of variation for seed yield per plant increased where as a decrease was observed in ML-9 x "K-851" (Table 8).

4.2 Quantitative characters in M_3, F_2 and M_3F_2 generations

4.2.1 Plant height

The mean plant height of both the varieties increased upon irradiation (Table 10). Significant mean square values for plant height were observed in all the genetic groups except K-851 x ML-9 (Table 9). Both the irradiated varieties when compared to their respective controls did not show any significant change in variance. A decrease in coefficient of variation was observed in irradiated

Table 7: Mean and variance for 100-seed weight in M_2 and M_2F_1 progenies.

	Mean (g)	Variance	Coefficient of variation
ML - 9	2.85 ± 0.06	0.05	7.84
"ML- 9"	3.15 ± 0.02	0.21	14.55
K-851	3.47 ± 0.90	0.17	11.88
"K-851"	3.88 ± 0.30	0.49	18.04
ML - 9 x K -851	3.17 ± 0.07	0.27	16.39
ML - 9 x "K-851"	3.67 ± 0.28	4.67	58.88
"ML-9" x K - 851	3.34 ± 0.07	0.41	19.17
"ML-9" x "K-851"	3.46 ± 0.05	0.27	15.02
K - 851x ML-9	3.55 ± 0.70	0.33	16.18
"K-851"x ML-9	4.01 ± 0.06	0.65	20.11
K-851 x "ML-9"	3.32 ± 0.11	0.46	20.43
"K-851"x "ML-9"	3.63 ± 0.11	1.84	37.37

" " indicates the irradiated parent

Table 8: Mean and variance for seed yield/plant in M_2 and M_2F_1 progenies.

	Mean(g)	Variance	Coefficient of variation
ML - 9	3.97 ± 0.45	3.68	48.67
"ML- 9"	4.74 ± 0.09	6.26	52.74
K - 851	5.23 ± 0.40	3.22	34.31
"K- 851"	4.96 ± 0.10	7.09	53.68
ML - 9 x K-851	4.85 ± 0.41	9.93	64.97
ML - 9 x "K-851"	6.09 ± 0.41	9.52	50.66
"ML-9" x K-851	4.06 ± 0.30	8.32	71.05
"ML-9" x "K-851"	2.96 ± 0.05	5.12	76.44
K - 851 x ML-9	4.25 ± 0.31	6.80	61.36
"K-851" x ML-9	4.80 ± 0.26	11.04	67.95
K-851 x "ML-9"	3.83 ± 0.39	6.18	64.91
"K-851" x "ML-9"	4.18 ± 0.23	8.69	70.57

" " indicates the irradiated parent

Table 9: ANOVA for various characters in single plant progenies of M_3, F_2 and M_3F_2.

	d.f.	Plant height	Number of pods/plant	Pod length	Number of seeds/pod	100-seed weight	Seed yield/ plant
ML - 9	17	172.42**	202.69**	0.29	1.49**	0 19	17.45**
"ML -9"	29	155.98**	101 18**	0.25**	1.73**	0.15**	13.02**
K - 851	14	170.15**	22.67	0.32	0.80	0.42**	3.14**
"K-851"	29	227.21**	33.53**	0.51**	1.45**	0.39	9.82**
ML - 9 x K-851	29	405 57**	76 33	0.75**	2.84**	0.30**	3.03**
ML - 9 x "K-851"	29	135.42**	57 19*	0.38	1.09**	0 49**	7.95**
"ML- 9" x K-851	29	196.20**	217 78**	0.48**	1.29	0 36**	12 24*
"ML-9" x "K-851"	29	215 89**	86.34	0.37	1.99*	0.31	13.67**
K - 851 x ML-9	29	64.34	77.42**	0 42	1.45*	0.45**	5 68**
"K- 851" x ML-9	29	152.05**	55 83	0 46*	1.51	0 59	5 44
K -851 x "ML-9"	29	130 20**	93 36**	0.48**	1.24	0.46**	3 66
"K-851" x "ML-9"	29	113.76**	46.40	0.56	1.60*	0.41	2.48

" " indicates the irradiated parent

* = Significant at 5%

** = Significant at 1%

Table 10: Mean and variance for plant height in M_3 and M_3F_2 progenies.

	Mean (cm.)	Variance	Coefficient of variation
ML -9	58.39 ± 0.89	87.04	15.98
"ML-9"	65.00 ± 0.71	82.38	13.96
K-851	47.77 ± 1.05	101.86	21.12
"K-851"	55.50 ± 0.48	87.71	16.87
ML-9 x K-851	58.93 ± 0.52	143.57	20.68
ML-9 x "K-851"	57.90 ± 0.85	90.20	16.40
"ML-9" x K-851	55.73 ± 0.98	130.80	20.52
"ML-9" x "K-851"	52.86 ± 0.71	169.60	24.64
K-851 x ML-9	60.00 ± 0.75	57.46	12.63
"K-851" x ML-9	61.12 ± 0.90	106.20	16.86
K-851 x "ML-9"	54.13 ± 0.71	90.26	17.55
"K-851" x "ML-9"	62.59 ± 0.74	82.24	14.48

" " indicates the irradiated parent

K-851. Use of irradiated ML-9 as one of the parents resulted in decrease in plant height. Among crosses no significant change in variance was observed. ML-9 x "K-851" showed a decrease in coefficient of variation while, an increase was observed in "ML-9"x "K-851", "K-851" x ML-9 and K-851 x "ML-9" crosses (Table 10).

A decrease in genotypic and phenotypic coefficient of variation, heritability and genetic advance was observed in irradiated ML-9, while reverse was true for irradiated K-851 except phenotypic coefficient of variation (Table 11). Lower values of genotypic and phenotypic coefficient of variation, heritability and genetic advance were observed when ML-9 was used as female parent, while reverse was true for crosses in which K-851 was used as female parent.

Irradiation of parental varieties was effective in causing an increase in the frequency of plants having greater plant height (Fig.1a and 1b). Some plants having height of around 87 cm were found in population derived from crossing the two control parents or where either one of the parent was irradiated but in population from parents, where both the parents were irradiated the maximum height was 83 cm (Fig.1c).

4.2.2 Number of pods per plant

Both the irradiated varieties showed no change in mean value (Table 12). Results in table 9 indicated that mean square values were significant in ML-9, "ML-9", "K-851", ML-9 x "K-851", "ML-9" x K-851, K-851 ML-9 and K-851 x "ML-9". Also no significant change in variance was found in both the varieties with irradiation. Irradiated ML-9 showed a decrease in coefficient of variation. Irradiation followed by hybridization increased the mean and it was

Table 11: Genotypic and phenotypic coefficient of variation, heritability and genetic advance for plant height in M_3 and M_3F_2 progenies.

	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability	Genetic advance
ML - 9	11.26	15.88	0.50	16.43
"ML-9"	9.35	13.94	0.45	12.93
K-851	13.25	19.88	0.44	18.19
"K-851"	14.95	17.05	0.77	26.98
ML - 9 x K-851	19.12	20.89	0.83	36.06
ML - 9 x "K-851"	8.62	16.22	0.27	8.92
"ML-9" x K-851	10.90	19.86	0.30	12.28
"ML-9" x "K-851"	11.88	22.15	0.29	13.12
K-851 x ML-9	3.62	12.35	0.08	2.19
"K-851' x ML-9	8.43	16.28	0.27	8.99
K-851 x "ML-9"	9.85	15.82	0.39	12.63
"K-851' x "ML-9"	7.40	13.44	0.30	8.40

" " indicates the irradiated parent

Fig. 1a. Frequency distribution for plant height in parent and M_3 progenies in ML-9

Fig. 1b. Frequency distribution for plant height in parent and M_3 progenies in K-851

Fig. 1c. Frequency distribution for plant height in M_3F_2 crosses.

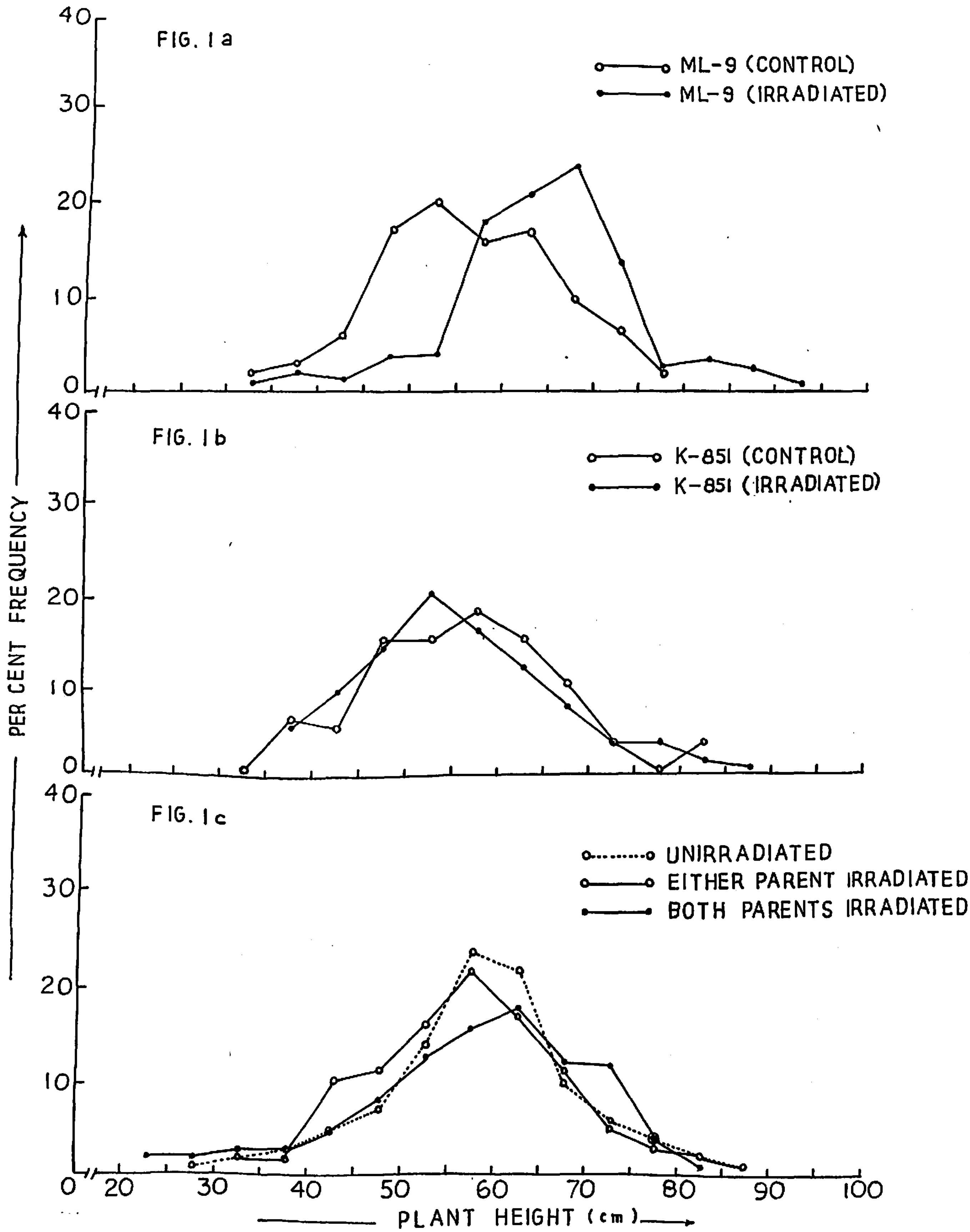
FIG. 1a
ML-9 (CONTROL)
ML-9 (IRRADIATED)
FIG. 1b
K-851 (CONTROL)
K-851 (IRRADIATED)
FIG. 1c
UNIRRADIATED
EITHER PARENT IRRADIATED
BOTH PARENTS IRRADIATED
PER CENT FREQUENCY
0
10
20
30
40
50
60
70
80
90
100
PLANT HEIGHT (cm)

Table 12: Mean and variance for number of pods per plant in M_3 and M_3F_2 progenies

	Mean	Variances	Coefficient of variation
ML - 9	19.25 ± 0.91	98.77	51.94
"ML-9"	21.83 ± 0.68	61.63	35.96
K-851	14.57 ± 0.67	24.54	34.00
"K-851"	16.05 ± 0.49	23.93	30.48
ML-9 x K-851	16.46 ± 0.55	42.57	39.64
ML-9 x "K-851"	20.04 ± 0.51	44.33	33 32
"ML-9"xK-851	27.25 ± 0.85	122.34	39.86
"ML-9" x "K-851"	22.28 ± 0.88	83.10	40.91
K-851 x ML-9	19.32 ± 0.55	42.86	33.89
"K-851"xML -9	21.90 ± 0.62	52.20	32.99
K-851 x "ML-9"	22.25 ± 0.54	54.29	33.11
"K-851"x"ML-9"	18.87 ± 0.49	31.29	29.64

" " indicates the irradiated parent

maximum in crosses where irradiated ML-9 was used as either parent. "ML-9" x K-851 showed increased value of variance. Among crosses no change in coefficient of variation was observed except in ML-9 x "K-851" and "K-851" x "ML-9" where a decrease in coefficient of variation was recorded (Table 12).

A decrease in genotypic and phenotypic coefficient of variation, heritability and genetic advance was observed in irradiated ML-9 while reverse was true for irradiated K-851 except phenotypic coefficient of variation which remained unchanged. Irradiation followed by hybridization resulted in a decrease in the values of these components except the crosses where irradiated ML-9 was used as one of the parents (Table 13).

Plants with higher number of pods per plant were observed only in irradiated K-851 (Fig.2a and 2b). Data presented in figure 2c showed that irradiation of either or both theparents before hybridization showed higher frequency of plants having more number of pods per plant as compared to hybridization alone.

4.2.3 **Pod length**

No change in mean pod length was recorded in irradiated ML-9 where as an increase was found in irradiated K-851 (Table 14). "ML-9", "K-851", ML-9 x K-851, "ML-9" x K-851, "K-851" x ML-9 and K-851 x "ML-9" showed significant mean square values for pod length (Table 9). Irradiated ML-9 showed a marginal decrease in variance and coefficient of variation where as no change was observed in irradiated K-851. In M_3F_2 when ML-9 or irradiated ML-9 was used as male parent, a decrease in mean was noticed. Increase in mean pod length was observed in ML-9 x "K-851". No significant

Table 13: Genotypic and phenotypic coefficient of variation, heritability and genetic advance for number of pods per plant in M_3 and M_3F_2 progenies.

	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability	Genetic advance
ML - 9	37.65	51.32	0.53	56.92
"ML-9"	20.40	41.80	0.24	20.54
K-851	5.27	31.52	0.03	1.82
"K-851"	13.36	30.73	0.20	11 96
ML-9 x K-851	24.67	40.00	0.38	31 30
ML-9 x "K-851"	14.66	31.54	0.22	14.02
"ML-9" x K-851	25.65	38.88	0.44	37.24
"ML-9" x "K-851"	10.66	31.88	0.08	6.02
K-851 x ML-9	21.23	34.23	0.38	27 11
"K-851" x ML-9	12.06	29.55	0.17	10 14
K-851 x "ML-9"	21.20	31.42	0.45	29.45
"K-851" x "ML-9"	15.20	28.98	0.28	16.43

" " indicates the irradiated parent

Fig.2a. Frequency distribution for number of pods per plant in parent and M_3 progenies in ML-9

Fig.2b. Frequency distribution for number of pods per plant in parent and M_3 progenies in K-851

Fig.2c. Frequency dsitribution for number of pods per plant in M_3F_2 crosses

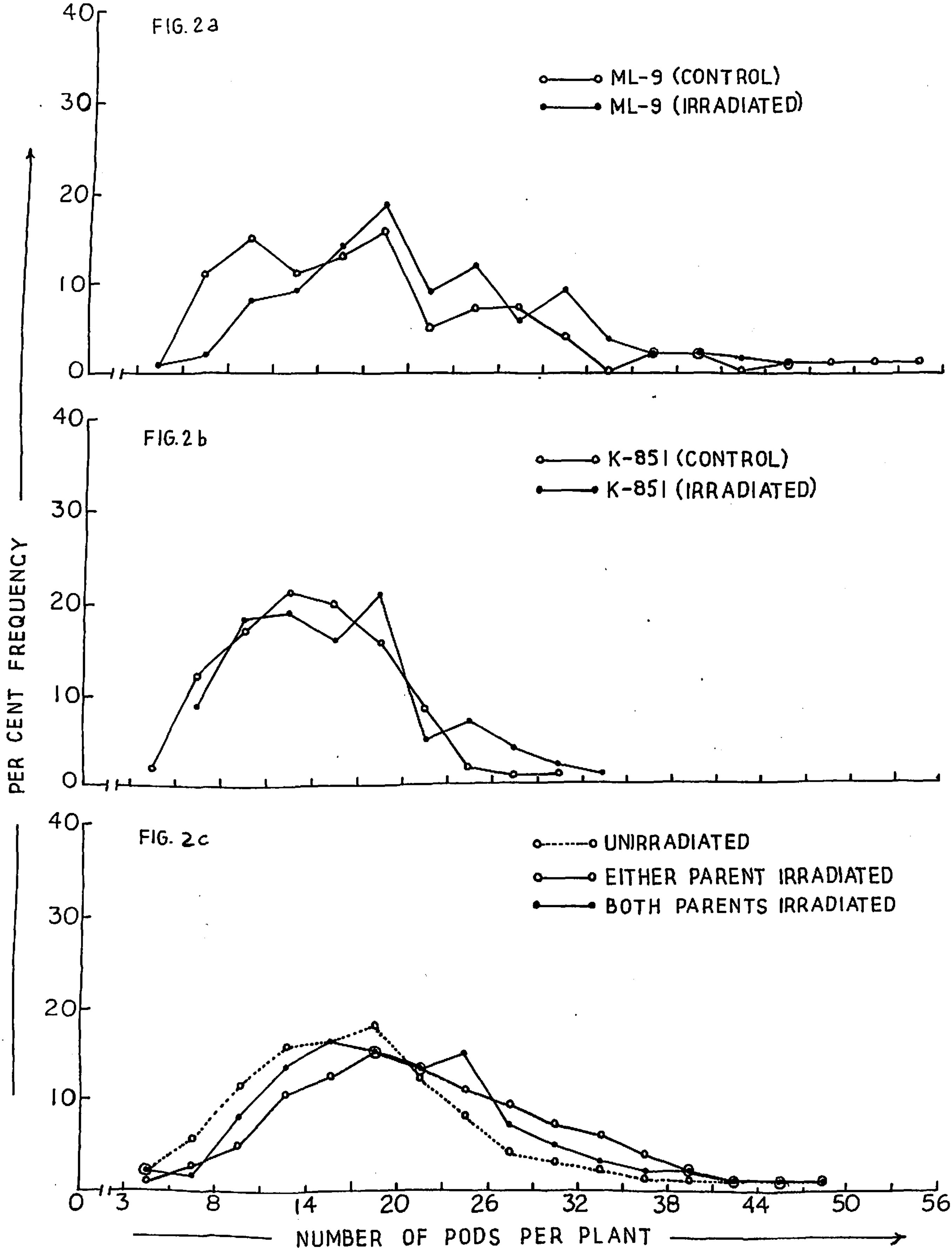

FIG. 2a
ML-9 (CONTROL)
ML-9 (IRRADIATED)
FIG. 2b
K-851 (CONTROL)
K-851 (IRRADIATED)
FIG. 2c
UNIRRADIATED
EITHER PARENT IRRADIATED
BOTH PARENTS IRRADIATED
PER CENT FREQUENCY
NUMBER OF PODS PER PLANT
0 3 8 14 20 26 32 38 44 50 56
0 10 20 30 40

Table 14: Mean and variance for pod length in M_3 and M_3F_2 progenies

	Mean (cm)	Variance	Coefficient of variation
ML - 9	6.26 ± 0.70	0.31	8.95
"ML-9"	6.25 ± 0.02	0.13	5.77
K-851	6.61 ± 0.06	0.25	7.59
"K-851"	7.00 ± 0.04	0.26	7.29
ML-9 x K-851	6.38 ± 0.03	0.31	8.72
ML-9 x "K-851"	6.81 ± 0.06	0.37	8.99
"ML-9" x K-851	6.24 ± 0.05	0.30	8.77
"ML-9" x "K-851"	6.37 ± 0.06	0.43	10.34
K-851 x ML-9	7.13 ± 0.06	0.38	8.61
"K-851" x ML-9	6.80 ± 0.06	0.44	9.82
K-851 x"ML-9"	6.18 ± 0.03	0.22	7.61
"K-851" x "ML-9"	6.59 ± 0.06	0.46	10.32

" " indicates the irradiated parent

change in variance was observed among crosses. An increase in coefficient of variation was observed in crosses having both the parents irradiated (Table 14).

Upon irradiation an increase in genotypic coefficient of variation, heritability and genetic advance was observed in both the varieties where as the phenotypic coefficient of variation remained unchanged. In the crosses where ML-9 or irradiated ML-9 was used as female parent a decrease in genotypic coefficient of variation, heritability and genetic advance was observed while the crosses having K-851 or irradiated K-851 as the female parent showed an increase in these components. Irradiation followed by hybridization resulted in a decrease in phenotypic coefficient of variation except the crosses where both the parents happened to be irradiated (Table 15).

Results presented in figure 3a and 3b showed that irradiation of both the varieties was uneffective in causing any change in frequency of plants having greater pod length. As compared to hybridization alone, irradiation of either or both the parents followed by hybridization showed higher frequency of plants with greater pod length (Fig.3c).

4.2.4 Number of seeds per pod

Irradiation increased the mean of both the varieties (Table 16). The data given in table 9 indicated that the mean square values were significant for all the genetic groups except K-851, "ML-9" x K-851, "K-851" x ML-9 and K-851 x "ML-9". With irradition no change in variance and coefficient of variation was observed in both the varieties. ML-9 x "K-851" showed an increased value of

Table 15: Genotypic and Phenotypic coefficient of variation, heritability and genetic advance for pod length in M_3 and M_3F_2 progenies.

	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability	Genetic advance
ML - 9	-	4.63	-	-
"ML- 9"	0.96	5.77	0.46	5.48
K - 851	0.75	7.26	0.22	3.25
"K-851"	4.95	7.42	0.44	6.80
ML - 9 x K-851	7 29	13.88	0.69	12 65
ML - 9 x "K-851"	-	9.05	-	-
"ML-9" x K-851	4.90	8.03	0.31	5.53
"ML-9" x "K-851"	8.45	18.64	0 21	8 08
K-851 x ML-9	0.32	13.72	0.05	0.45
"K-851" x ML-9	3.50	8.70	0.17	3 06
K-851 x "ML-9"	2.21	10.81	0.67	10.27
"K-851" x "ML-9"	4.01	16.20	0.17	3.39

" " indicates the irradiated parent

Fig.3a. Frequency distribution for pod length in parent and M_3 progenies in ML-9

Fig.3b. Frequency distribution for pod length in parent and M_3 progenies in K-851.

Fig.3c. Frequency distribution for pod length in M_3F_2 crosses.

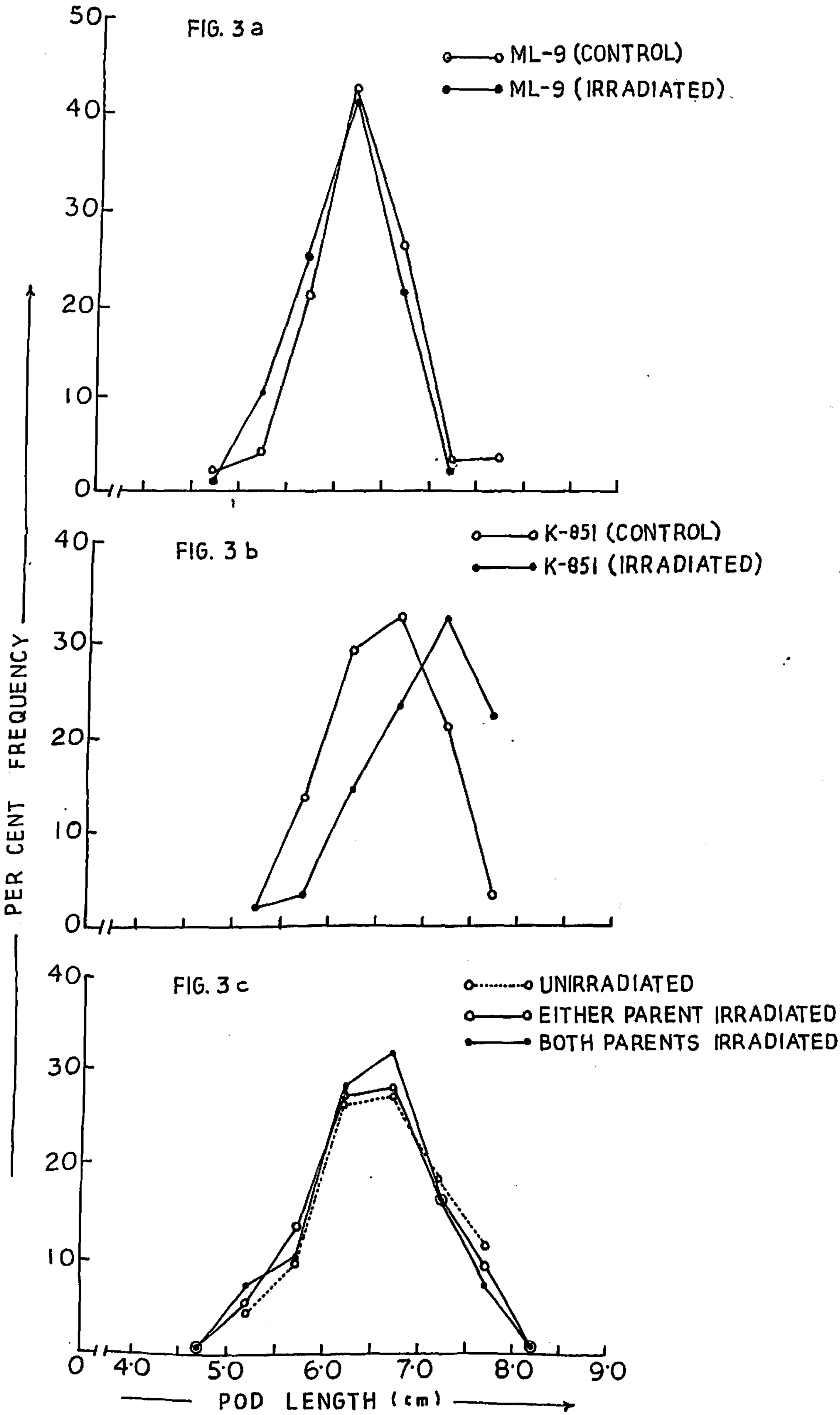
FIG. 3 a
ML-9 (CONTROL)
ML-9 (IRRADIATED)
FIG. 3 b
K-851 (CONTROL)
K-851 (IRRADIATED)
FIG. 3 c
UNIRRADIATED
EITHER PARENT IRRADIATED
BOTH PARENTS IRRADIATED
PER CENT FREQUENCY
POD LENGTH (cm)
0
10
20
30
40
50
4·0
5·0
6·0
7·0
8·0
9·0

Table 16: Mean and variance for number of seeds per pod in M_3 and M_3F_2 progenies.

	Mean	Variance	Coefficient of variation
ML - 9	9.31 ± 0.01	0.86	9.97
"ML-9"	9.70 ± 0.06	0.77	9.05
K-851	9.12 ± 0.13	0.90	10.41
"K-851"	9.96 ± 0.06	0.73	8.57
ML-9 x K-851	9.19 ± 0.10	1.51	13.36
ML-9 x "K-851"	10.04± 0.06	0.59	7 62
"ML-9" x K-851	9.37 ± 0.08	0.86	9.93
"ML-9" x "K-851"	9.44 ± 0.11	1.60	13.42
K-851 x ML-9	9.93 ± 0.10	1.14	11.90
"K-851" x ML-9	9.32 ± 0.11	1.25	12.02
K-851 x "ML-9"	9.27 ± 0.11	1.41	12.80
"K-851" x "ML-9"	9.03 ± 0.10	1.16	11.96

" " indicates the irradiated parent

mean but decreased values of variance and coefficient of variation. A decrease in coefficient of variation was also observed in "ML-9" x K-851 cross. Crosses having K-851 or irradiated K-851 as the female parent showed no change in mean, variance and coefficient of variation (Table 16).

Increased values of genotypic and phenotypic coefficient of variation, heritability and genetic advance were recorded in both the irradiated varieties. A decrease in genotypic coefficient of variation, heritability and genetic advance was observed in M_3F_2 generation. ML-9 x "K-851" and "ML-9" x K-851 showed lower value of phenotypic coefficient of variation. Exceptionally high values of phenotypic coefficient of variation were observed in crosses having irradiated ML-9 as the male parent (Table 17).

Inspite of an increase in mean values upon irradiation, irradiation, hybridization alone and irradiation followed by hybridization was not found to be effective in causing an increase in frequency of plants having more number of seeds per pod (Fig.4a, 4b and 4c).

4.2.5 100-seed weight

Table 18 showed that irradiated ML-9 showed a decrease in mean value for 100-seed weight. Mean square values for 100-seed weight were significnat in "ML-9", K-851, ML-9 x K-851, ML-9 x "K-851", "ML-9" x K-851, K-851 x ML-9, and K-851 x "ML-9" (Table 9). No change in variance was observed in both the varieties upon irradiation. A decrease in coefficient of variation was observed in irradiated ML-9 and reverse was true for irradiated K-851. Use of irradiated K-851 as one of the parents resulted in an increase in

Table 17: Genotypic and phenotypic coefficient of variation, heritability and genetic advance for number of seeds per pod in M_3 and M_3F_2 progenies:

	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability	Genetic advance
ML - 9	5.98	10.02	0.36	7.33
"ML- 9"	7.12	17.11	0.62	11.51
K - 851	-	9.80	-	-
"K-851"	6.02	15.90	0.49	8.67
ML - 9 x K - 851	8.80	13.46	0.42	11.81
ML - 9 x "K - 851"	4.91	7.72	0.40	6.31
"ML-9" x K - 851	5.44	9.36	0.34	6.53
"ML-9" x "K - 851"	5.70	12.58	0.21	5.34
K - 851 x ML- 9	7.67	11.08	0.18	4.04
"K-851" x ML-9	3.91	11.90	0.10	2.57
K - 851 x "ML-9"	2.64	23.34	0.05	1.26
"K-851" x "ML-9"	5.15	24.53	0.19	4.63

" " indicates the irradiated parent

Fig.4a. Frequency distribution for number of seeds per pod in parent and M_3 progenies in ML-9

Fig.4b. Frequency distribution for number of seeds per pod in parent and M_3 progenies in K-851.

Fig.4c. Frequency distribution for number of seeds per pod in M_3F_2 crosses.

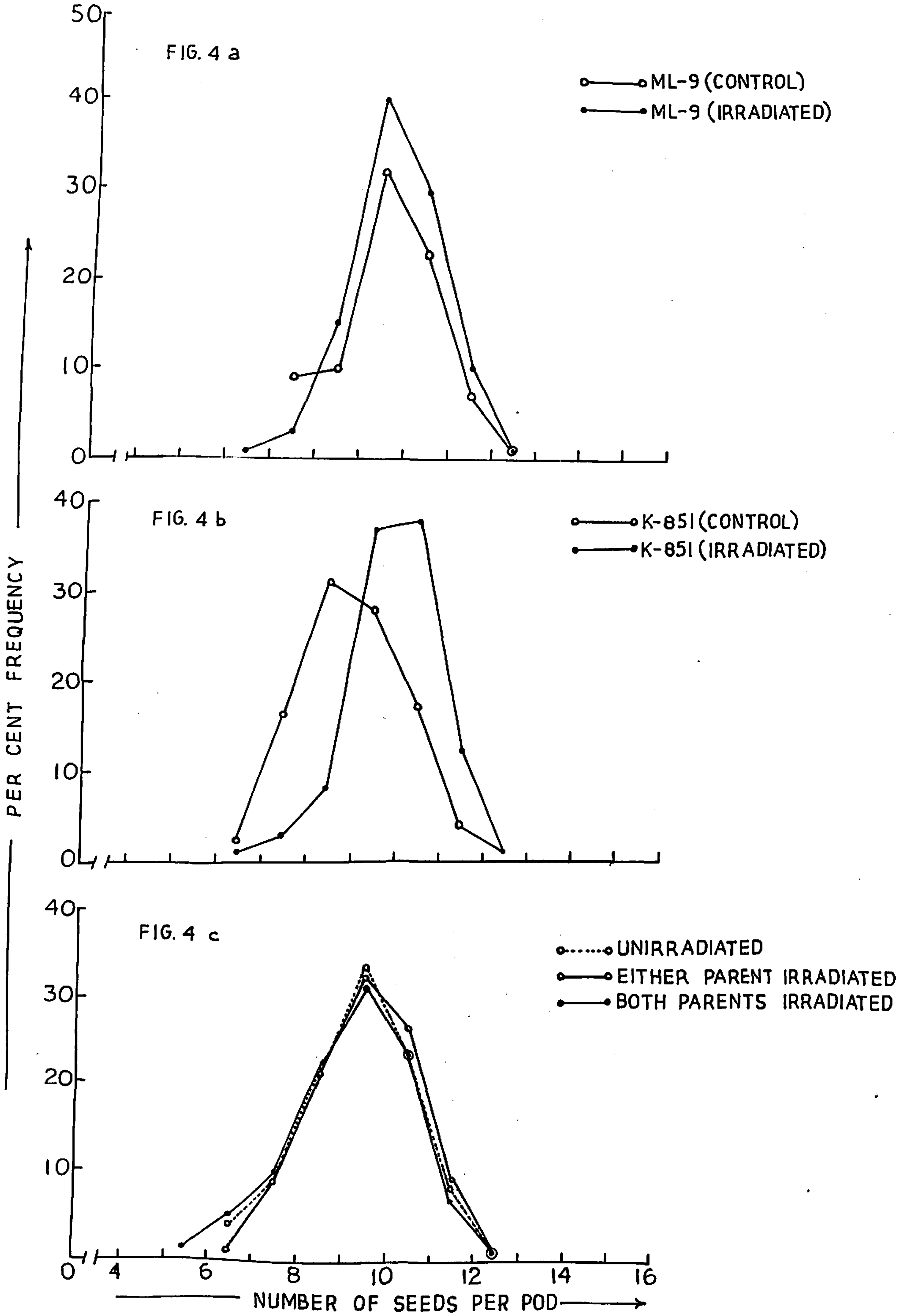
FIG. 4 a
ML-9 (CONTROL)
ML-9 (IRRADIATED)
FIG. 4 b
K-851 (CONTROL)
K-851 (IRRADIATED)
FIG. 4 c
UNIRRADIATED
EITHER PARENT IRRADIATED
BOTH PARENTS IRRADIATED
PER CENT FREQUENCY
NUMBER OF SEEDS PER POD
0
10
20
30
40
50
4
6
8
10
12
14
16

mean value. When irradiated K-851 is used as female parent, increase in variance and coefficient of variation was maximum. An increase in coefficient of variation was also found in ML-9 x "K-851" (Table 18).

Irradiated ML-9 showed increased value of genotypic coefficient of variation, heritability and genetic advance while reverse was observed for irradiated K-851. Phenotypic coefficient of variation remained unchanged in both the irradiated varieties (Table 19). Irradiation of both the parents before hybridization decreased the genotypic coefficient of variation, heritability and genetic advance. Reduced value of heritability and genetic advance was also shown by "K-851" x ML-9. When irradiated ML-9 was used as either parent, a decrease in phenotypic coefficient of variation was observed.

Plants with greater 100-seed weight were observed only in irradiated K-851 (Fig.5a and 5b). From the results shown in figure 5c it seemed that frequency of plants with greater 100-seed weight remained unchanged by hybridization alone and irradiation of either or both the parents before crossing.

4.2.6 Seed yield per plant

Mean, variance and coefficient of variation for seed yield per plant are shown in table 20. No change in mean was observed in irradiated ML-9 where as an increase was found in irradiated K-851. The mean square values for seed yield per plant were significant for all the genetic groups except "K-851" x ML-9, K-851 x "ML-9" and "K-851" x "ML-9" (Table 9). Both the varieties showed no change in variance upon irradiation. Irradiated ML-9 showed no change in coefficient of variation while an increase was observed in irradiated K-851. Increase in mean, variance and coefficient of variation was

Table 18: Mean and variance for 100- seed weight in M_3 and M_3F_2 progenies.

	Mean (g)	Variance	Coefficient of variation
ML - 9	3.40 ± 0.05	0.20	13.02
"ML-9"	3.08 ± 0.03	0.09	9.78
K-851	3.61 ± 0.03	0.16	11.27
"K-851"	3.49 ± 0.06	0.34	16.63
ML-9 x K-851	3.37 ± 0.03	0.16	11.79
ML-9 x "K-851"	3.58 ± 0.05	0.30	15.23
"ML-9" x K-851	3.36 ± 0.03	0.19	13.07
"ML-9" x "K-851"	3.43 ± 0.05	0.25	14.64
K - 851 x ML-9	3.41 ± 0.03	0.22	13.88
"K-851" x ML - 9	3.66 ± 0.07	0.53	19.86
K -851 x "ML-9"	3.43 ± 0.04	0.27	15.26
"K-851" x "ML-9"	3.46 ± 0.08	0.50	20.53

" " indicates the irradiated parent

Table 19: Genotypic and phenotypic coefficient of variation, heritability and genetic advance for 100-seed weight in M_3 and M_3F_2 progenies.

	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability	Genetic advance
ML - 9	2.94	13.13	0.06	1.46
"ML- 9"	5.30	10.26	0.30	6.42
K - 851	9.99	15.51	0.81	18.49
"K- 851"	4.38	16.70	0.06	2.01
ML - 9 x K -851	7.85	16.61	0.44	10.69
ML - 9 x "K- 851"	8.83	15.04	0.34	10.71
"ML-9" x K-851	8.76	12.97	0.47	12.78
"ML-9" x "K-851"	5.05	14.28	0.13	3.68
K - 851 x ML - 9	9.58	19.60	0.52	14.54
"K- 851" x ML - 9	7.05	18.53	0.15	5.82
K -851 x "ML - 9"	9.67	14.58	0.44	13.21
"K-851" x "ML - 9"	-	18.50	-	-

" " indicates the irradiated parent

Fig.5a. Frequency distribution for 100-seed weight in parent and M_3 progenies in ML-9

Fig.5b. Frequency distribution for 100-seed weight in parent and M_3 progenies in K-851.

Fig.5c. Frequency distribution for 100-seed weight in M_3F_2 crosses.

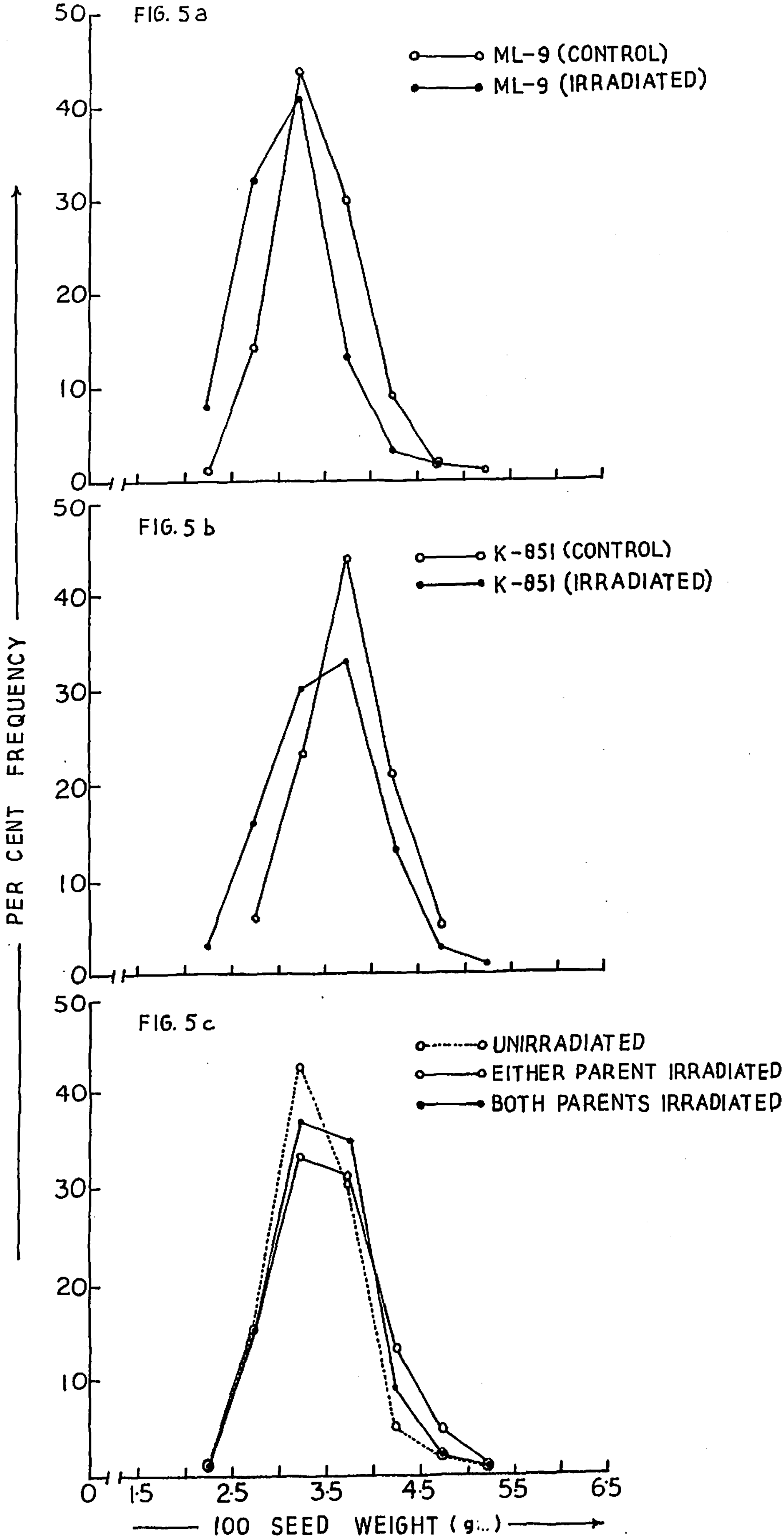
FIG. 5a
ML-9 (CONTROL)
ML-9 (IRRADIATED)
FIG. 5 b
K-851 (CONTROL)
K-851 (IRRADIATED)
FIG. 5 c
UNIRRADIATED
EITHER PARENT IRRADIATED
BOTH PARENTS IRRADIATED
PER CENT FREQUENCY
100 SEED WEIGHT (g...)
0
10
20
30
40
50
1·5
2·5
3·5
4·5
5·5
6·5

Table 20: Mean and variance for seed yield per plant in M_3 and M_3F_2 progenies.

	Mean (g)	Variance	Coefficient of variation
ML - 9	6.47 ± 0.36	10.20	49.36
"ML- 9"	5.73 ± 0.24	7.64	48.23
K - 851	3.86 ± 0.15	1.70	33.68
"K-851"	4.66 ± 0.12	4.13	43.61
ML - 9 x K - 851	4.55 ± 0.08	1.37	25.73
"ML-9" x "K-851"	5.81 ± 0.19	4.84	37.87
"ML-9" x K -851	6.77 ± 0.27	8.62	43.36
"ML-9" x "K-851"	6.67 ± 0.23	8.14	42.76
K - 851 x ML - 9	5.38 ± 0.19	4.09	37.55
"K- 851" x ML-9	5.42 ± 0.21	5.67	43.94
K -851 x "ML-9"	5.74 ± 0.18	3.57	32.91
"K-851" x "ML-9"	4.92 ± 0.14	1.93	28.22

" " indicates the irradiated parent

observed in crosses where ML-9 or irradiated ML-9 was used as female parent. "K-851" x "ML-9" showed a decrease in variance and coefficient of variation (Table 20).

Table 21 showed that there was no change in genotypic and phenotypic coefficient of variation, heritability and genetic advance in irradiated ML-9 while an increase was found in irradiated K-851. Crosses having ML-9 or irradiated ML-9 as the female parent showed greater value of phenotypic coefficient of variation. Heritability values were lower in crosses where ML-9 or irradiated ML-9 was used as the female parent ML-9 x "K-851" and "ML-9" x K-851 exhibited lower values of genetic advance. Crosses, in which K-851 or irradiated K-851 was used as the female parent, lower values of genotypic coefficient of variation, heritability and genetic advance, were observed. Lower values of phenotypic coefficient of variation were observed in K-851 x "ML-9" and "K-851" x "ML-9" crosses.

The scoring of individual plant yield in M_3 generation revealed a number of promising plants exhibiting higher seed yield than the control (Fig.6a and 6b). Irradiation of either or both the parents followed by hybridization was more effective for getting higher frequency of plantswith greater seed yield per plant than hybridization alone (Fig.6c).

4,3 Morphological mutants

Various morphological mutants were selected in M_2, F_1 and M_2F_1 (Table 22, 23 and 24). These mutants were classified in the following classes.

Table 21: Genotypic and phenotypic coefficient of variation, heritability and genetic advance for seed yield per plant in M_3 and M_3F_2 progenies.

	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heritability	Genetic advance
ML - 9	28.96	49.92	0.34	34.61
"ML- 9"	28.19	48.74	0.33	33.56
K - 851	21.83	33.98	0.41	28 86
"K-851"	35.97	43.78	0.67	60 33
ML- 9 x K - 851	19.82	25.93	0 58	30.90
ML - 9 x "K -851"	21.83	37.43	0.34	26.19
"ML -9" x K - 851	20.49	42.79	0.28	20.19
"ML -9" x "K - 851"	25.08	41.71	0.38	32.65
K - 851 x ML - 9	16.20	37.96	0.18	14.23
"K- 851" x ML - 9	13.56	38.53	0.12	9.83
K - 851 x "ML-9"	8.88	30.87	0.08	5.25
"K -851" x "ML-9"	10.56	28.25	0.14	8.09

" " indicates the irradiated parent

Fig.6a. Frequency distribution for seed yield per plant in parent and M_3 progenies in ML-9.

Fig.6b. Frequency distribution for seed yield per plant in parent and M_3 progenies in K-851.

Fig.6c. Frequency distribution for seed yield per plant in M_3F_2 crosses.

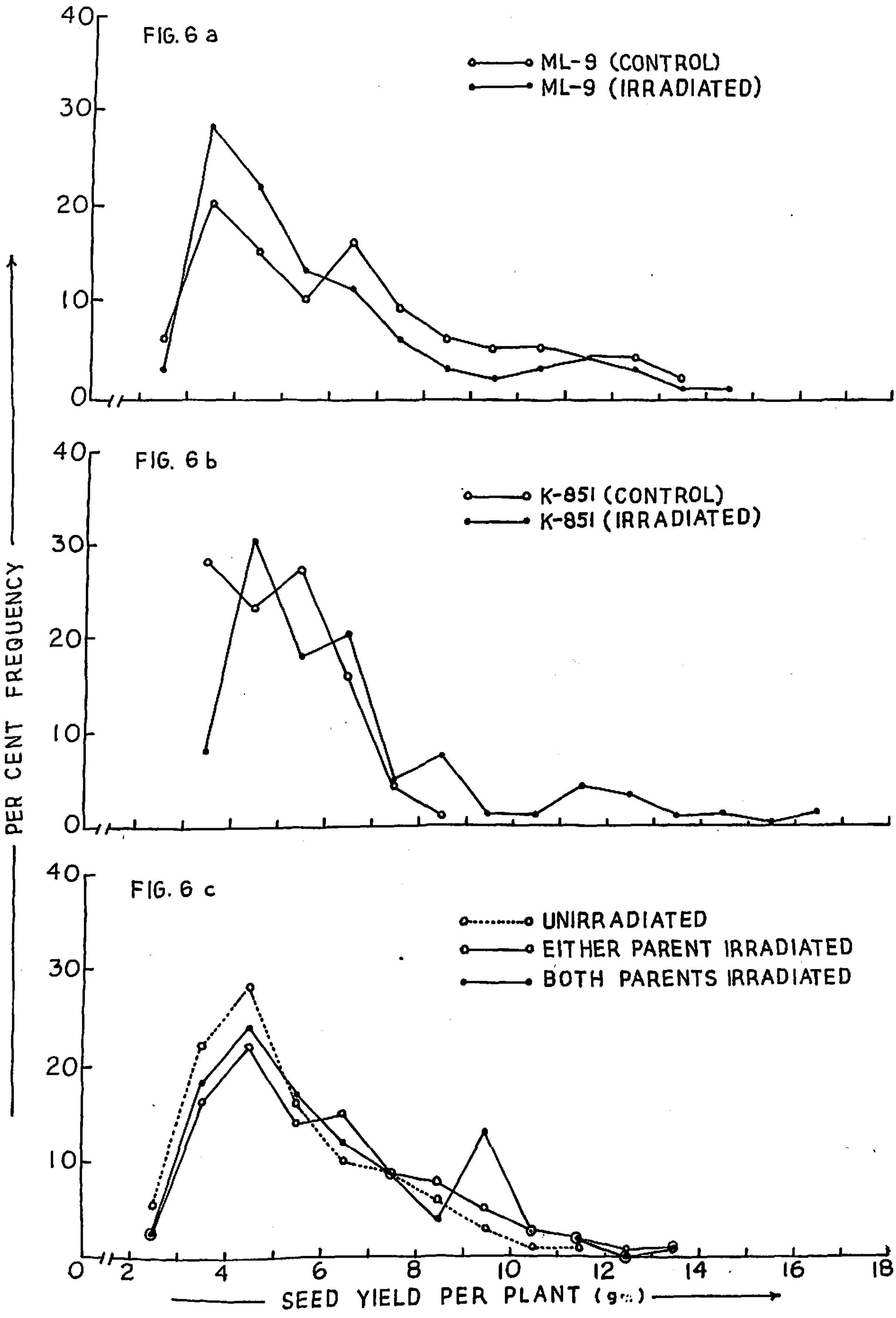
FIG. 6 a
ML-9 (CONTROL)
ML-9 (IRRADIATED)
FIG. 6 b
K-851 (CONTROL)
K-851 (IRRADIATED)
FIG. 6 c
UNIRRADIATED
EITHER PARENT IRRADIATED
BOTH PARENTS IRRADIATED
PER CENT FREQUENCY
SEED YIELD PER PLANT
0
10
20
30
40
2
4
6
8
10
12
14
16
18

Late	-	A plant which matures at least 10 days later than the average maturity of the parental variety.
Very late	-	A plant maturing at least 15 days later than the average maturity of the parental variety.
Early	-	A plant which matures 10 days earlier than the average maturity of the parental variety.
Tall	-	A plant having at least 15 cm more height as compared to the average height of the parental plant.
Dwarf	-	A plant which has at least 15 cm lesser height than the average height of the parental plant.
Trailing type plant	-	A plant which is vertical up to some distance but the major apical portion trails(become horizontal).
Tobacco type plant	-	A plant which resembles to the plants of tobacco, phenotypically.
Vigorous growth	-	A plant with increased growth of vegetative and reproductive portions.
Multileaflet	-	A plant having more number of leaflets as compared to parental variety.
Broad leaflet	-	A plant which has broader leaflets than the control plants.
Bold seed	-	A plant with bigger seed size as compared to parental plants.
Black colour of seeds	-	Colour of the seeds is black instead of greenish.
Less number of seeds in a pod	-	A plant which has at least 4 seeds per pod lesser than the average number of seeds per pod of the parental variety.
Less number of pods	-	A plant having 10 pods lesser than the average pod of control plant.

Table 22: Frequency of morphological variants in M_2 generation of ML-9 and K-851.

	"ML-9"	"K-851"
Late	14.51	14.55
Very Late	-	4.43
Early	11.29	13.29
Tall	13.44	12.66
Dwarf	7.52	9.49
Trailing type plant	3.29	3.80
Tobacco type plant	2.15	-
Vigorous growth	4.83	2.53
Multileaflets	9.67	8.86
Broad leaflet	9.14	4 43
Bold seed	9.14	13.92
Black colour of seeds	3.76	3.80
Less number of seeds in a pod	4.30	3.16
Less number of pods	7.53	5.69
No pod	5.37	1.90
Empty pod	3.22	3.80
Curved pod	-	1.26
Constricted pod	5.37	8.23

" " indicates the irradiated parent

Table 23: Frequency of morphological variants in M_2F_1 gereration of ML-9 x K-851 crosses.

	ML-9xK-851	ML-9x"K-851"	"ML-9"xK-851	"ML-9"x"K-851"
Late	36.36	26.08	24.13	37.50
Very late	-	-	-	8.33
Early	9.09	13.04	20.68	-
Tall	-	8.69	-	33.30
Dwarf	18.18	-	-	-
Trailing type plant	-	-	-	-
Tobacco type plant	-	-	-	-
Vigorous growth	-	-	13.79	8.33
Multileaflet	-	-	-	-
Broad leaflet	9.09	13.04	10.34	-
Bold seed	-	21.74	17.24	-
Black colour of seeds	-	-	-	-
Less number of seeds in a pod	-	-	-	16.66
Less number of pods	-	17.40	13.79	20.83
No pods	-	8.29	-	-
Empty pod	-	-	-	-
Curved pod	-	-	-	-
Constricted pods	27.27	-	6.89	-

" " indicates the irradiated parent

Table 24: Frequency of morphological variants in M_2F_1 generation of K-851 x ML-9 crosses.

	K-851xML-9	K-851x"ML-9"	"K-851"xML-9	"K-851" x"ML-9"
Late	33.3	19.04	30.55	18.42
Very late	-	4.76	8.33	-
Early	-	9.52	-	15.80
Tall	-	-	16.66	-
Dwarf	11.1	9.52	-	-
Trailing type plant	-	-	-	-
Tobacco type plant	-	-	-	-
Vigorous growth	-	9.52	5.55	13.15
Multileaflets	-	-	-	-
Broad leaflets	22.2	-	-	7.89
Bold seed	-	14.28	19.44	15.78
Black colour of seed	-	-	-	-
Less number of seeds in a pod	11.1	-	11.11	5.63
Less number of pods	-	19.04	13.89	13.15
No pods	-	9.52	-	5.26
Empty pod	-	-	-	-
Curved pod	-	-	-	-
Constricted pod	22.2	14.28	16.66	10.53

" " indicates the irradiated parent

No pod	-	Plants which are totally sterile having no pods.
Empty pod	-	Pods which do not contain any seeds
Curved pod	-	Pods which are not straight
Constricted pod	-	Pods which are not smooth but showed constrictions.

Maximum type of morphological variants were observed in the irradiated population of both the varieties (Table 22). F_1 and M_2F_1 also showed some morphological variants (Table 23 and 24). Very late and curved pod type of morphological variants were not found in irradiated ML-9 and irradiated K-851 did not show tobacco type of plants. Trailing type of plants, tobacco type of plants, multileaflets, black colour of seeds, empty pod and curved pods were absent in crosses where ML-9 (control or irradiated) was used as the female parent. Very late and less number of seeds in a pod were only present in "ML-9" x "K-851" (Table 23).

Crosses in which K-851 (control or irradiated) was used as female parent did not show trailing type plants, tobacco type plants, multileaflets, black colour of seeds, empty pod and curved pod types of morphological variants (Table 24). In all the crosses, constricted pod type of variants were present. Late type of variants were represented by all the crosses and also their frequency in each cross was high (Table 23 and 24).

The morphological mutants selected in M_2, F_1 and M_2F_1 were advanced for M_3, F_2 and M_3F_2 and the trend was found similar to M_2, F_1 and M_2F_1. There were more types of morphological variants in M_3 population of both the varieties as compared to F_2 and M_3F_2 as shown in table 25, 26 and 27.

Table 25: Frequency of morphological variants in M_3 generation of ML-9 and K-851.

	"ML-9"	"K-851"
Late	67.90	73.65
Very late	-	77 10
Early	73.30	67.84
Tall	73.64	80.12
Dwarf	59.60	60.50
Trailing type plant	57.90	44.40
Tobacco type plant	67.20	-
Vigorous growth	59.60	71.80
Multileaflets	72.91	56.50
Broad leaflet	75.34	40.01
Bold seeds	74.01	73 68
Black colour of seeds	89.90	100.00
Less number of seeds in a pod	62.90	80.67
Less number of pods	73.64	71.09
No pods	9.80	16.40
Empty pods	-	-
Curved pod	-	43.00
Constricted pods	74.50	68.63

" " indicates the irradiated parent

Table 26: Frequency of morphological variants in M_3 F_2 generation of ML-9xK-851 crosses.

	ML-9xK-851	ML-9x"K-861"	"ML-9"xK-851	"ML-9"x"K-851"
Late	52.60	65.90	76.80	64.40
Very late	-	-	-	65.40
Early	36.80	50.60	72.80	-
Tall	-	61.40	-	77.90
Dwarf	60.70	-	-	-
Trailing type plant	-	-	-	-
Tobacco type plant	-	-	-	-
Vigorous growth	-	-	41.80	54.90
Multileaflet	-	-	-	-
Broad leaflet	42.00	59.80	52.40	-
Bold seed	-	69.80	75.60	-
Black colour of seed	-	-	-	-
Less number of seeds in a pod	-	-	-	45.90
Less number of pods	-	67.90	67.80	57.80
No pod	-	-	-	-
Empty pod	-	-	-	-
Curved pod	-	-	-	-
Constricted pod	47.80	-	72.50	-

" " indicates the irradiated parent

Table 27: Frequency of morphological variants in M_3F_2 generation of K-851 x ML-9 crosses

	K-851xML-9	K-851x"ML-9"	"K-851"xML-9	"K-851"x"ML-9"
Late	41.80	70.20	69.80	65.40
Very late	-	56.40	60.40	-
Early	-	65.40	-	60.90
Tall	-	-	70.90	-
Dwarf	50.40	33.80	-	-
Trailing type plant	-	-	-	-
Tobacco type plant	-	-	-	-
Vigorous growth	-	61.90	69.40	70.10
Multileaflet	-	-	-	-
Broad leaflet	38.80	-	-	59.80
Bold seed	-	57.80	82.00	70.40
Black colour of seeds	-	-	-	-
Less number of seeds in a pod	45.60	-	58.40	56.20
Less number of pod	-	62.40	62.50	60.90
No pod	-	-	-	12.50
Empty pod	-	-	-	-
Curved pod	-	-	-	-
Constricted pod	36.40	65.40	71.90	65.80

" " indicates the irradiated parent

DISCUSSION

Mutation breeding and hybridization are recognized as valuable tools in creating genetic variability. Variations created by both the methods are equally heritable and respond to selection. The induction of random mutations in self pollinated species having a very large number of genes with small individual positive or negative effects on a particular character will depend upon the number of genes taking part, the relative portion of positive and negative genes and the degree to which the parental genome operates as a balanced system. The results obtained from the present study using the irradiated male or female or both parents in hybridization in mungbean are discussed here after.

5.1 Quantitative characters

5.1.1 Plant height

Irradiation alone, hybridization alone and irradiation followed by hybridization did not increase the mean plant height in M_2 and M_2F_1 generations (Table 3 and 28). However, in M_3, increase in mean plant height was observed in both the varieties (Table 10 and 29). Irradiated ML-9 used as male or female parent decreased the mean height in M_3F_2. In mungbean increase in mean plant height with gamma irradiation in M_2 was observed by Verma and Singh (1984).

The variance for plant height increased in irradiated ML-9 in M_2 and also in M_2F_1 derived from irradiated ML-9 male parent (Table 3 and 28). With gamma irradiation increase in variance for plant height in *Vigna radiata* was observed by Rajput (1974), Khan (1982) and Verma and Singh (1984) in M_2 generation. But in M_3 and M_3F_2 no significant change in variance was observed(Table 10 and 29).

Table 28: Effect of irradiation on mean and variance in M_2 and M_2F_1

	Plant height		Number of pods/plant		Pod length		Number of seeds/pod		100-seed weight		Seed yield/plant	
	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
"ML-9" vs ML-9		+	+	+					+	+		
"K-851" vs K-851										+		+
ML-9 x "K-851"	31.85		21.24		6.55	2.04	9.49		3.67	4.67	4.85	
"K-851" x ML-9	30.29		17.76		6.59	0.91	9.51		4.01	0.65	4.25	
"ML-9" x K-851	35.43		17.10	155.49	6.28	0.20	8.35	2.90	3.34		6.09	
K-851 x "ML-9"	35.47		15.35	87.66	5.93	0.79	8.20	5.18	3 32		4.80	
"ML-9" x "K-851"	32.04	34.95	11.71	59.12	6.03	0.64	8.16	3.56	3.46	0.27	2.96	5 12
"K-851" x "ML-9"	34.05	59.32	15.87	124.83	6.31	2.15	7.94	6.65	3.63	1.84	4.18	8 69
ML-9 x K-851 vs ML-9 x "K-851"	-			-		+	-	+		+	+	
ML-9 x K-851 vs "ML-9" x K-851					-	-	-	+				
ML-9 x K-851 vs "ML-9" x "K-851"	-		-	-	-	+	-	+	+		-	-
K-851 x ML-9 vs "K-851" x ML-9	-			+	-		-	+		+		+
K-851 x ML-9 vs K-851 x "ML-9"		+			-		-	+				
K-851 x ML-9 vs "K-851" x "ML-9"				+	-	+	-	+		+		

" " indicates the irradiated parent

+ and - signs indicate increase and decrease respectively

Table 29: Effect of irradiation on mean and variability parameters for plant height in M_3 and M_3F_2.

	Mean	Variance	Coefficient of variation	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heretabi-lity	Genetic advance
"ML-9" vs ML-9	+			-	-	-	-
"K-851" vs K-851	+		-	+	-	+	+
ML-9 x K-851 vs ML-9 x "K-851"			-	-	-	-	-
ML-9 x K-851 vs "ML-9"xK-851	-			-		-	-
ML-9 x K-851 vs "ML-9" x "K-851"	-		+	-		-	-
K-851 x ML-9 vs "K-851" x ML-9			+	+	+	+	+
K-851 x ML-9 vs K-851 x"ML-9"	-		+	+	+	+	+
K-851 x ML-9 vs "K-851" x "ML-9"				+		+	+

" " indicates the irradiated parent

+ and - signs indicate increase and decrease respectively

This may be due to the reason that from the M_2 and M_2F_1 populations only normal looking plants were carried to M_3 and M_3F_2 generations and therefore, no significant change in them was noticed.

In most cases plant height showed low values of genotypic and phenotypic coefficient of variation. Heritability values were high in irradiated K-851 and ML-9 x K-851 (Table 11 and 29) while in most other cases the heritability values of plant height were low. This shows that the character plant height in mungbean is largely influenced by environmental factors.

Genetic advance for plant height is to the extent of 36 percent in ML-9 x K-851 and 27 percent in "K-851" (Table 11 and 29). Also use of K-851 (control or irradiated) as female parent resulted in marginal gain in plant height. Thus plant height can be improved by irradiation alone, hybridization of non irradiated parents and use of K-851 or irradiated K-851 as the female parent in crosses . In pea, Mohan (1983) reported that hybridization had a greater advantage over mutagenesis.

5.1.2. Number of pods per plants

Average number of pods per plant increased only in M_2 generation of ML-9 (Table 4, 12, 28 and 30). No change in average number of pods per plant was observed by Bahl and Gupta (1982) and Seth et al. (1986), while Dahiya (1973) reported a decrease in number of pods per plant with gamma irradiations. In hybridization when both the parents used were irradiated ("ML-9" x "K-851"), the decrease in the number of pods per plant was noticed. This could be ascribed to the formation of inviable gametes or abnormal functioning at the time of the zygote formation. However, in M_3 F_2 the increase in the average number of pods per plant was observed in crosses where

Table 30: Effect of irradiation on mean and variability parameters for number of pods per plant in M_3 and M_3F_2.

	Mean	Variance	Coefficient of variation	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heretability	Genetic advance
"ML-9" vs ML-9			-	-	-	-	-
"K-851" vs K-851				+		+	+
ML-9 x K-851 vs ML-9 x "K-851"	+		-	-	-	-	-
ML-9 x K-851 vs "ML-9" x K-851	+	+				+	+
ML-9 x K-851 vs "ML-9" x "K-851"	+				-	-	-
K-851 x ML-9 vs "K-851" x ML-9	+			-	-	-	-
K-851 x ML-9 vs K-851 x "ML-9"	+					+	
K-851 x ML-9 vs "K-851" x "ML-9"			-	-	-	-	-

" " indicates the irradiated parent

\+ and - signs indicate increase and decrease repsectively irradiated ML-9 was used as the female parent. This showed that irradiation of maternal or paternal parent may show differential effect on mean expression of the quantitative character. This could be due to differential frequency of positive and negative mutations in these parents. In M_3F_2 when both the parents were irradiated as expected the less number of pods per plant was observed.

In M_2, increase in variance was observed in ML-9 with irradiation. Similar type of observations were also observed by Ojomo and Chedda (1972) with γ-rays and neutrones in cowpea. Verma and Singh (1984) also observed increase in mean and variance for number of pods per plant in mungbean with γ-rays. In M_2 increase in variance was also reported by Rajput (1974) and Khan (1982) in green gram. In M_2F_1, the variability was found to be more in crosses having irradiated K-851 as the female parent but less in crosses having the same variety as the male parent (Table 4 and 28). Reciprocal differences among variances were observed for number of pods per plant. Sisson et al. (1978) observed the reciprocal differences in soybean. It appears that these differences are due to the cytogenes residing in the cell orgenelles. Subhadra (1988) also observed the reciprocal differences in wheat. No significant change in variance was observed in M_3 and M_3F_2 except ML-9 x "K-851". The reason for not getting the significant differences in M_3 and M_3F_2 may be that these generations were descendant from the normal plants selected in M_2 and M_2F_1 generations.

Genotypic and phenotypic coefficient of variation decreased when irradiation was used and also when a irradiated parent was involved in hybridization as compared to their respective control population except genotypic coefficient of variation in irradiated K-851 (Table 13 and 30). The decrease in genotypic and phenotypic coefficient of variation may be ascribed due to the fact that only normal looking plants were involved in M_3 and M_3F_2 generations. The higher genotypic and phenotypic coefficient of variation, heritability and genetic advance values in control population of ML-9 may be because of residual heterogeneity. Similar type of results were also obtained by Oka et al. (1958) in rice. Heritability values for number of pods per plant were low in most cases except "ML-9" x K-851 and K-851 x "ML-9" where it was observed to be moderate. Moreover, the genetic advance in these two cases were to the extent of 37 percent and 30 percent, respectively. This showed that by the use of irradiated ML-9 as either parent, number of pods per plant could be increased. However, almost same extent of genetic advance could be achieved by hybridization alone. The number of pods per plant could also be improved to some extent by irradiating the parental variety K-851.

5.1.3 Pod length

No change in mean value of pod length was observed in M_2 but in M_3 pod length of irradiated K-851 had increased (Table 5, 14, 28 and 31). The increase in pod length in M_3 generation resulted due to directional selection of normal plants. With irradiation no change in pod length in mungbean was observed by Rajput (1974) while Seth et al. (1986) observed an increase in pod length with irradiation in green gram. In M_2F_1 and M_3F_2 decrease in mean was observed. This could be due to the occurrence of minus mutations

Upon irradiation no significant change in variance was observed

Table 31: Effect of irradiation on mean and variability parameters for pod length in M_3 and M_3F_2.

	Mean	Variance	Coefficient of variation	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heretability	Genetic advance
"ML-9" vs ML-9		-	-	+		+	+
"K-851" vs K-851	+			+		+	+
ML-9 x K-851 vs ML-9 x "K-851"	+			-	-	-	-
ML-9 x K-851 vs "ML-9" x K-851				-	-	-	-
ML-9 x K-851 vs "ML-9" x "K-851"			+		+	-	-
K-851 x ML-9 vs "K-851" x ML-9	-			+	-	+	+
K-851 x ML-9 vs K-851 x "ML-9"	-			+	-	+	+
K-851 x ML-9 vs "K-851" x "ML-9"	-		+	+	+	+	+

" " indicates the irradiated parent

\+ and - signs indicate increase and decrease respectively in both the varieties. The variance for pod length was higher in M_2F_1 when irradiated parent was used as the pollen parent (Table 5). In M_2F_1 differences for variances were observed in reciprocal crosses. These could be due to the cytogenes present in cell organelles. Such type of differences were also observed by Sisson et al. (1978) and Subhadra (1988). Variance was higher in M_2F_1 crosses where both the parents happened to be irradiated. Use of irradiated ML-9 as the female parent resulted in decrease in variance for pod length. In M_3 marginal decrease in variance for pod length was observed in irradiated ML-9. No significant change in variance in M_3F_2 was observed. The variance for pod length could be increased only through the use of K-851 as the irradiated parent. Mohan (1983) observed a decrease in variance for flowering time, number of pods, number of seeds, 100-seed weight, and seed yield in mutagen treated population of pea. Decrease in variance for plant height, tiller number and seed yield in rice was also observed by Virk et al. (1978).

Increase in genotypic and phenotypic coefficient of variation was observed with irradiation in both the parental varieties and also when both the irradiated parents were used in hybridization (Table 15 and 31). This showed that irradiation was effective for inducing the variability for pod length. The heritability values were moderate in both the irradiated varieties, ML-9 x K-851 and K-851x "ML-9" population, in other cases it was low.

The genetic advance for pod length was to the extent of 13 percent and 10 percent in ML-9 x K-851 and K-851 x "ML-9", respectively (Table 15). The significant gain in pod length was observed when K-851 or irradiated K-851 was used as the female parent. This showed that irradiation of control varieties, hybridization alone and the use of K-851 or irradiated K-851 as the female parent could lead to increase in pod length.

5.1.4 Number of seeds per pod

The mean number of seeds per pod did not vary with irradiation in both the parental varieties in M_2 generation. However, the seeds per pod decreased in M_2F_1 population. Increase in mean number of seeds per pod was observed in M_3 generation but in general no change in the mean was observed in M_3F_2 generation (Table 6,16,28 and 32). This showed that to improve the seeds per pod, the irradiation of parental varieties is useful where as involving the irradiated varieties in hybridization may not increase the seeds per pod. The decrease in number of seeds per pod in M_2 and M_2F_1 could have resulted due to accumulation of negative mutations from both the parents in irradiated population. Yaha Ashraf et al. (1975) in Vigna radiata reported lower values of number of seeds per pod with gamma rays while in broad bean an increase in number of seeds per pod was reported by Shamsi and Sofojy (1980).

In M_2 generation no significant change in variance for number of seeds per pod was observed but in M_2F_1 generation the variance for this trait was enhanced in the hybrid population when one or both the parents happened to be irradiated (Table 6 and 28). It showed that mutation induced added to the amount of variability created by hybridization for this character. Increase in variance was also reported by Krull and Frey (1961), Jalil Miah and Yamaguchi (1965), Gill et al. (1969), Khadri (1970), Kassem et al. (1976) and Gupta and Virk, (1977), and Mohan (1983). Irradiation of pollen parent resulted in more variability for number of seeds. In most

Table 32: Effect of irradiation on mean and variability parameters for number of seeds per pod in M_3 and M_3F_2.

	Mean	Variance	Coefficient of variation	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heretability	Genetic advance
"ML-9" vs ML-9	+			+	+	+	+
"K-851" vs K-851	+			+	+	+	+
ML-9 x K-851 vs ML-9 x "K-851"	+	-	-	-	-		-
ML-9 x K-851 vs "ML-9" x K-851			-	-	-	-	-
ML-9 x K-851 vs "ML-9" x "K-851"				-		-	-
K-851 x ML-9 vs "K-851" x ML-9				-		-	-
K-851 x ML-9 vs K-851 x "ML-9"				-	+	-	-
K-851 x ML-9 vs "K-851" x "ML-9"				-	+		-

" " indicates the irradiated parent

+ and - signs indicates increase and decrease respectively

of the cases the same extent of variation was observed in M_3 and M_3F_2 generation for seeds per pod. This indicated that hybridization did not create more variability over irradiated variability. Therefor the number of seeds per pod may be genetically manipulated through induced mutation.

The genotypic and phenotypic coefficient of variation were more in irradiated parental population. Generally the genotypic coefficient of variation was less when the hybrid population had one or both the irradiated parents. This may be attributed to the involvement of selected phenotypically normal plants in hybridization. However, the phenotypic coefficient of variation was more in crosses having K-851 or irradiated K-851 as the female parent and decrease in phenotypic coefficient of variation was observed in crosses having ML-9 or irradiated ML-9 as the female parent (Table 17 and 32). This led to high magnitude of heritability values in crosses having ML-9 or irradiated ML-9 as the female parent.

The genetic gain was expected only in the irradiated population of both the varieties. Hybridization involving the irradiated parents did not lead to much genetic advance for seeds per pod.

5.1.5 100-seed weight

M_2 generation of ML-9 showed an increase in 100-seed weight but it decreased in the M_3 generation (Table 7,18, 28 and 33). The decrease in value may, however, have resulted from accumulation of negative induced gene mutations hidden in heterozygous condition in M_2 generation. Conger et al. (1976) in soybean observed no change in mean value for 100-seed weight while an increase in mean value for this character in mungbean was observed by Verma and Singh (1984) In M_2F_1 and M_3F_2 no change in mean value was observed. This suggested that quantitative mutations occurred symmetrically in both positive and negative direction. Gregory (1955) also suggested that mutation with small phenotypic effects have high occurrence frequency and had equal probability of being negative or positive in their phenotypic effects.

In M_2 generation increase in variance for 100-seed weight was observed in both the varieties. The increase in variability in 100-seed weight in M_2 generation of green gram was also observed by Rajput (1974), Khan (1982), and Verma and Singh (1984). Variance generally increased in M_2F_1 generation except "ML-9" x "K-851" (Table 7 and 28). It showed that mutation induced substantial amount of variability. Similar type of results were also obtained by Gupta and Virk (1977) and Virk et al. (1978). No change in variance for 100-seed weight was observed in the M_3 generation while in M_3F_2 significant increase in variance was observed in crosses where irradiated K-851 was used as the female parent (Table 18 and 33). This suggests that 100-seed weight may be improved using the irradiated K-851 as the female parent.

Increase in genotypic coefficient of variation was observed in irradiated ML-9 but reverse was true for irradiated K-851 (Table 19 and 33). Involvement of both the irradiated parents in hybridization resulted in lowering the genotypic doefficient of variation. This may be the effect of genetic drift compiled with selection pressure applied in M_1 plants used for hybridization, Decrease in phenotypic coefficient of variation was observed in irradiated ML-9 and the crosses having irradiated ML-9 as one of the parent. The

Table 33: Effect of irradiation on mean and variability parameters for 100-seed weight in M_2 and M_3F_2.

	Mean	Variance	Coefficient of variation	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heretabi-lity	Genetic advance
"ML-9" vs ML-9	-		-	+		+	+
"K-851" vs K-851			+	-		-	-
ML-9 x K-851 vs ML-9 x "K-851"	+		+			-	
ML-9 x K-851 vs "ML-9" x K-851					-		+
ML-9 x K-851 vs "ML-9" x "K-851"				-		-	-
K-851 x ML-9 vs "K-851" x ML-9	+	+	+			-	-
K-851 x ML-9 vs K-851 x "ML-9"					-	-	
K-851 x ML-9 vs "K-851" x "ML-9"		+	+	-		-	-

" " indicates the irradiated parent

+ and - signs indicates increase and decrease respectively

heritability values were low for generation descending from irradiated K-851 and the crosses involving it. This means that irradiation of this variety resulted in more sensitivity to environmental changes, where as the moderate heritability values were observed for other crosses Natural increase of genetic variability possibly due to spontaneous mutations during bulk propagation or residual heterogeneity may result in significant heritability in control as suggested by Oka et al. (1958) in rice. To some extent the genetic gain for 100-seed weight could be achieved by irradiating ML-9 and involving it in hybridization as one of the parent. Similarly, hybridization alone also gives the same degree of genetic gain.

5.1.6. **Seed yield per plant**

No change in mean value for seed yield per plant was observed in M_2 generation in both the varieties. This implied that the irradiation was not a potent tool to improve this character in the present material. Moreover, in the M_2F_1 generation there had been decrease in the mean value for seed yield per plant particularly in crosses where irradiated ML-9 was the female parent (Table 8 and 28). This suggested the high frequency of negative mutations for seed yield. However, the mean seed yield per plant increased in irradiated K-851 in M_3 generation and M_3F_2 crosses in which ML-9 or irradiated ML-9 is the female parent (Table 20 and 34). This improvement may be explained due to selection pressure where phenotypically normal plants from M_2F_1 advanced to M_3F_2 generation. In green gram, decrease in seed yield per plant with mutagenic treatment was reported by Dahiya (1973) and Yaha Ashraf et al. (1975), while Bahl and

Gupta (1982), Singh and Yadava(1982), Avila and Murty (1983) reported an increase in seed yield per plant in mutagen treated population of mungbean.

Increase in variance was recorded in M_2 generation of irradiated K-851 (Table 8,28). The decrease or no change in variance in most of the cases in M_2F_1 and M_3F_2 could be related with the selection pressure exercised during advancement of the generation and in crossing programme. In M_2 generation increase in the variability for seed yield per plant was observed by Rajput (1974), and Khan (1982). Verma and Singh (1984) in green gram reported a decrease in mean and increase in variance with gamma rays.

The irradiation of ML-9 did not reveal any significant change in genotypic and phenotypic coefficient of variation where as that of K-851 showed an increase in both these values (Table 21 and 33). Therefore, different genetic background of the varieties affected the nature and the type of genetic variability created through irradiation. But in hybridization if irradiated ML-9 was used as female parent in combination with irradiated K-851 then there was increase in genotypic and phenotypic coefficient of veriation and it was other way round in reciprocal cross. The heritability estimates were generally moderate where ML-9 was used as the female parent and quite low where K-851 was used as the female parent. Genetic gain for seed yield per plant was to the extent of 60 per cent in irradiated K-851 population but its involvement in crossing was only useful when irradiated ML-9 was used as the female parent. In all other cases the hybridization of the non irradiated parents was more effective in improving the seed yield per plant.

Table 34: Effect of iradiation on mean and variability parameters for seed yield per plant in M_3 and M_3F_2.

	Mean	Variance	Coefficient of variation	Genotypic coefficient of variation	Phenotypic coefficient of variation	Heretability	Genetic advance
"ML-9" vs ML-9							
"K-851" vs K-851	+		+	+	+	+	+
ML-9 x K-851vs ML-9 x "K-851"	+	+	+		+	-	-
ML-9 x K-851 vs "ML-9" x K-851	+	+	+		+	-	-
ML-9 x K-851 vs "ML-9" x "K-851"	+	+	+	+	+	-	
K-851 x ML-9 vs "K-851" x ML-9			+	-		-	-
K-851 x ML-9 vs K-851 x "ML-9"				-	-	-	-
K-851 x ML-9 vs "K-851" x "ML-9"		-	-	-	-	-	-

" " indicates the irradiated parent

+ and - signs indicates increase and decrease respectively

Small differences in variance were observed when only one of the irradiated parent was used in the crosses. However, these differences became significant for all the chracters in M_2F_1 when both the parents are irradiated (Table 3-8 and 28). It seems probable that these differences get accumulated and are expressed in the latter case.

5.2 Morphological variants

Morphological variation for different plant parts such as leaves, roots, stem and flowers are often encountered in irradiated population. Various morphological variants obtained in the present study are described in Tables 22 to 27. Some of the morphological variants, which could be exploited directly or indirectly i.e. by involving them in hybridization programme for incorporating their desirable characters, such as early maturing, dwarf, bold seeded were obtained. All other morphological variants such as multileaflets, broad leaflets, less number of pods, less number of seeds per pod, curved pod and constricted pod were of academic interest only.

The morphological variants observed in F_1 could be due to the transposable genetic elements which have been summarized by Neevers et al. (1986) in Phaseolus and several other plant species. A variegated phenotype such as yellow sector of variable size on a green background in soybean (Peterson and Weber, 1969; Sheridan and Palmer, 1977), change of leaf form from laciniata (narrow leaf) to "hypernormal" in Malva parviflora (Kihara, 1979), dwarf plants in garden petunia (Bianchi et al., 1974), yellow leaves with green areas of variable size in Phaseolus vulgaris (Coyne, 1966, 1967; Kirk and Tilney - Bassett, 1978) and white flowers with purple spots in garden pea (De Haan, 1930) have been produced due to the presence of transponable genetic elements.

Results of the present investigation have shown that irradiation of the parental varieties was effective in increasing the mean values of various characters. The genetic advance also in irradiated population was satisfactory. Use of irradiated ML-9 as either parent proved to be advantageous for number of pods per plant and 100-seed weight. Plant height and pod length could be improved using irradiated K-851 as the female parent. However, involvement of both the irradiated parents in hybridization did not prove to be a useful approach. Therefore,the improvement of a particular trait in mungbean could be affected through hybridization alone, hybridization involving one of the irradiated parent or irradiating the parental varieties.

SUMMARY

The study was conducted to evaluate the use of irradiated parental varieties in hybridization programme for improvement of mungbean (Vigna radiata L. Wilczek).

Seeds of two varieties (ML-9, K-851) were irradiated with a single dose of 20kR gamma irradiation. The seeds were sown to have M_1 generation. Normal looking M_1 plants were used in hybridization programme so that either both or one of the parents was irradiated. These genetic groups were carried to next generation to have M_3, F_2 and M_3F_2 generations.

Data were recorded for plant height, number of pods per plant, pod length, number of seeds per pod, 100-seed weight and seed yield per plant.

1. M_2 generation of ML-9 had higher mean values for number of pods per plant and 100-seed weight while no change in mean value was observed in irrdiated K-851.
2. Many fold increase in variance for plant height, number of pods per plant and 100-seed weight was observed in irradiated ML-9. Irradiated K-851 showed increase in variance for 100-seed weight and seed yield per plant.
3. In M_2F_1 reciprocal differences among variances for number of pods per plant and pod length were observed.
4. Irradiation of pollen parent resulted in more variability for pod length and number of seeds per pod.
5. When both the parents were irradiated in M_2F_1 crosses significant differences in variance for all the characters were observed.

6. In M_2F_1 crosses decrease in mean values but increase in variance for pod length and number of seeds per pod was observed.

7. Irradiation followed by hybirdization increased the variance for most of the characters when K-851 was the female parent.

8. Maximum types of morphological variants were observed in the irradiated populations of both the varieties.

9. In M_3 generation of ML-9 mean values increased for plant height and number of seeds per pod while irradiated K-851 showed increase in mean value for all the characters except number of pods per plant and 100-seed weight.

10. In neither of the varieties change in variance was significant except for decrease in pod length in irradiated ML-9.

11. Number of pods per plant was higher in M_3F_2.

12. Mean and variances for seed yield per plant were higher in crosses having ML-9 or irradiated ML-9 as the female parent. Crosses having K-851 or irradiated K-851 as the female parent showed a decrease in mean for pod length and increase in variance for 100-seed weight.

13. Irradiated ML-9 showed an increase in genotypic coefficient of variation, heritability and genetic advance for pod length, number of seeds per pod and 100-seed weight while irradiated K-851 showed an increase in the above variability parameters for all the characters except for 100-seed weight.

14. Crossing of non-irradiated parents is useful in causing an increase in genotypic coefficient of variation, heritability

and genetic advance for most of the characters studied. Irradiated ML-9 used either as male or female parent increased the genotypic coefficient of variation, heritability and genetic advance for number of pods per plant and 100-seed weight. Use of K-851 or irradiated K-851 as the female parent resulted in greater values of genotypic coefficient of variation, heritability and genetic advance for plant height and pod length.

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*Original not seen.

GENETIC VARIABILITY IN GREEN GRAM (*Vigna radiata* L. Wilczek) FOLLOWING IRRADIATION AND HYBRIDIZATION

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(An abstract of the thesis submitted to the Haryana Agricultural University in partial fulfilment of the requirements for the degree of Ph.D.)

The study was conducted to evaluate the advantage of using irradiated parental lines in hybridization programme for generating more variability in mungbean (*Vigna radiata* L. Wilczek). Seeds of two varieties of green gram (ML-9, K-851) were irradiated with a single dose of 20 kR gamma irradiation Normal looking M_1 plants were used in hybridization programme so that either one or both of the parents were irradiated. Data were recorded for plant height, number of pods per plant, pod length, number of seeds per pod, 100-seed weight and seed yield per plant on M_2,F_1 and M_2F_1 generations. Normal looking plants from these genetic groups were used to have the M_3,F_2 and M_3F_2 generations

It was observed that in M_2 generation irradiated population of ML-9 showed an increase in mean values for number of pods per plant and 100-seed weight while no change in mean value was observed in irradiated K-851. Irradiated ML-9 showed many fold increase in variance for plant height, number of pods per plant and 100-seed weight and irradiated K-851 showed increase in variance for 100-seed weight and

and seed yield per plant. There were reciprocal differences among variances for number of pods per plant and pod length in M_2F_1 generation. Irradiation of pollen parent resulted in more variability for pod length and number of seeds per pod. M_2F_1 crosses having both the parents irradiated showed significant differences in variances for all the characters. Decrease in mean but increase in variance for pod length and number of seeds per pod was observed in M_2F_1 generation. Use of K-851 (control or irradiated) as female parent in hybridization resulted in increase in variance for most of the characters. Irradiated population of both the varieties showed maximum types of morphological variants.

Mean values of various characters were higher in M_3 generation of both the varieties. But there was no significant change in variance except for pod length in ML-9. Use of irradiated ML-9 as either parent proved to be advantageous for number of pods per plant and 100-seed weight. Plant height and pod length could be improved using irradiated K-851 as the female parent. However, involvement of both the irradiated parents in hybridization did not prove to be a useful approach. Therefore the improvement of a particular trait in mungbean could be affected through hybridization alone, hybridization involving one of the irradiated parent or irradiating the parental varieties.