STUDIES ON INDUCED MUTATIONS IN GROUNDNUT
(*Arachis hypogaea* L.)

THESIS SUBMITTED IN PART FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN PLANT BREEDING AND GENETICS TO THE TAMIL NADU AGRICULTURAL UNIVERSITY COIMBATORE

By

T. RAMANATHAN, M. Sc. (Ag.)

DEPARTMENT OF AGRICULTURAL BOTANY
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE-641003

1979

Certificate

This is to certify that the thesis entitled "STUDIES ON INDUCED MUTATIONS IN GROUNDNUT (*Arachis hypogaea* L.)" submitted in part fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY (Agriculture) IN PLANT BREEDING AND GENETICS to the Tamil Nadu Agricultural University, Coimbatore, is a record of *bona fide* research work carried out by Thiru. T. RAMANATHAN under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles and that the work has not been published in part or full in any scientific or popular journal or magazine.

Date : 14th Nov. 1979.

Place : Coimbatore

(Dr. M. Rathinam)
Chairman

Approved by

Chairman : (Dr. M. Rathinam)

Members :

(Prof. S. Kamalanathan)

(Prof. V. S. Raman)

(Dr. Y. B. Moraehan)

(Thiru V. Ramakrishnan)

CONTENTS

	Page
List of Tables	
List of Figures	
List of Plates	
ACKNOWLEDGEMENT	
INTRODUCTION	1
REVIEW OF LITERATURE	3
MATERIALS AND METHODS	19
EXPERIMENTAL RESULTS	28
A. Studies on germination, survival and seedling height in M_1 generation	28
B. Studies on qualitative mutations in M_2 generation	32
C. Studies on quantitative mutations	51
1. M_2 generation	51
2. M_3 generation	64
3. Studies on character association in M_3 generation	84
D. Evaluation of productive mutant lines	87
DISCUSSION	90
SUMMARY	115
REFERENCES	

LIST OF TABLES

Table number		Page
1	Pedigree and characteristics of the varieties	19
2	Mutagen source and action	19
3	Particulars of mutagenic treatment	20
4	Germination and survival in M_1 generation	29
5	Seedling height in M_1 generation	31
6	Chlorophyll mutation frequency in M_2 generation	33
7	Spectrum of chlorophyll mutations in M_2 generation	34
8	Viable mutation frequency in M_2 generation	36
9	Spectrum of viable mutations in M_2 generation	37
10	Description of viable mutants	39
11	Quantitative characters of viable mutants	41
12	Quantitative characters of viable mutants	42
13	Quantitative characters of viable mutants	44
14	Quantitative characters of viable mutants	45
15	Quantitative characters of viable mutants	46
16	Quantitative characters of viable mutants	47
17	Quantitative characters of viable mutants	48
18	Quantitative characters of viable mutants	50
19	Mean, variance, heritability and genetic advance for height of main stem in M_2 generation	52

(Contd...)

LIST OF TABLES (Contd..)

Table number		Page
20	Mean, variance, heritability and genetic advance for length of primary branch in M_2 generation	54
21	Effect of mutagenic treatments on number of branches, mature pods and kernels per plant in M_2 generation	56
22	Mean, variance, heritability and genetic advance for number of flowers per plant in M_2 generation	58
23	Effect of mutagenic treatments on pod and kernel yield in M_2 generation	60
24	Effect of mutagenic treatments on 100-pod weight, 100-kernel weight and shelling per cent in M_2 generation	62
25	Mean, variance, heritability and genetic advance for height of main stem in M_3 generation	65
26	Mean, variance, heritability and genetic advance for length of primary branch in M_3 generation	67
27	Mean, variance, heritability and genetic advance for number of branches in M_3 generation	68
28	Effect of mutagenic treatments on number of flowers and shelling per cent in M_3 generation	70
29	Mean, variance, heritability and genetic advance for number of mature pods per plant in M_3 generation	72
30	Mean, variance, heritability and genetic advance for number of kernels per plant in M_3 generation	74

(Contd....)

LIST OF TABLES (Contd..)

Table number		Page
31	Mean, variance, heritability and genetic advance for pod yield per plant in M_3 generation	76
32	Mean, variance, heritability and genetic advance for kernel yield per plant in M_3 generation	78
33	Mean, variance, heritability and genetic advance for 100-pod weight in M_3 generation	80
34	Mean, variance, heritability and genetic advance for 100-kernel weight in M_3 generation	82
35	Total correlation coefficients between pod yield and its components in M_3 generation of TMV 9	85
36	Total correlation coefficients between pod yield and its components in M_3 generation of Ah 7911	86
37	Pod yield (g)/plant of mutant lines in M_3 generation	88
38	Yield performance of selections from M_3 lines in M_4 generation	89

LIST OF FIGURES

1. Mutagenic effects on germination in M_1 generation

2. Mutagenic effects on survival in M_1 generation

3. Frequency distribution of number of mature pods per plant in M_2 and M_3 generations of TMV 9

4. Frequency distribution of number of mature pods per plant in M_2 and M_3 generations of Ah 7911

5. Frequency distribution of pod yield per plant in M_2 and M_3 generations of TMV 9

6. Frequency distribution of pod yield per plant in M_2 and M_3 generations of Ah 7911

7. Frequency distribution of 100-kernel weight in M_2 and M_3 generations of TMV 9

8. Frequency distribution of 100-kernel weight in M_2 and M_3 generations of Ah 7911

9. Frequency distribution of shelling per cent in M_2 and M_3 generations of TMV 9

10. Frequency distribution of shelling per cent in M_2 and M_3 generations of Ah 7911

LIST OF PLATES

I. Morphological features of viable mutants

II. Variation in kernel size and testa colour

Acknowledgement

ACKNOWLEDGEMENT

I express my deep sense of gratitude to Dr. M.Rathinam Associate Professor (Breeding), Department of Forestry, Tamil Nadu Agricultural University and Chairman of my Advisor Committee for his inspiring guidance, encouragement and valuable suggestions during the course of the investigation. I am grateful to Prof. A.Subramaniam, Emeritus Scientist for constant encouragement throughout the course of investigation

I am indebted to Prof. S.Kamalanathan, Prof. V.S.Raman Dr. Y.B.Morachan and Thiru V .Ramakrishnan, members of my Advisory Committee for their helpful suggestions and encourag ment in the present study.

My sincere thanks are due to Dr. D.Jagathesan for valuable suggestions in the preparation of manuscript.

My thanks are also due to my collegues Dr. M.Stephen Dorairaj and Thiru Muralidharan and my friends for their help

Finally, I gratefully acknowledge the Tamil Nadu Agricultural University for permitting me to carry out the present investigation as a part time student.

Introduction

INTRODUCTION

Induced mutation has now become an important tool in developing new genetic variability and in improving specific characteristics of crop plants. Ever since the discovery of the mutagenic action of X-rays on Drosphilla by Muller and on barley by Stadler five decades ago, several plant breeders have turned to this line of investigation and have made contributions to the understanding of the basic processes of mutation. The discovery of the mutagenic action of chemicals by Oehlkers and Auerbach during the early forties was at first considered more of theoretical than of practical interest. However, the evidence that certain chemicals give different spectra of mutations from those of X-rays and the desire to obtain directed mutations has prompted investigations employing both chemicals and radiations.

The striking feature is that induced mutation seem capable of improving most of the characters of the plant. The crop varieties of both the cereals and legumes which have been developed through induced mutations have shown improvement for the characters such as yield, resistance to lodging, shattering and disease, early maturity, short stem, winter hardiness, higher protein and improved plant type (Sigurbjor and Micke, 1974).

The major problem in breeding autogamous crop like groundnut is that the available natural variability is limit

Intensive work on induced mutagenesis has been attempted in groundnut next only to cereal crops. The development and release of NC 4-X in North Carolina (Gregory, 1960) and Trombay groundnut mutants (Patil and Thakare, 1969) in India are examples of success achieved in this direction as a resul of X-ray induced mutations.

Investigations involving chemical mutagens were mostly directed to assess the physiological sensitivity of differen varieties of groundnut (Ashri and Goldin, 1965; Ashri and Hersog, 1972; Ashri and Levy, 1974). Information on the effect of chemical mutagens on the quantitative characters of groundnut is meagre.

One of the approaches in mutation breeding is to enla the spectrum and increase the frequency of mutation by treat the material with the physical and chemical mutagens and the combinations (Sharma and Swaminathan, 1969).

The present investigation was therefore undertaken wi the following objectives:

1. To increase the spectrum and frequency of variability in qualitative and quantitative characters by the use of phyeical and chemical mutagens and their combination,
2. To assess the effect of mutagenic treatments on characte association and
3. To isolate mutant selections with higher productivity.

Review of Literature

REVIEW OF LITERATURE

Research on induced mutations in recent years has been conducted mostly on cereals and more specially on barley, wheat and rice; far less research has been done in crops belonging to other families (Sigurbjörnsson and Micke, 1969). Notable exceptions to this are peas (reviewed by Blixt, 1972) and peanuts (reviewed by Gustafsson and Gadd,1965; Gregory,1968 and Norden,1973).

The advantages and disadvantages that go with polyploids are felt in groundnut crop because of the presence of many duplicate loci: the multivalents, trivalents and univalents that were reported to occur at meiosis would also greatly influence the population dynamics and mutation frequency. Some traits are controlled by duplicate and multiple factors and so contain induced mutations which remain cryptic (Ashri and Goldin, 1965).

Ashri (1972) considered groundnut as a suitable material for mutation breeding since its embryos having 6-8 leaf primordia with buds in their axil (Yarbrough,1949) which provide several potential targets for mutation.

The mutagenic studies on groundnut in the earlier period were restricted to only physical mutagen, mostly X-rays, later, gamma rays, thermal and fast neutrons have been employed (Gregory 1956a; Bhatt et al.,1961; Shivaraj and

Ramama Rao, 1963; Emery et al., 1965). More recently chemical mutagens like diethyl sulphate (DES), ethylmethane sulphonate (EMS), N-Methyl N-Nitro N-Nitrosoguanidine (MNNG), Sodium azide (SA), Ethydium bromide (EB) and acriflavine were also employed (Ashri and Goldin, 1965; Levy and Ashri, 1973;1978).

Mutagen dose

Physical mutagens have been used in most of the experiments on induced mutations in groundnut. Gilles and De Vinck (1959) found in one experiment that X-irradiation of seeds presoaked in water for 48 hours with 10,000 r to 20,000 r caused complete lethality. In another experiment they concluded that the LD_{50} for survival lay between 2,000 to 5,000 r. Bilques and Martin (1961) irradiated dry seeds of two varieties with 5 per cent moisture content with doses ranging from 8,000 to 40,000 r of X-rays and found that while one variety showe high survival rate even after the application of highest dose, LD_{50} for germination in the case of another variety was around 32,000 r.

In his first set of experiments conducted with X-ray doses 2,500, 5,000, 10,000 and 20,000 r units on dry seeds of 8 per cent moisture content, Gregory (1955) reported data on survival after 54 days indicating LD_{50} around 15,000 r.

Bhatt et al. (1961) presented data of X-ray effects on growth, development and fertility, applying 25,000 and 75,000 r to dry seeds of the variety "Spanish Improved" and found LD_{50} for survival (after 100 days) was about 25,000 r. Patil and Bora (1961) irradiated dry seeds with doses ranging from 25,000 to 75,000 r. The highest dosage was reported to be almost lethal with only about 10 per cent survival. They found meiotic irregularities including translocations, inversion bridges, fragments and laggards as well as spindle abnormalities.

Shivaraj et al.(1962),Shivaraj and Ramana Rao (1963) concluded from their studies on fast neutron effects that there was a gradual decline of seed germination, growth, pollen fertility and yield with doses ranging from 25 x 10^{12} to 5 x 10^{13}n/cm^2/sec (integrated flux). Aberrant meiotic behaviour was also reported.

Osborne and Lunden (1961) reported an LD_{50} for field survival of strain 'Spantex' (dry seeds) to be 10,000 r and 3,700 reps for fast neutrons.

The 50 per cent growth reduction for groundnut was reported to be around 35-45 krad and a useful dose range of 20-30 krad of gamma rays has been recommended based on the experience gained from service treatments rendered by the IAEA Seibersdorf laboratory (Conger et al.,1977).

The efficiency of EB (ethidium bromide) in solutions of 0.63 mM and 1.26 mM was compared with EMS (19.33 mM, 38.66 mM and 58.0 mM, 0.2%, 0.4% and 0.6% respectively) for chlorophyll, leaflet, plant size and growth habit mutations in groundnut (Levy and Ashri,1975).

Sensitivity of genotypes

Results of several experiments have shown evidences in support of differential sensitivity of the genotypes to mutagenic treatments. Bilques and Marilin (1961) found that while X-irradiation at 32,000 r reduced the germination to 50 per cent in a variety 48115, the decrease in germination was not more than 12 per cent in another variety 28204 even after the application of the highest dose of 40,000 r.

Gregory (1956b and 1956c) recorded a wide range of variation in sensitivity to X-radiation of four parent strains and five hybrid combinations. These observations were based on the data collected on X_1 survival, plant vigour and time of flowering. "Evidence for the association of genotype with radio sensitivity can be derived from both X-ray and neutron treatments with different genotypes responding in different ways to the two radiations". (Gregory, 1956c)

Radio sensitivity of parental and hybrid embryos of a single cross has been studied in populations with near perfect emergence by adjusting seed moisture content above threshold levels known to be associated with severe seedling damage. These studies have led Emery et al.(1970) to conclude that parental embryos were in general more radio sensitive than either of reciprocal F_1 hybrids.

Significant differences between varieties in their physiological sensitivity to alkylating agents such as DES and EMS have been demonstrated as judged by their germination rate and seedling height (Ashri and Herzog,1972). They found that in both resistant and sensitive varieties older seeds were more susceptible to injury than freshly harvested seeds and presoaking in deionised water increased the sensitivity of the seeds to DES but not to EMS. There are several other reports on the differences in M_1 sensitivity to radiation or chemical mutagens between cultivars or lines in groundnut (Emery et al., 1970; Levy and Ashri,1973; Ashri and Levy,1974; Levy et al.,1979).

Gregory (1961) concluded that there is reason to believe that despite the different frequencies of similar mutations obtained with different mutagens, the chief limiting factor in mutation production and mutant recovery is the genic constitution of the experimental organism and not the type of mutagen used.

Varietal difference in response to mutagenic treatments for mutation yield has been reported (Ashri and Goldin, 1965; Avadhani and Ramana Rao,1968).

Emery (1972) found that hybrids were more radio resistant than parents and viable mutation frequency was more with sensitive genotypes.

Chlorophyll mutations

Information on induced chlorophyll mutation in groundnut is meagre. Patil and Bora (1963) described the origin of one Xantha and one virescent mutant after irradiation. The segregation ratio of the virescent types was not clear. It ranged from 1:1 and 15:1 indicating that the development of chlorophyll in groundnut was possibly controlled by more than one gene locus. Shehori and Ashri (1970) have reported that xanthamaculata (xm) and virescent (vr) were monogenic recessives. The spectrum of chlorophyll mutation thus appeared to be narrow.

Mutation rate

The rates of induced mutations following X-irradiatio were presented by Gregory (1957) in the following way: 1770 X_1 plants of 1949 gave rise in 1950 to 84213 X_2 plants. Among these, there were 11,502 visibly altered plants (14%)

The M2 chlorophyll mutation frequency was found to be maximum at 12 hours of presoaking with four hours of chemical treatment. The doses of 30 krad of gamma irradiation and 40 mM of EMS treatment were reported as optimum on the basis of maximum chlorophyll mutation frequency (Sivasubramanian, 1978).

Viable mutations

In the course of his studies of X-irradiation treatment with 18,500 r, Hammons (1953 a, b) found a 'cup' mutant. It is characterised by a complex of morphological features ascribed to pleiotropy such as involute leaflets in the form of a 'cup' and easily broken succulent stems. 'Cup', cu is a simple monogenic recessive. Mutant phenotypes showed recognisible grades of intensity, attributed to the interaction of the 'changed' gene and the modifying effects of the altered genotypic background in which it was expressed.

Gregory (1968) identified twenty four classes of morphological deviants. In addition to the occurrence of these major class characters individually, there also appeared occassional major class combinations at various grades. Within a given plant, two or more characters varied independently in grade, combinations usually involving two major class characters but occasionally three or four were designated as 'puck', 'ilex' and 'hedera'.

Variants affecting almost every character of the plant such as plant height, branching habit, leaf character, chlorophyll development and floral parts have been reported (Patil, 1966). Investigations of Ashri and Goldin (1965) revealed the occurrence of deviants to growth habit affecting more than one character through DES treatment. Mutations involving 2 or 3 characters at a time were interpreted as pleiotropic mutants with syndrome effect.

Inheritance of macromutants have been reported. The macromutants 'flop', 'cup', 'ilex' were simply inherited and that the inheritance of the mutants 'hedera' and 'corduroy' were determined by duplicate recessive genes (Emery et al., 1964). This was further tested by Loesch and Hammons (1968) by diallel crosses between the latter two mutants and through critical tests in F2 and confirmed the genetic control. Shohori and Ashri (1970) found that five out of eight macromutants derived from DES inherited monogenically with mutant alleles being fully recessive as shown by crosses between the mutants with the original variety.

Ashri (1968) reported the isolation of a sterile brachytic dwarf in groundnut after diethyl sulphate treatment which demonstrated that undesirable recessive alleles accumulated in self-pollinating amphidiploid species

containing duplicate loci. These dwarfs were smaller than normal, densely leaved and semisterile. Their progeny produced three types of plants (i) normal which produced normals (ii) extremely reduced which produced sterile and (iii) the intermediate ones that resembled the M1 plants, normal and sterile. Three dwarf mutants induced by DES in groundnut were reported to be monogenic recessives (Shehori and Ashri, 1970).

Induced plasmon mutations affecting growth habit of peanuts have been reported (Levy and Ashri, 1978). Mutagenic treatments of the trailing line TMR (V4) resulted in isolation of 135 erect mutants from among 1804 M_2 families. Fourteen of them behaved as plasmon mutations (7 induced by gamma rays, 6 by EMS and one by acriflavine). They have also reported the occurrence of 32 trailing mutants recovered from 3895 M_2 families following treatment of several erect lines.

Mutations in quantitative characters

The magnitude of variability released through small changes induced by X-irradiation has been well demonstrated (Gregory, 1955). He classified X_1 plants into few groups such as severely involved seedlings (A) and normal seedlings (B) while control seedlings were denoted as (C), A and B plants have given rise to X_2 and X_3 progenies containing

in the 'cup' mutant arose from the action of non-allelic modifiers intensifying or reducing the expression of the basic gene 'cu'. Since the 'cup' mutants arose in different X_1 plants they were assumed to represent different alleles or allelic systems. A certain proof of their hypothesis was afforded by the phenotypic reversion to less expressivity of another recessive gene 'hedera' which was reirradiated.

Five mutant genes (cup, flop, ilex, hedera and corduroy) were tested by Loesch (1961 and 1964) in such a way that mutant F_2 plants were extracted from an array of mutant x mutant families and mutant xcontrol families and they were then compared in the F_3 generation showing thereby that background effects were separable from the major mutant locus. Support is thereby given to the position that breedi progress may be achieved through the use of induced mutation having small effects, even with the background associated with deleterious mutants (Loesch, 1964). Emery et al. (1964 concluded that the use of stable but mutated backgrounds in recombination adds diversity to the breeder's limited collec of self-pollinated varieties. Emery et al.(1965) separated the deleterious markers from the background in question. Th F_3 families displaying recessive markers were then removed from hybrid populations and the effect of background measure among the normal appearing F_2 families in the F_4 generation. Significant variances were noticed.

Under the mutated background hypothesis, therefore, segregation of a given mutant and an array of other X-ray induced mutants from the same autogamous line would be expected to differ as a function of the segregating genotype backgrounds of the other mutants.

Another significant contribution for the understanding of micromutation was provided by Gregory (1965). He postulated that as the magnitude of phenotypic effect of mutation decreased the frequency of mutant plants increased exponentially. Small induced changes have higher probability of effecting an improvement than larger changes. He related the probability of improvement to Fisher's adaptation sphere.

Mutation at different loci affecting the same complex trait have the effect of extremely small magnitude of change at several loci which have almost equal chances of improving or worsening adaptation. It implies that if a change in phenotype is large it is very likely to be both rare and unfavourable; whereas if it is very small it will have approximately 50 per cent probability of being favourable and will occur with a frequency correlated with its diminishing size. Gregory's proof of this hypothesis (1968) with supporting data established its importance in plant improvements through appropriate method of selection.

Gregory (1965) concluded that distribution of the effects of micromutation is continuous with effects of

macromutations and no sharp boundary exists where it is possible to say that macromutation lies on one side and micromutation on the other.

Selection procedure

Investigations relating to selection procedures for improvement of economic attributes are few. The effect of a selection procedure involving ten highest and ten lowest yielding progenies on the X_5 and X_4 yields was found to result in lack of significant difference among the high groups (Gregory, 1955). The low groups were inferior to irradiated high. He, however, found that none of the lines selected in this way were superior to the original line. Further experiments revealed that 10 per cent of the vigorous looking lines possessed demonstrable superiority in yield compared to control (Gregory, 1957).

Mutation success

Gregory's pioneering work on induced mutations in peanut has led to the successful release of a mutant variety NC-4 x. The most widely cultivated peanut variety, NC-2 covering 75 per cent of peanut acreage of North Carolina had some shortcomings. It developed serious pod cracks under certain soil conditions with subsequent discolouring or decay of the kernels by ground water. This "kernel damage" drastically lowered the quality and market price of the crop. The mutant variety NC-4 x released in 1959 has outyielded the

mother strain besides having thicker hull and good quality with resistance to pod cracks (Gregory, 1960).

Gregory (1956b) reported an increased resistance to the non-specific fungus Sclerotium rolfsii. Cooper and Gregory (1960) detected 70 mutants more or less resistant to Cercospora in a total of 84,213 X_2 plants, i.e., a ratio of about 1:1300. This ratio then decreased by the subsequent testing upto X_9 generation, with 21 mutants showing sustained resistance, i.e., a ratio of 1:4000. Bilquez et al. (1965) reported mutants with increased oil content ranging from 45.3 to 53.3 per cent. Patil and Thakare (1969) found that three mutants (TG-1, -3, and -6) had a potential of over 19 per cent increased pod yield. The use of cross breeding among mutants was demonstrated by Patil (1973a).

Seven bunch type selections (TG-7 to TG-13) develope by crossing two induced mutants "Large pod" (TG-1) x "Virescent" from 'Spanish Improved Variety' showed 2-4 per cent increased oil content over 'Spanish Improved'. Patil and Mouli (1978) have isolated 'TG-17' from a cross between two radiation induced mutants, 'TG-1' and 'Darker Green' which is short in stature with bold kernels and high productivity.

Character association

Information on the effects of mutagenic treatments on character association in groundnut is meagre. Alteration of character association in the population derived from gamma irradiation of groundnut has been reported (Sathiamoorthy et al., 1978). Their study revealed that plant height was positively associated with yield at 30 krad and negatively at 40 krad while there was no correlation in the control population. As against the positive association between primary branches with yield in the control population, negati relationship was observed at 30 krad while there was no correlation at 20 krad and 40 krad treatments. The positive association between pod number and yield observed in the control population remained unaltered in the treated populati

The foregoing review thus covered the different aspect of induced mutations in groundnut. This is perhaps one crop, other than cereals, in which detailed investigations on induc mutations have been attempted. Yet the achievements are limi Informations on the effects of chemical mutagens and combinat of physical and chemical mutagens on economic characters are rare. This points to the need for critical evaluation of the effects of not only the physical and chemical mutagens but al their combination on the nature and extent of induced variabi and for isolation of mutants of economic importance.

Materials and Methods

MATERIALS AND METHODS

MATERIALS

Two improved cultivars of groundnut, TMV 9 and Ah 791 were chosen for the study. Details of the varieties are furnished in Table 1.

TABLE 1: Pedigree and characteristics of the varieties

Particulars	Varieties	
	TMV 9	Ah 7911
Pedigree	Hybrid derivative of Ah 3490 (Bromie-3) x Ah 477 (Bassi)	Hybrid derivativ of Ah 4218 (Gudiyatham) x Ah 477 (Bassi)
Characteristics		
Habit	Bunch	Bunch
Duration (days)	105	110
Testa colour	Rose	Rose

Mutagens: Gamma rays, ethyl methane sulphonate (EMS) and their combinations were employed for seed treatment. Their source, dosimetry/half life and mode of action are given in Table 2.

Table 2: Mutagen source and action

Mutagen	Source	Dosimetry/Half li
1. Gamma ray	Co^{60} gamma cell (1000 curie) at TNAU, Coimbatore	3175 rads/minute
2. EMS $CH_3\ SO_2\ OC_2\ H_5$ (Mol. wt.124.16)	Eastman Kodak Co. Rochester, New York, U.S.A	30 hours

METHODS

A. Studies on germination, survival and seedling height in M_1 generation

Two hundred seeds retained by 21/64 inch sieve having a moisture content of 5.5 per cent were treated in each dose as detailed in Table 3.

Table 3: Particulars of mutagenic treatment

Particulars	Mutagen		
	Physical: Gamma rays (krad)	Chemical: EMS (mM)	Combination* Gamma ray + EMS (krad + mM)
Treatment (dose/ concentration)	20,30 and 40	40,60 and 80; solution/seed volume ratio 3:1	20 krad + 40 mM
Pretreatment of seed	Dry seeds	Presoaked in deionised water for 12 hours	Dry seeds were irradiated followed by presoaking as in chemical treatment.
Control	Dry seeds	Soaked seeds	Dry seeds
Duration of treatment (hours)	-	Four (with intermittant shaking)	Four (with intermittant shaking)
Treatment conditions			
i) pH	-	7.5	7.5
ii) Temperature °C	24	24	24
iii) Relative humidity	75	75	75
Post washing	-	In running tap water for 1 hour	

* The lower dose of gamma irradiation and EMS concentrations were chosen for the combination treatment to reduce the biological damage as M_1 survival was reduced more than additively when large doses of mutagen were combined (Doll and Sandfaer, 1969).

M_1 generation: The seeds subjected to single and combination treatments were immediately sown in the field along with the controls in randomised block design with five replications in March 1975. Two rows of 3 m length spaced 30 cm apart constituted the plot size. Twenty seeds were dibbled per row leaving a spacing of 15 cm between seeds in the row. The following observations were recorded in the seedling stage.

Germination	:	Seedlings emerged upto 15th day after sowing were counted and expressed as percentage of total seeds sown.
Survival	:	Seedlings survived on the 30th day after sowing were counted and expressed as percentage on total seeds sown.
Seedling height	:	Measured in cm on 30th day after sowing from the collar to the tip of the main stem for ten plants chosen at random/ replication/treatment and the mean height recorded.

B. Studies on qualitative mutation

M_2 generation: Seeds harvested from fifty randomly selected M_1 plants in each treatment were advanced to raise M_2 generation in April 1976 in randomised blocks with three replications. Control lines were raised from seeds obtained from randomly chosen plants in the parent varieties. The

population raised under various treatments are presented in Table 6.

i) Chlorophyll mutations: The M_1 plant progenies in M_2 generation were examined upto 15th day after germination for chlorophyll mutation. The mutation frequency was estimated and expressed as percentage on M_2 plant basis (Gaul, 1957). The mutant and normal seedlings were counted separately to determine the segregation ratio, i.e., percentage of mutants to total progenies. The chlorophyll mutations were classified according to the system proposed by Gustafsson (1940) and Blixt (1961). Synergism was calculated by the formula $(a)+(b)=\frac{1}{k}-(a+b)$, where 'a' and 'b' are the two treatments and 'k' is the interaction coefficient. The value of 'k' should be one, if the interaction is additive. Deviation from this value towards positive or negative direction would show synergistic or less than additive effect (Sharma and Swaminathan, 1969).

ii) Viable mutations: The M_2 plants were observed periodically upto maturity for viable mutations and morphological deviants identified were labelled and harvested separately. Viable mutation frequency was estimated on the basis of 100 M_2 plants. Progenies of the viable mutants were raised in M_3 generation in non replicated rows along with the parental varieties. Observations on quantitative characters were recorded on twenty plants chosen at random as detailed in the M_2 generation.

C. Studies on quantitative mutations

i) M_2 generation: Observations on eleven quantitative characters detailed below were recorded on five plants chosen at random in each replication.

1. Height of main stem: Height was measured in cm. from the collar region to the tip of the main stem.

2. Length of primary branch: It was measured from the point of attachment of the branch at the main stem to the tip of the primary branch.

3. Number of branches: This included the number of primary and secondary branches in a plant.

4. Number of flowers/plant: Daily flower production was recorded from the 5th to 10th week after sowing and the total number of flowers produced during the period assessed.

5. Number of mature pods/plant: Only mature pods were counted and recorded discarding immature pods.

6. Number of kernels/plant: The pods were thoroughly sun-dried and shelling of the pods was done. The number of kernels obtained by shelling the pods of each plant was recorded.

7. Pod yield/plant: The pod weight in gram of individual plant was recorded before shelling.

8. Kernel yield/plant: The kernel weight in gram after shelling was recorded.

9. 100-pod weight: This was calculated from the weight and number of pods of individual plants and expressed in gram.

10. 100-kernel weight: From the weight and number of kernels of individual plants, this was calculated and expressed in gram.

11. Shelling per cent: The proportion of kernel to pod by weight expressed as per cent was recorded as shelling per cent.

Phenotypic frequency distributions for four important characters, namely, number of mature pods, pod yield, 100-kernel weight and shelling per cent are presented in graphs based on the observations of 360 plants in each treatment.

ii. M_3 generation: Seeds obtained from 24 normal plants chosen from 24 families containing not less than 60 seeds per plant in each treatment in the M_2 generation were advanced to raise progenies in the M_3 generation. Similar selection of plants was made in the parent varieties to raise control lines. The experiment was raised in April 1977 in randomised block design with three replications. The population raised in M_3 generation under various treatments in the two varieties consisted of 17,280 plants. The progenies of viable mutants raised separately in non-replicated rows included 665 plants. Observations on eleven quantitative characters were recorded as in M_2 generation. Phenotypic frequency distributions for characters as mentioned in M_2 generation are presented in graphs.

D. Evaluation of productive mutant lines

Forty plants which recorded higher yield in M_2 than that of control were selected for further study. The progenies were raised in M_3 in rows of 3 m length spaced 30 cm between rows and 15 cm between plants in the row in randomised blocks replicated four times along with parental varieties. Ten plants were chosen at random in each progeny per replication for yield assessment.

M_4 generation: Twenty one plants from five lines which showed positive yield performance in M_3 were chosen at random and the progenies were raised in April, 1978 in M_4 along with the controls in three replications. The row length, spacing and random samples for yield assessment were similar to that of M_3 generation.

E. Statistical analyses

The data on mean values in respect of quantitative characters in M_1, M_2 and M_3 generations were analysed statistically using the standard procedures. Percentages were transformed to angular scale and the transformed values are given in the text and tables while in text figures actual percentages are indicated. The different quantitative characters were compared with control by 't' test and the variance by the 'F' test.

From the total variance in the M_2 and M_3 generations, the estimates of genotypic variance and heritability were

calculated following the method of Brook and Latter (1961). The estimated genetic advance under selection was based on the formulae suggested by Lush (1949) and Johnson et al.,(1965).

The genetic parameters were calculated as detailed below:

Genotypic variance (GV) : $\frac{\text{Progenies M.S} - \text{Error M.S}}{r}$

where M.S. is mean square
r is replication

Genotypic coefficient of variability (GCV) : $\frac{g \times 100}{\bar{X}}$

where g is genotypic standard deviation

$\bar{X}$ is the mean

Heritability (h^2) : $\frac{g^2}{p^2}$

where g^2 is genotypic variance
p^2 is phenotypic variance

Genetic advance expressed as per cent on mean (GA) : $h^2 \times k \times p \times \frac{100}{\bar{X}}$

where p is the phenotypic standard deviation and k is the constant (2.06), the selection differential at 5 per cent selection intensity.

Correlation coefficients were worked out between yield and its components and also between pairs of yield components in the M_3 generation to determine the extent to which the mutagenic treatments had altered the type and strength of character association. The components correlated with yield were, height of the main stem, length of primary branch, number of branches, number of flowers and number of pods/plant.

Abbreviation Used:

CD	: Critical difference at 5% level
SE	: Standard error
NS	: Not significant
EMS	: Ethylmethane sulphonate
mM	: Millimoles
krad	: doses of radiation in kilo rad
GV	: Genotypic variance
GCV	: Genotypic coefficient of variability
h^2	: Heritability expressed as per cent
GA	: Genetic advance expressed as per cent of mean
GM	: General mean
DS	: Dry seed
SS	: Soaked seed

Experimental Results

EXPERIMENTAL RESULTS

A. Studies on germination, survival and seedling height in M_1 generation

The effects of mutagenic treatments on groundnut varieties, TMV 9 and Ah 7911 were studied by subjecting them to three doses of gamma rays, three concentrations of EMS and a combination treatment of 20 krad of gamma rays plus 40 mM of EMS. The data collected on three M_1 indices namely, germination, survival and seedling height are presented in Tables 4 and 5.

1. Germination

Gamma irradiation resulted in reduction in germination in the varieties compared to that of control (Table 4 and Fig.1). In TMV 9, the germination per cent was reduced to 62.12 at 20 krad, 59.40 at 30 krad and 55.10 at 40 krad compared to 73.10 in the control. In Ah 7911, there was a reduction in germination per cent from 76.44 in the control to 60.57 at 20 krad, 57.16 at 30 krad and 53.79 at 40 krad. Decrease in germination was observed as the doses increased.

Reduction in germination was observed at each concentration of EMS treatment compared to control in the varieties. In TMV 9, the germination per cent was 61.84 at 40 mM, 50.79 at 60 mM and 38.58 at 80 mM. In Ah 7911, a similar trend in reduction was observed.

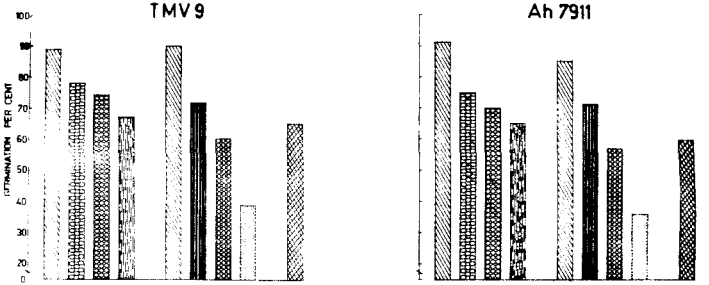


FIG.1 MUTAGENIC EFFECTS ON GERMINATION IN M_1 GENERATION

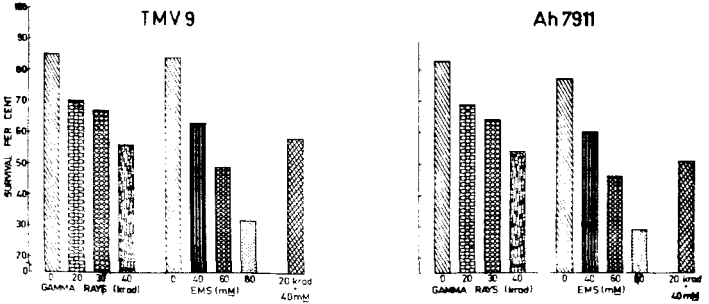


FIG.2 MUTAGENIC EFFECTS ON SURVIVAL IN M_1 GENERATION

Treatment	Germination per cent				Survival per cent			
	TMV 9	Per cent on control	Ah 7911	Per cent on control	TMV 9	Per cent on control	Ah 7911	Per cent on control
Control (DS)	73.10	100.00	76.44	100.00	67.69	100.00	68.31	100.00
Gamma rays 20 krad	62.12	84.98	60.57	79.25	57.50	84.96	56.76	83.10
30 krad	59.40	81.27	57.16	74.78	54.76	80.91	53.40	78.16
40 krad	55.10	75.39	53.79	70.37	48.25	71.27	47.30	69.24
Mean	58.87	80.54	57.17	74.78	53.50	79.05	52.48	76.83
Combination 20 krad + 40 mM	53.86	75.06	52.68	68.93	49.67	73.38	47.72	69.85
Control (SS)	73.85	100.00	74.44	100.00	69.53	100.00	64.53	100.00
EMS 40 mM	61.84	83.73	57.51	77.27	53.06	76.30	50.87	78.83
60 mM	50.79	72.04	49.04	65.89	44.42	63.87	42.69	66.15
80 mM	38.58	52.24	36.83	49.48	34.32	49.35	32.55	50.44
Mean	50.40	68.87	47.79	64.19	43.93	63.17	42.04	65.13

Source	S.E.	C.D	S.E.	C.D
Variety	1.33	N.S	1.19	N.S
Treatment	2.82	7.94	2.52	7.11
Variety x Treatment	3.98	N.S	3.57	N.S

Combination treatment showed a greater reduction in germination than that of the component single treatments. There was similar response to mutagenic treatments among the varieties.

2. Survival

Gamma irradiation resulted in reduction in survival (Table 4 and Fig.2). The lowest survival of 48.25 per cent in TMV 9 and 47.30 per cent in Ah 7911 was recorded at the maximum dose of 40 krad. EMS treatments showed reduction in survival at each concentration compared to that of control. In TMV 9, the survival was reduced from 69.53 per cent in the control to 53.06 per cent at 40 mM, 44.42 at 60 mM and 34.32 at 80 mM. A similar trend was observed in Ah 7911. Combination treatment showed greater reduction in survival than that of the component single treatments.

3. Seedling height

Gamma irradiation showed reduction in the height of seedling compared to that of control (Table 5), TMV 9 recorded 4.8 cm at 20 krad, 4.4 cm at 30 krad and 3.4 cm at 40 krad compared to 5.2 in the control. In Ah 7911, there was reduction from 6.1 cm in the control to 5.5 cm at 20 krad and 4.6 cm at 30 krad and 3.6 cm at 40 krad. A similar trend in reduction in the height of seedling was observed in EMS treatments. In TMV 9, there was reduction from 4.9 cm in the control to 2.2 cm at the maximum

TABLE 5: Seedling height in M_1 generation

Treatment	Seedling height (cm)			
	TMV 9	Per cent on control	Ah. 7911	Per cent on control
Control (D S)	5.2	100.00	6.1	100.00
Gamma rays 20 krad	4.8	92.30	5.5	90.16
30 krad	4.4	84.63	4.6	75.43
40 krad	3.4	65.39	3.6	59.02
Mean	4.2	80.76	4.6	75.43
Combination 20 krad + 40 mM	4.3	82.69	4.4	72.14
Control (S S)	4.9	100.00	6.0	100.00
EMS 40 mM	3.7	75.51	5.0	83.33
60 mM	3.2	65.30	2.7	45.00
80 mM	2.2	44.89	2.0	33.33
Mean	3.0	87.76	3.2	52.46

Source	S.E	C.D
Variety	0.01	0.03
Treatment	0.22	0.61
Variety x Treatment	0.31	0.86

concentration of 80 mM. Ah 7911 recorded reduction from 6.0 cm in the control to 2.0 cm in the maximum concentration of 80 mM. Height of the seedling in the combination treatment was intermediate between that of the component single treatments in TMV 9. In Ah 7911, the value was lower than that of the single treatments.

B. Studies on qualitative mutations in M_2 generation

Observations were recorded on the frequency and spectrum of chlorophyll and viable mutations. Observations on the frequency of their occurrence were estimated as percentage on M_2 plants and the changes in the spectrum due to different mutagenic treatments are presented below.

1. Chlorophyll mutations

The frequency of chlorophyll mutations expressed as per cent on M_2 plants in TMV 9 was 1.26 in the combination treatment followed by 1.07 at 30 krad of gamma irradiation (Table 6). A frequency of 0.44 per cent was observed in 60 mM concentration of EMS treatment. In Ah 7911, a mutation frequency of 1.44 per cent was induced by 40 krad of gamma irradiation followed by 1.11 per cent in the combination treatment and 0.85 per cent at 80 mM concentration of EMS treatment.

The spectrum of chlorophyll mutations observed were albina, alboviridis, chlorina, xantha and viridis (Table 7).

Variety	Treatment	Number of M_1 families*	Number of M_2 plants	Per cent of M_1 families segregating	Per cent of M_2 plants mutated	Amount of synergism
TMV 9	Gamma 20 krad	50	2705	8	0.81	-
	30 krad	50	2692	10	1.07	-
	40 krad	50	2685	6	0.81	-
	EMS 40 mM	50	2724	8	1.06	-
	60 mM	50	2675	4	0.44	-
	80 mM	50	2585	6	1.00	-
	20 krad + 40 mM	50	2536	8	1.26	0.67
Ah 7911	Gamma 20 krad	50	2675	14	1.04	-
	30 krad	50	2663	6	1.01	-
	40 krad	50	2635	12	1.44	-
	EMS 40 mM	50	2654	10	1.20	-
	60 mM	50	2595	8	1.04	-
	80 mM	50	2573	6	0.85	-
	20 krad + 40 mM	50	2515	8	1.11	0.49

* in each rep. & non-rep.

TABLE 7: Spectrum of Chlorophyll mutations in M_2 generation

Variety	Treatment	Mutation spectrum (Per cent)					Total number
		Albina	Albo-viridis	Chlorina	Xantha	Viridis	
TNV 9	Gamma 20 krad	27.27	36.36	36.37	-	-	22
	30 krad	34.48	34.48	31.04	-	-	29
	40 krad	9.10	54.54	36.36	-	-	22
	EMS 40 mM	6.90	41.38	17.24	13.79	20.69	29
	60 mM	-	33.33	25.00	41.67	-	12
	80 mM	-	26.92	34.62	38.46	-	26
	20 krad + 40 mM	18.75	34.37	21.88	18.75	6.25	32
Ah 7911	Gamma 20 krad	-	25.00	42.86	32.14	-	28
	30 krad	7.41	22.22	29.63	22.22	18.52	27
	40 krad	10.53	23.68	34.21	31.58	-	38
	EMS 40 mM	28.13	37.50	-	-	34.37	32
	60 mM	25.93	-	-	29.63	44.44	27
	80 mM	27.27	-	-	40.91	31.82	22
	20 krad + 40 mM	14.28	17.86	42.86	25.00	-	28

The varieties differed in their response to mutagenic treatments with regard to spectrum of chlorophyll mutations. While xantha and viridis were not noticed in the gamma irradiated populations of TMV 9, they occurred in Ah 7911. Chlorina was absent in the EMS treated populations of Ah 7911 while it appeared with a range of 17.24 to 34.62 per cent in the corresponding populations of TMV 9. The occurrence of alboviridis in the EMS treated populations of TMV 9 and in 40 mM concentration in Ah 7911 was also recorded. Combination treatment resulted in the production of five types of chlorophyll mutations in TMV 9 and four types in Ah 7911.

2. Viable mutations

In TMV 9, a frequency of 0.66 per cent of viable mutants on M_2 plant basis was observed at EMS 40 mM treatment (Table 8). There was reduction in frequency at higher concentrations. A similar trend of result was observed in Ah 7911. Viable mutants were found in combination treatment only in TMV 9.

The spectrum of viable mutations included mutations for height (dwarf), growth habit (semi spreading and spreading), leaf size and shape (small, obovate and medium, elliptic-obovate) shape and nature of pods and kernels (cylindrical pods with 3 kernels) and testa colour (brown,

Variety	Treatment	Number of M_1 families *	Number of M_2 plants at maturity	Per cent of M_1 families segregating	Per cent of M_2 plants mutated
TMV 9	Gamma 20 krad	50	2415	4	0.33
	30 krad	50	2372	6	0.38
	40 krad	50	2365	-	-
	EMS 40 mM	50	2441	6	0.66
	60 mM	50	2384	4	0.17
	80 mM	50	2273	4	0.26
	20 krad + 40 mM	50	2242	4	0.27
Ah 7911	Gamma 20 krad	50	2385	4	0.25
	30 krad	50	2356	4	0.21
	40 krad	50	2342	-	-
	EMS 40 mM	50	2365	8	0.51
	60 mM	50	2290	2	0.04
	80 mM	50	2265	2	0.09
	20 krad + 40 mM	50	2224	-	-

* in each rep. & non-rep.

TABLE 9: Spectrum of viable mutations in M_2 generation

Variety	Treatment	Mutation spectrum (per cent)						Mutations for		Total number
		Dwarf mutant	Growth habit mutant	Leaf size shape mutant	Sterile mutant	Pod size, shape, kernelled nature	Testa colour mutant	Two* traits	Three+ traits	
TMV 9	Gamma 20 krad	-	-	50.00	25.00	12.50	12.50	-	-	8
	30 krad	11.11	-	11.11	11.11	44.44	22.23	-	-	9
	40 krad	-	-	-	-	-	-	-	-	-
	EMS 40 mM	-	6.25	62.50	-	12.50	6.25	6.25	6.25	16
	60 mM	-	60.00	40.00	-	-	-	-	-	5
	80 mM	-	-	66.67	-	16.67	16.66	-	-	6
	20 krad + 40 mM	-	-	33.34	-	-	33.33	33.33	-	6
Ah 7911	Gamma 20 krad	-	-	66.67	-	33.33	-	-	-	6
	30 krad	20.00	-	-	40.00	-	40.00	-	-	5
	40 krad	-	-	-	-	-	-	-	-	-
	EMS 40 mM	-	8.33	16.67	-	50.00	16.67	-	8.33	12
	60 mM	-	-	-	-	-	-	100.00	-	1
	80 mM	-	50.00	50.00	-	-	-	-	-	2
	20 krad + 40 mM	-	-	-	-	-	-	-	-	-

* Growth habit and pod size

\+ Growth habit, pod size and testa colour

purple, red, white and variegated testa) (Table 9). Wide spectrum of viable mutations was observed at 40 mM of EMS treatment in TMV 9. Mutations affecting two traits, namely, growth habit and pod size were observed at 40 mM and combination treatment in TMV 9 and 60 mM treatment in Ah 7911. Mutations involving three traits, namely, growth habit, pod size and testa colour were induced by 40 mM concentration of EMS in the varieties.

Plants in M_2 which differed morphologically in one or more characters from that of the parent variety were selected and their progeny in M_3 generation were studied to identify the mutants. Descriptions of such morphological deviants are presented in Table 10. Observations on the quantitative characters were recorded on twenty plants chosen at random in each and the mean values are presented in Tables 11 to 18. Viable mutants induced by different doses of mutagenic treatments are presented below.

a. Gamma 20 krad: The M_2 population of Ah 7911 showed two plants possessing bold kernels. Their progenies in the M_3 generation bred true for bold kernels (Mutant-3 and -4). They were indistinguishable from the parent variety except for the increased size and weight of pod and kernel. The mean 100-kernel weight was 40.6 g

TABLE 10: Description of viable mutants

M_3 Progeny number	Mutant number	Variety	Treatment	Description
7-5-2	1	Ah 7911	Gamma 30 krad	Dwarf plant, very small pods and kernels
14-13-9	2	TMV 9	Gamma 30 krad	Dwarf plant very small pods
204-15-4	3	Ah 7911	Gamma 20 krad	Bunch, bold pods and kernels
23-2-4	4	Ah 7911	Gamma 20 krad	Bunch, bold pods and kernels
10-8-8	5	TMV 9	Gamma 30 krad	Bunch, small pods
312-8-1	6	TMV 9	Gamma 20 krad	Bunch, occurrence of 3 seeded pods
23-1-4	7	Ah 7911	Gamma 30 krad	Bunch, purple kernelled mutant
21-7-10	8	Ah 7911	EMS 40 mM	Bunch, purple kernelled mutant
24-10-1	9	TMV 9	20 krad + 40 mM	Bunch, purple kernelled mutant
80-2-9	10	Ah 7911	EMS 40 mM	Bunch, brown kernelled mutant
145-1-2	11	TMV 9	EMS 40 mM	Bunch, brown kernelled mutant
194-10-4	12	TMV 9	EMS 80 mM	Bunch, white kernelled mutant
41-9-6	13	Ah 7911	30 krad	Bunch, Rose kernels with purple lining of micropil
77-10-4	14	Ah 7911	30 krad	Bunch, Rose kernels with purple lining of micropil
233-4-2	15	Ah 7911	EMS 40 mM	Semispreading, variegated kernelled testa mutant
156-14-1	16	TMV 9	20 krad + EMS 40 mM	Semispreading, bold pods and kernels
380-4-7	17	TMV 9	20 krad + EMS 40 mM	Semispreading, bold pods and kernels
145-11-4	18	TMV 9	EMS 40 mM	Semispreading, red kernels
29-7-1	19	Ah 7911	EMS 60 mM	Semispreading
235-8-6	20	Ah 7911	EMS 80 mM	Semispreading
228-8-8	21	TMV 9	EMS 40 mM	Spreading
228-13-11	22	TMV 9	EMS 40 mM	Spreading, bold pods and kernels

in mutant-3 and 43.2 g in mutant-4 compared to 33.0 g in the parent (Tables 11 and 12). There was, however, reduction in the number of mature pods and shelling per cent in these mutants compared to the parent variety.

One plant with bunch growth habit having three-seeded pods in a proportion of 20 per cent of total pods was observed in the M_2 generation of TMV 9. This plant was found to breed true to the trait in the same proportion in the M_3 generation (Mutant-6) (Plate I).

b. Gamma - 30 krad: Dwarf plants were observed in the M_2 generation in Ah 7911 and TMV 9. The true breeding behaviour for dwarf plant type was observed in the M_3 generation. The mean height of main stem at maturity was 6.9 cm in mutant-1 compared to 21.3 cm in the parent and that in mutant-2 was 9.8 cm as against 20.3 cm in the parent (Plate I). These dwarf mutants showed reduction in pod yield and 100-kernel weight compared to that of the parents (Table 11).

One plant possessed small kernels in the M_2 generation in TMV 9. Its progeny in the M_3 generation was found to breed true for small kernels (Mutant-5). The 100-kernel weight of this mutant was 22.5 g compared to 28.2 g in the parent (Table 12).

PLATE -I

Morphological features of Viable mutants

a. Control (TMV 9)

b. Dwarf bunch

c. Semispreading

d. Semispreading with profuse branching

e. Spreading type

f. Pod characters:

1. Control

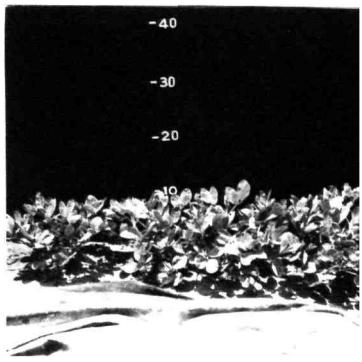
2. Three-seeded

3. Small sized

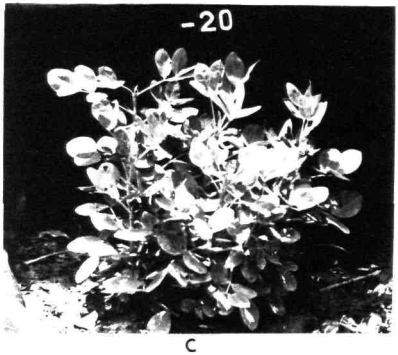
4-6 . Variation in constriction.

PLATE-1

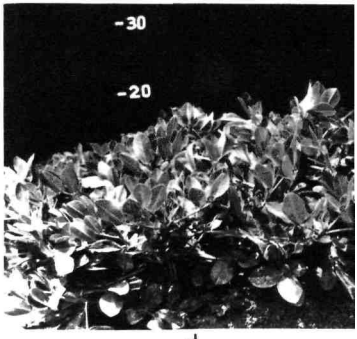
a



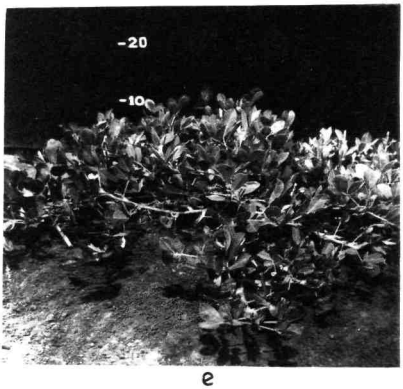
b



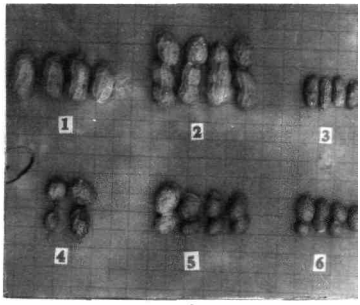
c



d



e



f

(mean of 20 plants)

Characters	Mutant-1 (Ah 7911,30 krad)		Mutant-2 (TMV 9, 30 krad)		Mutant-3 (Ah 7911, 20 krad)		TMV 9 (Control)	Ah 7911 (Control)
	Mean ± SE	Per cent on cont-rol	Mean ± SE	Per cent on cont-rol	Mean ± SE	Per cent on control	Mean ± SE	Mean ± SE
Height of main stem (cm)	6.9±0.9	32.4	9.8±0.5	48.3	21.2± 2.0	99.5	20.3±1.6	21.3±1.5
Length of primary branch (cm)	7.5±0.9	27.3	12.5±0.7	52.3	27.0± 2.5	98.2	23.9±2.3	27.5±3.3
Number of primaries	4.5±1.0	91.8	4.6±0.3	102.2	3.3± 0.7	67.4	4.5±0.8	4.9±0.9
Number of secondaries	-	-	2.2±1.0	66.7	3.7± 1.5	142.3	3.3±0.9	2.6±0.7
Number of pods/plant	15.8±4.5	82.3	23.6±2.1	113.5	14.3± 0.9	74.5	20.8±2.1	19.2±2.5
Number of kernels/ plant	20.8±6.7	69.6	39.2±2.6	114.6	19.7± 2.6	65.9	34.2±2.5	29.9±3.0
Pod yield (g)/plant	3.7±1.0	23.4	8.1±0.8	49.4	11.3± 1.0	71.5	16.4±0.9	15.8±1.2
Kernel yield (g)/ plant	1.8±0.5	19.6	5.0±0.6	46.3	7.5± 0.8	81.5	10.8±0.6	9.2±0.8
100 pod weight (g)	25.6±3.6	33.7	34.7±1.9	51.5	80.1±10.8	105.5	67.4±4.6	75.9±4.0
100 kernel weight(g)	9.0±0.7	27.3	12.9±0.8	85.7	40.6± 2.5	123.0	28.2±1.5	33.0±2.5
Shelling per cent	50.2±7.5	71.4	61.5±1.5	85.7	66.0± 1.2	93.9	71.8±2.7	70.3±2.3

(Control 100.0 per cent)

(mean of 20 plants)

Characters	Mutant-4 (Ah 7911,20 krad) Mean ± SE	Per cent on control	Mutant-5 (TMV 9, 30 krad) Mean ± SE	Per cent on control	Mutant-6 (TMV 9, 20 krad) Mean ± SE	Per cent on control	TMV 9 (Control) Mean ± SE	Ah 7911 (Control) Mean ± SE
Height of main stem (cm)	20.2±1.5	94.8	19.5±4.0	96.1	22.4±2.8	110.3	20.3±1.6	21.3±1.5
Length of primary branch (cm)	27.5±2.2	100.0	27.3±2.8	114.2	29.7±2.3	124.3	23.9±2.3	27.5±3.3
Number of primaries	5.3±0.4	108.2	4.5±0.5	100.0	5.5±0.6	122.2	4.5±0.8	4.9±0.9
Number of secondaries	2.4±0.9	92.3	2.0±1.0	60.6	8.0±1.1	242.4	3.3±0.9	2.6±0.7
Number of pods/plant	12.9±2.0	67.2	11.5±0.5	55.3	18.7±4.2	89.9	20.8±2.1	19.2±2.5
Number of kernels/ plant	15.4±2.2	51.5	18.5±3.5	54.1	31.1±8.3	90.6	34.2±2.5	29.9±3.0
Pod yield (g)/plant	9.4±1.3	59.5	10.5±2.8	64.0	14.7±4.4	89.6	16.4±0.9	15.8±1.2
Kernel yield (g)/ plant	5.8±0.6	63.0	7.3±2.3	67.6	9.8±3.1	90.7	10.8±0.6	9.2±0.8
100 pod weight (g)	82.0±5.9	108.0	70.0±2.0	103.9	76.7±5.5	113.8	67.4±4.6	75.9±4.0
100 kernel weight (g)	43.2±3.3	130.9	22.5±4.9	94.0	30.3±2.1	107.5	28.2±1.5	33.0±2.5
Shelling per cent	67.0±2.9	95.3	68.5±3.5	95.4	65.1±2.3	90.7	71.8±2.7	70.3±2.3

(Control 100.0 per cent)

In the M_2 population of Ah 7911, one plant possessed kernels containing purple testa. Its progeny in the M_3 generation showed the true breeding behaviour of the purple testa (Mutant-7).

Two plants having rose kernels with purple lining around micropyle were observed in the M_2 generation in Ah 7911. The true breeding nature of the deviant trait was observed in their progeny in the M_3 generation (Mutant-13 and -14).

c. EMS 40 mM: One plant containing kernels with purple testa and another possessing kernels with brown testa were observed in the M_2 generation in Ah 7911. The true breeding behaviour of the character, testa colour was observed in their progeny in the M_3 generation (Mutant-8 and -10). In the M_2 generation of TMV 9, one plant having kernels with brown testa was observed. Its progeny in M_3 bred true for brown testa (Mutant-11) (Plate II).

One plant with semispreading growth habit having kernels with variegated testa was observed in the M_2 generation of Ah 7911. Its progeny in the M_3 generation showed the true breeding behaviour for the two deviant traits, namely growth habit and testa colour (Mutant-15).

One plant with semi-spreading habit and red kernels and two plants with spreading habit containing bold kernels were observed in the M_2 generation of TMV 9. Their

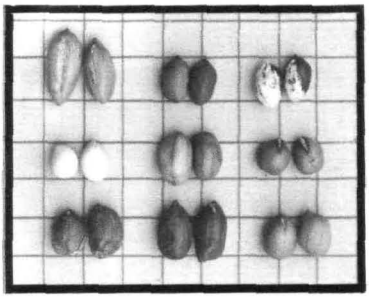
PLATE -II

Variation in kernel size and testa colour

(left to right)

Top row :	(i)	Bold size
	(ii)	Purple testa
	(iii)	Variegated testa
Middle row:	(i)	White testa
	(ii)	Medium size
	(iii)	Purple lining around micropyle
Bottom row	(i)	Brown testa
	(ii)	Red testa
	(iii)	Control

PLATE-II



(mean of 20 plants)

Characters	Mutant-7 (Ah 7911,30 krad)		Mutant-8 (Ah 7911, EMS 40 mM		Mutant-9 (TMV 9,20 krad+ 40 mM		TMV 9 (Control)	Ah 7911 (Control)
	Mean±SE	Per cent on control	Mean ± SE	Per cent on control	Mean± SE	Per cent on control	Mean±SE	Mean±SE
Height of main stem (cm)	17.6±2.9	82.6	18.3±1.4	85.9	19.5±1.1	96.1	20.3±1.6	21.3±1.5
Length of primary branch (cm)	20.4±4.8	74.2	29.3±5.3	106.6	25.0±2.1	104.6	23.9±2.3	27.5±3.3
Number of primaries	5.3±0.8	108.2	4.7±0.3	95.9	4.1±0.2	91.1	4.5±0.8	4.9±0.9
Number of secondaries	2.8±2.1	107.7	4.9±0.8	188.5	3.7±1.0	112.1	3.3±0.9	2.6±0.7
Number of pods/ plant	6.5±0.9	33.9	17.9±2.4	93.2	15.7±1.9	75.5	20.8±2.1	19.2±2.5
Number of kernels/ plant	9.5±0.9	31.8	27.4±3.2	91.6	24.5±2.8	71.6	34.2±2.5	29.9±3.0
Pod yield(g)/plant	5.1±0.8	32.3	13.4±2.0	84.8	13.9±1.7	84.8	16.4±0.9	15.8±1.2
Kernel yield (g)/ plant	3.4±0.3	37.0	8.2±1.0	89.1	9.6±1.1	88.9	10.8±0.6	9.2±0.8
100 pod weight (g)	79.5±2.1	104.7	75.2±2.4	99.1	92.5±4.4	137.2	67.4±4.6	75.9±4.0
100 kernel weight (g)	35.6±1.7	107.9	30.4±1.1	92.1	40.0±1.3	141.8	28.2±1.5	33.0±2.5
Shelling per cent	67.1±4.8	95.5	64.2±2.2	91.3	69.8±1.6	97.2	71.8±2.7	70.3±2.3

(Control 100.0 per cent)

(Mean of 20 plants)

Characters	Mutant-10 (Ah.7911, EMS 40 mM)		Mutant-11 (TMV 9, EMS 40 mM)		Mutant-12 (TMV 9, EMS 80 mM)		TMV 9 (Control)	Ah 7911 (Control)
	Mean± SE	Per cent on control	Mean ± SE	Per cent on control	Mean ± SE	Per cent on control	Mean± SE	Mean ± SE
Height of main stem (cm)	18.1±1.3	85.9	20.2±1.3	99.5	16.8±1.5	82.8	20.3±1.6	21.3±1.5
Length of primary branch (cm)	20.8±1.0	75.6	28.6±1.5	119.7	20.4±2.0	85.4	23.9±2.3	27.5±3.3
Number of primaries	4.5±0.2	91.8	4.3±0.2	95.6	4.6±0.9	102.2	4.5±0.8	4.9±0.9
Number of secondaries	3.2±0.7	123.1	2.1±0.4	63.6	2.3±1.2	69.2	3.3±0.9	2.6±0.7
Number of pods/plant	16.2±1.5	84.4	23.5±2.0	113.0	14.4±1.7	69.2	20.8±2.1	19.2±2.5
Number of kernels/ plant	27.1±2.4	90.6	35.0±3.2	102.3	22.1±2.4	64.6	34.2±2.5	29.9±3.0
Pod yield (g)/plant	13.2±1.1	83.5	18.0±1.7	109.8	8.9±0.9	54.3	16.4±0.9	15.8±1.2
Kernel yield (g)/ plant	9.7±0.8	105.4	10.5±1.0	97.2	5.9±0.7	54.6	10.8±0.6	9.2±0.8
100 pod weight(g)	83.8±2.5	110.4	73.8±3.7	109.5	63.1±2.8	93.6	67.4±4.6	75.9±4.0
100 kernel weight(g)	37.1±1.3	112.4	30.2±1.7	107.1	26.5±1.1	94.0	28.2±1.5	33.0±2.5
Shelling per cent	73.5±1.2	104.6	65.3±2.1	91.0	65.8±2.2	91.6	71.8±2.7	70.3±2.3

(Control 100.0 per cent)

(mean of 20 plants)

Characters	Mutant-13 (Ah 7911, 30 krad)		Mutant-14 (Ah 7911, 30 krad)		Mutant-15 (Ah 7911, EMS 40 mM		Ah 7911 (Control)
	Mean ± SE	Per cent on control	Mean ± SE	Per cent on control	Mean ± SE	Per cent on control	Mean ± SE
Height of main stem (cm)	21.9±1.6	102.8	18.8±2.4	88.3	14.7±2.0	69.0	21.3±1.5
Length of primary branch (cm)	25.3±2.2	92.0	21.3±1.8	77.5	21.0±1.1	76.4	27.5±3.3
Number of primaries	4.1±0.1	83.7	4.3±1.0	87.8	11.7±1.1	238.8	4.9±0.9
Number of secondaries	3.8±1.6	146.2	6.3±1.9	41.3	14.8±1.8	569.2	2.6±0.7
Number of pods/plant	14.1±1.7	73.4	17.3±1.9	90.1	12.4±1.7	64.6	19.2±2.5
Number of kernels/ plant	23.3±3.0	77.9	27.2±1.9	91.0	20.3±3.0	66.9	29.9±3.0
Pod yield(g)/plant	11.2±1.5	70.9	16.8±1.7	106.3	13.2±1.8	83.5	15.8±1.2
Kernel yield (g)/ plant	7.3±1.1	79.4	10.6±1.4	115.2	9.3±1.3	101.1	9.2±0.8
100 pod weight (g)	77.8±4.2	102.5	98.4±6.4	129.6	107.0±4.7	141.0	75.9±4.0
100 kernel weight (g)	25.7±1.7	77.9	39.0±3.3	118.2	48.7±2.8	147.6	33.0±2.5
Shelling per cent	63.3±2.5	90.0	64.2±6.5	91.3	70.9±3.0	100.9	70.3±2.3

(Control 100.0 per cent)

TABLE 16: Quantitative characters of viable mutants in M_3 generation

(mean of 20 plants)

Characters	Mutant - 16 (TMV 9, 20 krad + 40 mM)		Mutant - 17 (TMV 9, 20 krad + 40 mM)		TMV 9 (Control)
	Mean ± SE	Per cent on control	Mean ± SE	Per cent on control	Mean ± SE
Height of main stem (cm)	10.3 ± 0.6	50.7	11.2 ± 0.8	55.2	20.3 ± 1.6
Length of primary branch (cm)	23.1 ± 1.0	96.7	22.8 ± 0.7	95.4	23.9 ± 2.3
Number of primaries	12.9 ± 0.8	286.7	12.4 ± 0.2	275.6	4.5 ± 0.8
Number of secondaries	10.0 ± 1.4	303.7	9.9 ± 1.1	300.0	3.3 ± 0.9
Number of pods/plant	23.4 ± 1.5	112.5	21.0 ± 1.5	101.0	20.8 ± 2.1
Number of kernels/plant	37.7 ± 2.1	110.2	34.0 ± 2.3	99.4	34.2 ± 2.5
Pod yield (g)/ plant	26.2 ± 1.7	159.8	21.7 ± 1.6	132.3	16.4 ± 0.9
Kernel yield (g)/plant	19.4 ± 1.3	179.6	15.5 ± 0.8	143.5	10.8 ± 0.6
100 pod weight (g)	114.6 ± 5.0	170.0	103.0 ± 2.0	152.8	67.4 ± 4.6
100 kernel weight (g)	52.4 ± 2.0	185.8	50.3 ± 2.3	178.4	28.2 ± 1.5
Shelling per cent	72.7 ± 4.2	101.3	74.2 ± 2.4	103.3	71.8 ± 2.7

(Control 100.0 per cent)

(mean of 20 plants)

Characters	Mutant-18 (TMV 9, EMS 40 mM)		Mutant-19 (Ah 7911, EMS 60 mM)		Mutant-20 (Ah 7911, EMS 80 mM)		TMV 9 (Control)	Ah 7911 (Control
	Mean±SE	Per cent on control	Mean±SE	Per cent on control	Mean±SE	Per cent on control	Mean±SE	Mean±SE
Height of main stem (cm)	16.4±0.3	80.8	16.2±0.6	76.1	12.2±0.4	57.3	20.3±1.6	21.3±1.5
Length of primary branch (cm)	24.2±0.6	101.3	25.1±0.7	91.3	25.2±0.5	91.6	23.9±2.3	27.5±3.3
Number of primaries	12.8±0.6	284.4	18.1±1.4	369.4	16.9±0.7	344.9	4.5±0.8	4.9±0.9
Number of secondaries	17.3±1.0	524.2	22.8±1.4	876.9	19.2±1.3	738.5	3.3±0.9	2.6±0.7
Number of pods/plant	16.4±1.3	78.9	17.2±1.5	89.6	18.6±1.1	96.9	20.8±2.1	19.2±2.5
Number of kernels/ plant	23.4±1.9	68.4	25.6±2.6	85.6	27.4±2.1	91.6	34.2±2.5	29.9±3.0
Pod yield(g)/plant	13.8±1.1	84.2	14.5±1.3	91.8	14.9±1.0	94.3	16.4±0.9	15.8±1.2
Kernel yield (g)/ plant	8.2±0.6	75.9	8.5±0.9	92.4	8.9±0.6	96.7	10.8±0.6	9.2±0.8
100 pod weight (g)	82.6±2.7	122.6	86.3±2.3	113.7	78.5±2.0	103.4	67.4±4.6	75.9±4.0
100 kernel weight (g)	37.5±1.2	133.0	34.1±1.3	103.3	34.9±1.0	105.8	28.2±1.5	33.0±2.5
Shelling per cent	63.5±1.9	88.4	58.9±1.7	83.8	60.5±1.4	86.1	71.8±2.7	70.3±2.3

(Control 100.0 per cent)

progeny in the M_3 generation showed the true breeding behaviour for the deviant traits (Mutant-18, -21 and -22 respectively). The mutants showing spreading growth habit (Mutant-21 and -22) possessed increased number of primary and secondary branches besides higher yield than the parent variety (Table 18).

d. EMS 60 mM : One plant with semispreading growth habit was observed in the M_2 generation in Ah 7911. Its progeny in the M_3 generation showed the true breeding behaviour for semispreading growth habit (Mutant-19). Increased number of primary and secondary branches were observed in this mutant compared to parent variety (Table 17).

e. EMS 80mM : In the M_2 generation of TMV 9, one plant possessed kernels with white testa. Its progeny in the M_3 generation showed the true breeding behaviour for white testa (Plate II, Mutant-12). One plant with semispreading growth habit was observed in the M_2 generation of Ah 7911. Its progeny in the M_3 generation was breeding true for semispreading growth habit (Mutant-20).

f. Combination treatment: In the M_2 generation of TMV 9, one plant with bunch habit containing bold kernels with purple testa and two plants showing semispreading growth habit with bold kernels were observed. Their progeny in the M_3 generation showed the true breeding

(mean of 20 plants)

Characters	Mutant -21 (TMV 9, EMS 40 mM)		Mutant-22 (TMV 9, EMS 40 mM)		TMV 9 (Control)
	Mean ± SE	Per cent on control	Mean ± SE	Per cent on control	Mean ± SE
Height of main stem (cm)	16.0 ± 2.1	78.8	11.4 ± 0.7	56.2	20.3 ± 1.6
Length of primary branch (cm)	29.2 ± 0.9	122.2	28.2 ± 1.1	118.0	23.9 ± 2.3
Number of primaries	16.5 ± 2.1	366.7	19.9 ± 0.8	442.2	4.5 ± 0.8
Number of secondaries	18.8 ± 4.2	569.7	24.1 ± 1.8	730.3	3.3 ± 0.9
Number of pods/plant	27.1 ± 5.1	130.3	27.2 ± 2.1	130.8	20.8 ± 2.1
Number of kernels/plant	44.7 ± 8.1	130.7	38.4 ± 3.2	112.3	34.2 ± 2.5
Pod yield (g)/plant	26.4 ± 5.0	161.0	23.2 ± 1.7	141.5	16.4 ± 0.9
Kernel yield(g)/plant	17.0 ± 3.4	157.4	14.7 ± 1.1	136.1	10.8 ± 0.6
100 pod weight (g)	91.9 ± 4.6	136.4	87.1 ± 2.7	129.2	67.4 ± 4.6
100 kernel weight (g)	37.6 ± 1.5	133.3	40.0 ± 1.4	141.8	28.2 ± 1.5
Shelling per cent	64.5 ± 1.9	89.8	63.9 ± 0.9	89.0	71.8 ± 2.7

(Control 100.0 per cent)

behaviour for the deviant traits. Mutant-9 possessed bold kernels with purple testa, the 100-kernel weight being 40.0 g compared to 28.2 g in the parent (Table 15). Mutation for two traits, namely semispreading habit and bold kernels was observed in Mutant-16 and -17. These two mutants showed increased yield and shelling per cent, besides higher 100-kernel weight compared with the parent variety (Table 16).

C. Studies on quantitative mutations

1. M_2 generation

Observations recorded on induced variability in eleven quantitative characters studied in M_2 generation are presented below.

a. Height of main stem: In TMV 9, decrease in the mean height of main stem was observed at 30 and 40 krad, 40 and 80 mM and combination treatment (Table 19). In Ah 7911, all treatments have recorded reduction in mean values compared to that of control.

Increase in genotypic variance was observed in the mutagenic treatments. The increase in GV was three-fold at 40 krad, and two-fold at 30 krad, 60 mM and 80 mM treatments in TMV 9 compared to that of control. There was three-fold increase in GV at 20 krad and combination treatment in Ah 7911 compared to that of control. The

TABLE 19: Mean, variance, heritability and genetic advance for height of main stem (cm) in M_2 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	C.V	G.C.V	h^2	G.A
TMV 9	Control	14.91 ± 1.21	100.00	7.74*	3.05	8.14	27.37	8.78
	Gamma 20 krad	15.43 ± 1.30	103.49	8.18	3.78	12.40	43.65	16.87
	30 krad	12.63 ± 1.68	84.71	27.91**	10.65	21.87	76.31	39.36
	40 krad	10.77 ± 1.52	72.23	8.18*	12.86	12.40	43.65	16.87
	EMS 40 mM	12.67 ± 1.31	84.98	12.09**	4.58	16.89	75.81	30.30
	60 mM	14.16 ± 1.82	94.97	24.96**	10.77	23.17	86.32	44.35
	80 mM	11.56 ± 1.41	77.53	24.81**	10.46	27.96	84.09	52.83
	20 krad + 40 mM	11.33 ± 1.65	75.99	16.37**	5.46	20.62	66.69	34.69
Ah 7911	Control	17.08 ± 1.73	100.00	11.99	3.41	14.38	40.24	18.79
	Gamma 20 krad	15.56 ± 1.80	91.10	31.87**	12.71	22.89	79.74	42.12
	30 krad	12.73 ± 1.83	74.53	15.35**	4.33	16.35	56.48	25.32
	40 krad	13.47 ± 1.81	78.86	16.21**	4.82	16.29	59.52	25.89
	EMS 40 mM	12.43 ± 1.63	72.78	18.72**	6.72	20.84	71.75	36.36
	60 mM	10.40 ± 1.74	60.89	20.66**	7.31	24.00	70.77	45.06
	80 mM	11.45 ± 1.74	67.04	15.57**	4.78	19.07	61.32	30.76
	20 krad + 40 mM	10.79 ± 1.89	63.17	44.76**	12.35	25.74	86.47	49.31

*Significant at 5% level

**Significant at 1% level.

Source	S.E	C.D
Variety	0.20	0.55
Treatment	0.40	1.10
Variety x Treatment	0.57	1.56

GCV values ranged from 12.40 at 20 krad to 27.96 at 80 mM treatment in TMV 9 compared to 8.14 in the control. The GCV values in Ah 7911 ranged from 16.29 at 40 krad to 25.74 in the combination treatment against 14.38 in the control.

Heritability estimates in TMV 9 varied from 43.65 at each of 20 krad and 40 krad to 86.32 at 60 mM of EMS compared to 27.37 in the control. In Ah 7911, the h^2 ranged from 56.48 at 30 krad to 86.47 at combination treatment against 40.24 in the control.

Genetic advance in TMV 9 ranged from 16.87 at each of 20 krad and 40 krad to 52.83 at 80 mM treatment against 8.78 in the control. In Ah 7911,the range in genetic advance was from 25.32 at 30 krad to 49.31 in the combination treatment compared to 18.79 in the control.

b. Length of primary branch: In TMV 9, decrease in the mean length was observed in the combination treatment compared to that of control (Table 20). In Ah 7911, mutagenic treatments have recorded decreased mean values compared to that of control.

Increase in genotypic variance was observed in the mutagenic treatments except at 30 krad in Ah 7911 in which there was reduction compared to that of control. In TMV 9, there was three-fold increase in GV at 20 krad and 40 krad

TABLE 20: Mean, variance, heritability and genetic advance for length of primary branch (cm) in M_2 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (Between progenies)	G.V.	G.C.V	h^2	G.A
TMV 9	Control	22.90 ± 2.26	100.00	36.73	4.19	2.03	10.15	6.42
	Gamma 20 krad	23.69 ± 2.75	103.45	47.39**	16.11	16.93	68.00	28.77
	30 krad	22.65 ± 3.81	98.91	33.11	20.00	6.24	12.08	4.47
	40 krad	21.12 ± 3.82	92.23	32.62	16.89	6.15	20.35	10.77
	EMS 40 mM	21.22 ± 3.20	92.66	31.75*	5.62	9.65	35.42	11.83
	60 mM	24.56 ± 4.43	107.25	69.08*	18.85	15.82	42.99	22.73
	80 mM	20.99 ± 3.14	91.66	40.13**	10.15	15.17	50.59	22.23
	20 krad + 40 mM	18.15 ± 3.58	79.26	6.07	22.10	13.57	48.58	15.83
Ah 7911	Control	27.42 ± 3.28	100.00	6.08	6.07	15.84	32.10	13.57
	Gamma 20 krad	24.25 ± 3.52	88.44	43.82	9.52	19.75	43.44	17.27
	30 krad	24.60 ± 4.69	89.72	49.83	2.89	6.91	11.62	4.86
	40 krad	23.68 ± 2.58	86.36	11.57	21.74	23.56	72.13	41.21
	EMS 40 mM	18.76 ± 3.16	68.42	38.87**	9.44	16.37	48.58	23.51
	60 mM	19.33 ± 4.49	70.50	66.58*	13.10	18.72	39.35	24.20
	80 mM	21.33 ± 4.67	77.79	79.19**	17.83	19.80	43.44	17.27
	20 krad + 40 mM	19.76 ± 4.00	72.06	21.48	8.42	17.53	49.32	15.43

* Significant at 5% level

** Significant at 1% level

Source	S.E	C.D
Variety	0.33	0.92
Treatment	0.67	1.84
	0.94	2.61

of gamma irradiation and four-fold increase at 30 krad and combination treatment. In Ah 7911, treatments 40 krad and 80 mM have shown two-fold increase in GV. In TMV 9, the GCV values ranged from 6.15 at 40 krad to 16.93 at 20 krad against 2.03 in the control. In Ah 7911, the GCV values varied from 6.91 at 30 krad to 23.56 at 40 krad compared to 15.84 in the control.

In TMV 9, heritability estimates varied from 12.08 at 30 krad to 68.00 at 20 krad treatment against 10.15 in the control. Heritability estimates in Ah 7911 ranged from 11.62 at 30 krad to 72.13 at 40 krad compared to 32.10 in the control.

In TMV 9, the genetic advance ranged from 4.47 at 30 krad to 28.77 at 20 krad against 6.42 in the control. In Ah 7911, the GA varied from 4.86 in 30 krad to 41.21 at 40 krad against 13.57 in the control.

e. Number of branches: In TMV 9, gamma irradiation treatments have decreased the mean number of branches compared to that of control (Table 21). There was reduction in the mean number of branches at EMS 60 mM, 80 mM and combination treatment. In Ah 7911, mutagenic treatments have resulted in the decreased number of branches compared to that of control. The GV, GCV, h^2 and GA values are nil.

TABLE 21: Effect of mutagenic treatments on number of branches, mature pods and kernels/plant in M_2 generation

Variety	Treatments	Number of branches		Number of mature pods/ plant		Number of Kernels/ plant	
		Mean±S.E	Per cent on control	Mean±S.E	Per cent on control	Mean ±S.E	Per cent on control
TMV 9	Control	7.63±0.55	100.00	20.82±2.10	100.00	34.23±2.46	100.00
	Gamma 20 krad	5.87±0.35	76.93	16.95±2.09	81.41	26.72±3.86	78.06
	30 krad	6.31±1.42	82.70	19.57±2.61	94.00	30.87±2.32	90.18
	40 krad	6.44±0.64	84.40	17.95±2.91	86.22	28.69±3.72	83.82
	EMS 40 mM	6.91±0.71	90.56	15.89±1.26	76.32	24.96±2.32	72.92
	60 mM	6.01±0.87	78.77	18.77±2.33	90.15	30.17±3.12	88.14
	80 mM	5.80±0.39	76.02	16.53±1.75	79.39	26.28±2.47	76.77
	20 krad+40 mM	6.77±0.46	88.73	15.29±2.97	73.44	25.30±3.42	73.91
Ah 7911	Control	10.05±1.27	100.00	19.15±2.50	100.00	29.87±3.02	100.00
	Gamma 20 krad	6.12±0.89	60.90	12.22±1.65	63.81	19.17±3.23	56.00
	30 krad	7.88±0.68	78.91	17.26±3.08	90.13	26.29±3.92	88.01
	40 krad	8.32±1.57	82.79	18.72±2.81	97.75	29.57±2.95	99.00
	EMS 40 mM	7.36±0.40	73.23	13.77±2.26	71.91	21.60±2.72	72.31
	60 mM	6.59±0.83	65.57	13.97±1.74	72.95	21.85±3.09	73.15
	80 mM	6.21±0.60	61.79	12.87±2.65	67.21	20.53±2.26	68.73
	20 krad+40 mM	8.13±1.46	80.90	11.46±1.08	59.84	16.01±2.89	53.60

Source	S.E	C.D	S.E	C.D	S.E	C.D
Variety	0.14	0.38	0.36	1.01	0.62	1.71
Treatment	0.27	0.76	0.73	2.02	1.24	3.43
Variety x Treatment	0.39	1.07	1.03	2.86	1.75	4.85

d. Number of flowers per plant: In TMV 9, there was decrease in the number of flowers at 40 krad, 40, 60 and 80 mM and combination treatment compared to that of control (Table 22). In Ah 7911, 20 krad, 40 mM, 60 mM, 80 mM and combination treatment resulted in decreased number of flowers compared to that of control.

In TMV 9, the genotypic variance increased in all mutagenic treatments except in the combination treatment in the two varieties. The GCV values in TMV 9 ranged from 7.57 at 80 mM to 25.82 at 40 krad treatment against 6.94 in the control. In Ah 7911, the GCV values varied from 17.71 at 40 mM to 27.84 at 20 krad against 11.26 in the control. In TMV 9, heritability estimates ranged from 13.08 at 80 mM to 73.79 at 20 krad compared to 11.95 in the control. In Ah 7911, h^2 values ranged from 25.28 at 40 mM to 77.24 at 20 krad compared to 21.78 in the control.

In TMV 9, genetic advance varied from 5.64 at 80 mM to 42.31 at 20 krad against 4.94 in the control. The GA values in Ah 7911, ranged from 18.35 at 40 mM to 50.41 at 20 krad treatment against 6.70 in the control.

Treatments 20 krad, 40 krad and 60 mM have resulted in high degree of variability, heritability and genetic advance in the two varieties.

TABLE 22: Mean, variance, heritability and genetic advance for number of flowers per plant in M_2 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	66.21±3.52	100.00	221.75	12.76	6.94	11.95	4.94
	Gamma 20 krad	63.00±3.92	95.15	627.38**	231.46	23.91	73.79	42.31
	30 krad	62.93±3.29	95.05	350.90**	94.06	15.40	53.61	23.24
	40 krad	55.47±3.07	83.78	661.85**	205.14	25.82	61.91	41.88
	EMS 40 mM	51.43±2.70	77.68	213.52	64.71	12.49	68.53	38.35
	60 mM	60.00±2.88	90.62	561.23**	203.48	23.77	72.51	41.71
	80 mM	53.00±3.47	80.05	252.64	16.52	7.57	13.08	5.64
	20 krad+ 40 mM	46.22±3.67	69.81	101.64	-	-	-	-
Ah 7911	Control	69.16±2.68	100.00	368.48	29.60	11.26	21.78	6.70
	Gamma 20 krad	50.13±3.91	72.48	810.87**	313.17	27.84	77.24	50.41
	30 krad	63.56±4.76	91.90	565.18**	184.10	18.72	55.28	28.35
	40 krad	63.59±3.08	91.95	714.65**	211.91	22.88	59.30	36.31
	EMS 40 mM	48.32±2.29	69.87	165.52*	84.10	17.71	25.28	18.35
	60 mM	46.98±4.25	67.93	754.32	122.51	23.56	32.48	27.66
	80 mM	57.77±3.21	83.53	345.79**	105.45	20.48	60.79	32.94
	20 krad+ 40 mM	51.89±3.65	75.03	189.34	-	-	-	-

*Significant at 5% level
**Significant at 1% level

Source	S.E	C.D
Variety	1.03	N.S
Treatment	2.06	5.72
Variety x Treatment	2.92	8.08

e. Number of mature pods per plant: Mutagenic treatments decreased the mean number of mature pods except at 30 krad in TMV 9 and at 30 krad and 40 krad in Ah 7911 (Table 21). The GV, GCV, h^2 and GA values are nil. The frequency distribution of this trait in mutagen treated populations was compared with that of control in Fig.3 and 4. In TMV 9, modal value of 15 pods was observed in 40 krad of gamma irradiation 40 mM, 60 mM and 80 mM of EMS and combination treatment compared to 20 pods in the control. There was no alteration in the modal value in 30 krad treatment. The curve was a bimodal one in 20 krad, the first peak at 10 pods and second peak of less frequency at 20 pods. In Ah 7911, a modal value of 15 pods was observed at 30 krad and 40 krad, compared to 20 pods in the control. Gamma irradiation doses in Ah 7911 showed a peak at 10 pods.

f. Number of kernels per plant: In TMV 9, there was decrease in the mean number of kernels in mutagenic treatments except at 30 krad (Table 21). In Ah 7911, mutagenic treatments decreased the mean number of kernels except at 40 krad. The GV, GCV, h^2 and GA values are nil.

g. Pod yield per plant: In TMV 9, decrease in mean pod yield was observed in mutagenic treatments (Table 23). A similar trend of result was observed in Ah 7911 except at 40 krad. The GV, GCV, h^2 and GA values are nil.

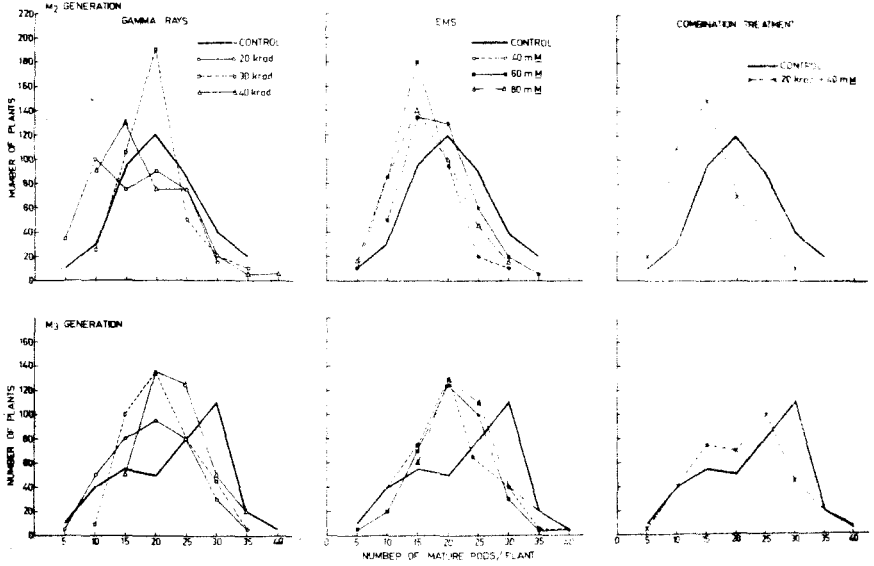


FIG. 3 FREQUENCY DISTRIBUTION OF NUMBER OF MATURE PODS PER PLANT IN M_2 AND M_3 GENERATIONS OF TMV 9

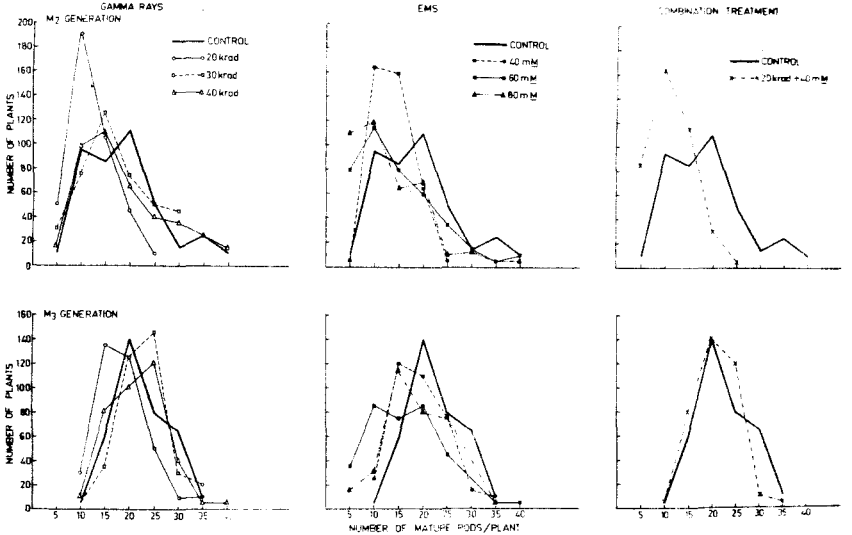


FIG. 4 FREQUENCY DISTRIBUTION OF NUMBER OF MATURE PODS PER PLANT IN M_2 AND M_3 GENERATIONS OF Ah7911

TABLE 23: Effect of mutagenic treatments on pod and kernel yield in M_2 generation

Variety	Treatment	Pod yield (g)/plant		Kernel yield (g)/Plant	
		Mean ± S.E	Per cent on control	Mean ± S.E	Per cent on control
TMV 9	Control	16.36±0.93	100.00	9.82±0.56	100.00
	Gamma 20 krad	12.29±1.32	75.12	7.66±0.72	78.00
	30 krad	14.46±2.53	88.39	8.97±1.63	91.34
	40 krad	13.22±1.81	80.81	8.11±0.93	82.59
	EMS 40 mM	11.64±1.09	71.15	6.86±0.79	69.86
	60 mM	11.49±1.97	70.23	9.08±1.94	92.46
	80 mM	12.33±1.05	75.37	7.70±0.82	78.41
	20 krad+ 40 mM	9.89±0.84	60.45	6.59±0.47	67.11
Ah 7911	Control	15.78±1.15	100.00	9.16±0.82	100.00
	Gamma 20 krad	9.58±1.76	60.71	6.13±1.49	66.92
	30 krad	12.91±1.43	81.81	7.70±0.92	84.06
	40 krad	14.16±2.24	89.73	8.21±1.78	89.63
	EMS 40 mM	8.79±1.05	55.70	5.65±0.43	61.68
	60 mM	10.35±2.93	65.59	6.29±1.72	68.67
	80 mM	10.67±1.29	67.62	6.39±0.94	69.76
	20 krad+ 40 mM	8.24±0.62	52.22	4.66±0.72	50.87

Source	S.E	C.D	S.E	C.D
Variety	0.31	0.85	0.18	0.50
Treatment	0.61	1.70	0.36	1.01
Variety x Treatment	0.87	2.41	0.51	1.42

The frequency distribution is presented in Fig.5 and 6. In TMV 9, the modal value of 13.0 g remained unaltered in three concentrations of EMS and 30 krad as in the control and the mode got shifted to 8.0 g at 20 krad of gamma irradiation and combination treatment. In Ah 7911 gamma irradiation at 30 krad showed a modal value at 13.0 g compared to 18.0 g in the control and got shifted to 8.0 g at 20 and 40 krad, three concentrations of EMS and combination treatment.

h. Kernel yield per plant: There was decrease in the mean kernel yield in the mutagenic treatments except at 30 krad and 60 mM in TMV 9 and except at 40 krad in Ah 7911 (Table 23). The GV, GCV, h^2 and GA values are nil.

i. 100-pod weight: Decrease in the mean 100-pod weight was observed in all treatments except at 80 mM in TMV 9 and except at 20 krad, 30 krad and 80 mM in Ah 7911 (Table 24). The GV, GCV, h^2 and GA values are nil.

j. 100-kernel weight: In TMV 9, there was decrease in the mean 100-kernel weight in the combination treatment compared to that of control (Table 24). In Ah 7911, EMS at 40 mM and combination treatment resulted in decreased mean 100-kernel weight. The mean 100-kernel weight at EMS 80 mM increased to 32.93 g compared to 30.89 g in the control. The GV, GCV, h^2 and GA values are nil.

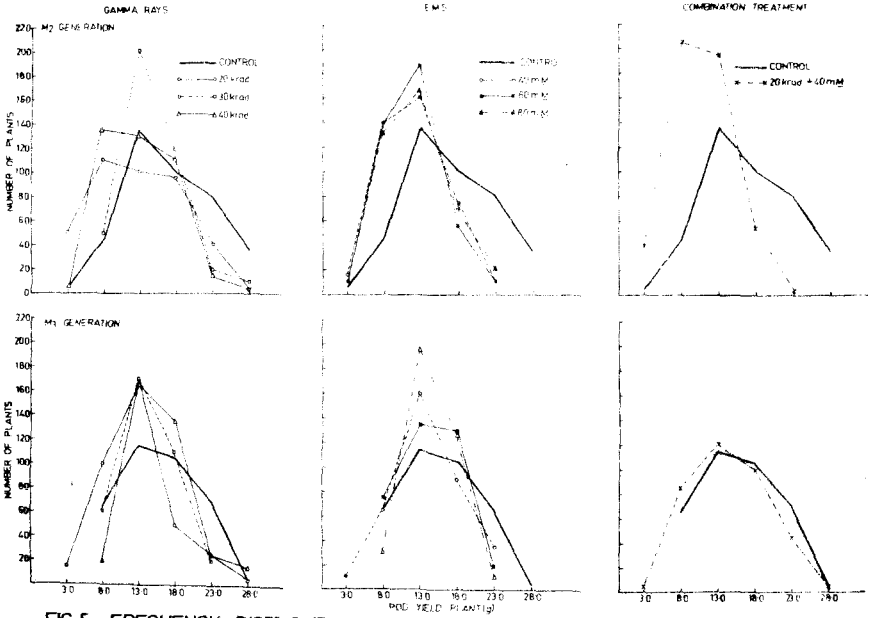


FIG. 5 FREQUENCY DISTRIBUTION OF POD YIELD PER PLANT (g) IN M_2 AND M_3 GENERATIONS OF TMV 9

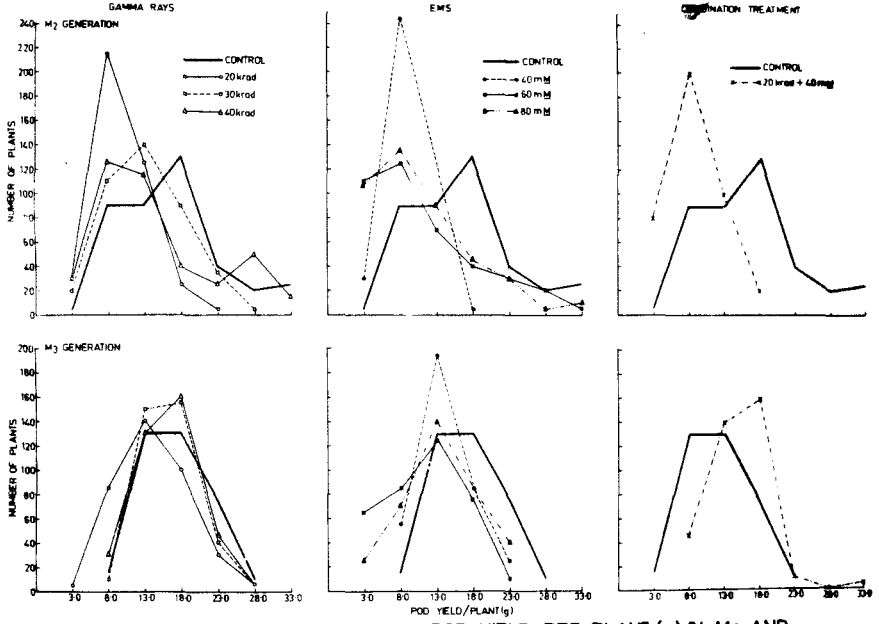


FIG.6 FREQUENCY DISTRIBUTION OF POD YIELD PER PLANT (g) IN M_2 AND M_3 GENERATIONS OF Ah 7911

TABLE 24: Effect of mutagenic treatments on 100-pod weight, 100 kernel weight and shelling per cent in M_2 generation

Variety	Treatment	100 pod weight (g)		100-kernel weight (g)		Shelling per cent (angles)	
		Mean±S.E	Per cent on control	Mean±S.E	Per cent on control	Mean±S.E	Per cent on control
TMV 9	Control	78.18±3.32	100.00	29.04±1.46	100.00	51.71±2.73	100.00
	Gamma 20 krad	71.24±3.79	91.12	29.12±1.73	100.28	53.70±3.43	103.85
	30 krad	73.61±2.97	94.15	29.25±1.21	100.72	51.92±2.26	100.41
	40 krad	73.25±3.49	93.69	28.61±0.72	98.52	52.62±3.36	101.76
	EMS 40 mM	72.46±4.32	92.68	27.26±1.92	93.87	50.53±2.53	97.72
	60 mM	61.48±3.46	78.64	30.22±2.13	104.06	64.10±3.12	123.96
	80 mM	76.34±2.92	97.65	29.58±1.93	101.86	52.42±2.35	101.37
	20 krad + 40 mM	63.13±3.45	80.75	24.89±1.63	85.71	52.96±3.12	102.42
Ah 7911	Control	81.35±4.21	100.00	30.89±1.73	100.00	50.52±2.24	100.00
	Gamma 20 krad	78.80±4.73	96.87	32.52±0.93	105.28	54.14±2.76	107.17
	30 krad	77.11±3.29	94.79	30.62±1.37	99.13	51.26±3.52	101.46
	40 krad	73.01±4.58	89.75	30.42±1.63	98.48	51.00±2.92	100.95
	EMS 40 mM	63.82±3.18	78.45	26.22±1.29	84.88	53.55±2.97	106.00
	60 mM	71.04±3.92	87.33	30.13±1.53	97.54	54.66±2.94	108.19
	80 mM	81.01±4.28	99.58	32.93±0.89	106.60	53.98±3.72	106.85
	20 krad + 40 mM	69.49±2.94	85.42	26.14±1.34	91.10	50.29±1.84	99.54
	Source	S.E	C.D	S.E	C.D	S.E	C.D
	Variety	0.76	2.12	0.31	0.87	0.33	0.90
	Treatment	1.53	4.24	0.63	1.74	0.65	1.81
	Variety x Treatment	2.16	5.99	0.89	N.S	0.92	2.55

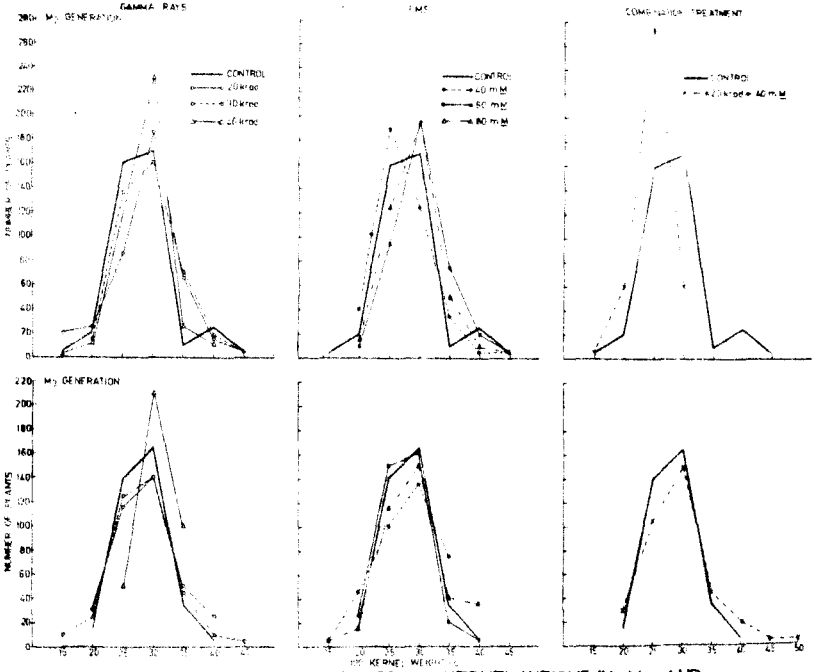


FIG. 7 FREQUENCY DISTRIBUTION OF 100-KERNEL WEIGHT IN M_2 AND M_3 GENERATIONS OF TMV 9

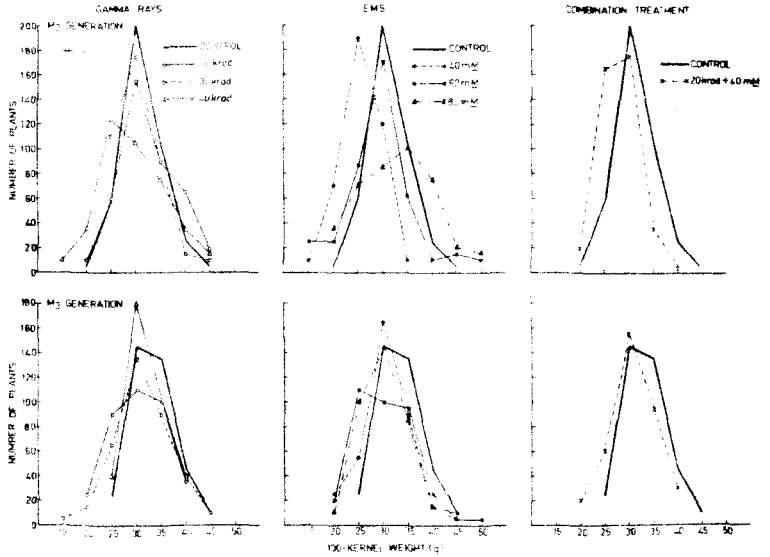


FIG.6 FREQUENCY DISTRIBUTION OF 100-KERNEL WEIGHT IN M_2 AND M_3 GENERATIONS OF Ah 7911

The frequency distribution for this trait is presented in Fig. 7 and 8. In TMV 9, 40 mM concentration of EMS and combination treatment showed modal value of 25.0 g compared to 30.0 g in the control. The distribution was similar to control in other treatments. In Ah 7911, treatments 40 krad of gamma irradiation and 40 mM concentration of EMS showed modal value of 25.0 g compared to 30.0 g in the control. A positive shift of mode to 35.0 g was observed in EMS 80 mM concentration.

k. Shelling per cent: In TMV 9, the mean shelling per cent at 60 mM treatment increased to 64.10 compared to 51.71 in the control (Table 24). In Ah 7911, irradiation at 20 krad and three concentrations of EMS have increased the shelling per cent compared to that of control. The GV, GCV, h^2 and GA values are nil.

The frequency distribution in TMV 9 showed modal value of 60 per cent in 40 krad, and 80 mM treatments against 65 per cent in the control. There was a positive shift in the modal value to 70 per cent in 20 krad. In Ah 7911, there was a decline in the modal value from 65 per cent in the control to 60 per cent in 40 krad and 55 per cent in combination treatment. In Ah 7911, three peaks were observed at EMS 80 mM treatment, the first one of greater frequency at 55 per cent, the second one at 70 per cent and the third at 80 per cent (Fig. 9 and 10).

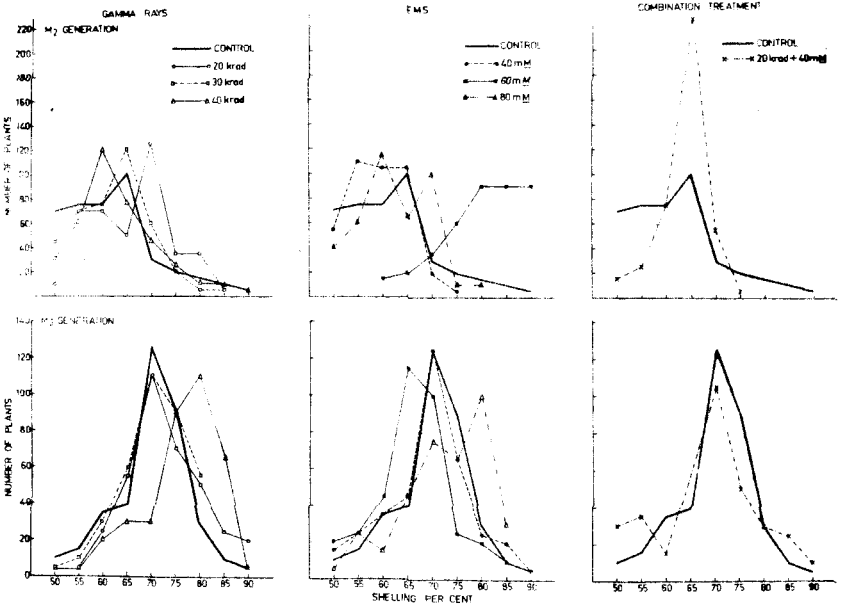


FIG. 9 FREQUENCY DISTRIBUTION OF SHELLING PER CENT IN M_2 AND M_3 GENERATIONS OF TMV 9

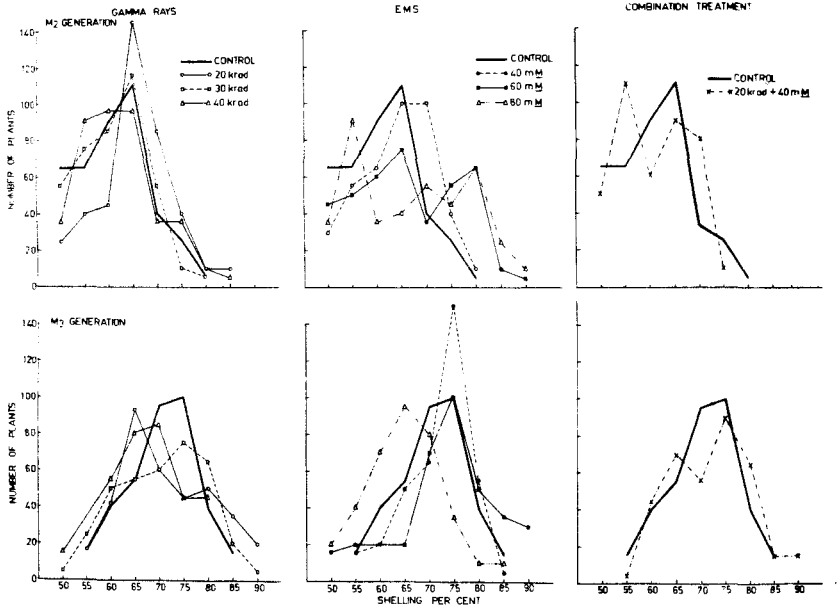


FIG.10 FREQUENCY DISTRIBUTION OF SHELLING PER CENT IN M_2 AND M_3 GENERATIONS OF Ah 7911

2. M_3 Generation

Observations on induced variability in eleven quantitative characters in M_3 generation are presented below:

a. Height of main stem: There was decrease in the mean height of main stem in the mutagenic treatments in TMV 9 (Table 25). In Ah 7911, 30 krad, three concentrations of EMS and combination treatment resulted in decreased mean height compared to that of control.

The genotypic variance was higher than that of control in mutagenic treatments in the two varieties. Increase in GV in TMV 9 was two-fold at 20 krad and 30 krad of gamma irradiation and four-fold at 40 mM and 60 mM of EMS treatments. In TMV 9, the GCV values ranged from 10.30 at 40 krad to 18.40 at 60 mM treatment against the control value of 5.04. The GCV values in Ah 7911 varied from 6.91 at 20 krad to 16.89 at 60 mM treatment against 3.19 in the control.

In TMV 9, heritability estimates varied from 68.94 in the combination treatment to 92.91 at 60 mM treatment against 30.64 in the control. In Ah 7911, h^2 ranged from 58.71 at 20 krad to 90.17 at 60 mM treatment against 31.15 in the control. In TMV 9, GA ranged from 18.58 at 40 krad to 36.55 at 60 mM compared to 8.73 in the control and in Ah 7911, it ranged from 10.93 at 20 krad to 33.02 at 60 mM against 2.18 in the control.

TABLE 25: Mean, variance, heritability and genetic advance for height of main stem in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (Between progenies)	GV	GCV	h^2	GA
TMV 9	Control	21.28±1.61	100.00	11.28	2.15	5.04	30.64	8.75
	Gamma 20krad	18.87±1.31	88.67	23.67**	6.17	13.17	78.26	24.01
	30krad	17.07±1.38	80.22	26.62**	6.95	15.44	78.28	28.12
	40krad	19.81±1.13	93.09	16.30	4.16	10.30	76.62	18.58
	EMS 40 mM	19.16±2.02	90.04	44.37**	10.67	17.05	72.14	29.85
	60 mM	17.70±0.90	83.18	34.23**	10.60	18.40	92.91	36.55
	80 mM	16.22±1.48	76.22	20.39**	4.61	13.24	67.85	22.14
	20 krad+40 mM	18.55±1.56	87.17	23.49**	5.40	12.33	68.94	21.40
Ah 7911	Control	21.39±1.47	100.00	11.18	1.42	3.19	31.15	2.18
	Gamma 20krad	22.14±1.28	103.51	11.97**	3.34	6.91	58.71	10.93
	30krad	19.50±1.13	91.16	10.41**	3.20	7.60	63.27	12.46
	40krad	20.20±1.82	94.44	18.47**	2.98	9.33	64.72	15.47
	EMS 40 mM	17.23±1.41	80.55	15.30**	3.10	10.22	60.77	16.42
	60 mM	17.20±0.96	80.41	28.08**	8.43	16.89	90.17	33.02
	80 mM	16.44±1.60	76.86	28.95**	7.10	16.21	73.58	28.65
	20 krad+40 mM	16.82±1.47	78.63	22.41**	5.32	13.71	71.20	23.84

** Significant at 1% level

Source	S.E	C.D
Variety	0.26	N.S
Treatment	0.42	1.02
Variety x Treatment	0.62	1.54

b. Length of primary branch: In TMV 9, decrease in the mean length of primary branch was observed at 30 krad and three concentrations of EMS compared to that of control (Table 26). A similar trend of result was observed in Ah 7911. Combination treatment resulted in decreased mean length of primary branch in Ah 7911.

Increase in genotypic variance was observed at all treatments in TMV 9 and at 80 mM and combination treatment in Ah 7911. High degree of variability was observed at 40 krad and combination treatments in TMV 9. The GCV values in TMV 9 at 60 mM and combination treatment were 10.58 and 11.64 respectively compared to 3.55 in the control. In Ah 7911, maximum coefficient of variability was observed at 80 mM treatment in Ah 7911.

Heritability estimates in TMV 9 ranged from 12.01 at 30 krad to 49.23 in the combination treatment. In Ah 7911, h^2 values ranged from 22.83 at 20 krad treatment to 42.27 at 80 mM treatment compared to 18.02 in the control. The genetic advance was maximum in the combination treatment in TMV 9.

c. Number of branches: In TMV 9, there was reduction in the mean number of branches at 30 krad and three concentrations of EMS compared to that of control (Table 27). In Ah 7911, the mean number of branches in mutagenic treatments

TABLE 26: Mean, variance, heritability and genetic advance for length of primary branch in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	23.82±3.36	100.00	31.54	0.91	3.55	10.16	2.33
	Gamma 20 krad	24.50±2.58	102.85	22.30	7.56	4.26	15.26	2.89
	30 krad	22.00±2.59	92.36	22.79	2.52	4.34	12.01	3.10
	40 krad	24.37±2.36	102.31	21.38	8.56	5.13	21.90	4.94
	EMS 40 mM	22.63±3.69	95.00	45.62	7.58	5.56	20.42	3.70
	60 mM	21.56±2.28	90.51	31.26*	5.21	10.58	49.00	5.42
	80 mM	21.64±2.26	90.85	26.65	3.74	8.97	42.47	2.05
	20krad + 40mM	23.82±2.81	100.00	46.93*	7.77	11.64	49.23	16.83
Ah 7911	Control	27.53±2.43	100.00	28.89	3.01	3.79	18.02	2.21
	Gamma 20 krad	27.13±2.51	98.55	24.59	1.87	5.93	22.83	5.83
	30 krad	25.23±2.50	91.65	23.34	1.52	5.73	19.59	5.23
	40 krad	26.31±2.41	95.57	16.09	-	-	-	-
	EMS 40 mM	23.05±2.62	83.73	17.09	-	-	-	-
	60 mM	21.51±2.69	78.13	22.36	1.76	5.67	23.59	4.84
	80 mM	21.42±3.13	77.81	51.12	7.20	12.52	42.27	6.77
	20krad + 40mM	22.06±2.83	80.13	26.23	8.73	7.02	38.79	9.00

* Significant at 5% level

Source	S.E	C.D
Variety	0.21	0.58
Treatment	0.42	1.16
Variety x Treatment	0.60	N.S

TABLE 27: Mean, variance, heritability and genetic advance for number of branches in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	8.0 ± 1.1	100.00	3.61	0.06	7.72	21.79	2.62
	Gamma 20 krad	7.3 ± 1.1	91.25	12.49**	2.87	23.10	68.83	39.47
	30 krad	6.8 ± 1.0	85.00	5.44	0.74	12.66	40.73	16.65
	40 krad	7.9 ± 1.2	98.75	6.91	0.82	11.48	35.88	14.16
	EMS 40 mM	6.8 ± 0.9	85.00	8.93**	2.22	21.90	74.78	39.02
	60 mM	6.6 ± 0.7	82.50	12.84**	3.83	29.47	89.43	57.40
	80 mM	6.8 ± 0.9	85.00	9.70**	2.36	26.59	72.97	39.97
	20 krad + 40 mM	7.6 ± 1.9	95.00	10.70	2.16	18.18	67.53	30.77
Ah 7911	Control	7.3 ± 1.1	100.00	3.91	0.15	5.72	18.81	4.05
	Gamma 20 krad	7.7 ± 1.4	105.48	10.07*	1.55	16.25	46.05	22.72
	30 krad	7.3 ± 1.0	100.00	4.43	0.58	10.45	39.53	13.54
	40 krad	7.4 ± 1.1	101.37	6.39	0.93	13.10	43.43	17.77
	EMS 40 mM	7.2 ± 1.0	98.63	8.23**	1.84	18.93	67.14	32.00
	60 mM	6.7 ± 0.9	91.78	6.29**	1.34	17.36	63.97	38.37
	80 mM	6.5 ± 1.2	89.04	4.59	0.29	6.74	22.55	4.92
	20 krad + 40 mM	6.9 ± 1.1	94.52	6.29	0.97	13.48	46.36	18.91

* Significant at 5% level

** Significant at 1% level

Source	S.E	C.D
Variety	0.20	0.56
Treatment	0.36	0.98
Variety x Treatment	0.54	1.42

were not significantly different from that of control. Increase in GV was observed at all treatments in two varieties. The variability was highest at 60 mM treatment in TMV 9 and 40 mM treatment in Ah 7911. The GCV values in TMV 9 ranged from 12.66 at 30 krad to 29.47 at 60 mM compared to 7.72 in the control.

In Ah 7911, GCV values varied from 6.74 at 80 mM treatment to 18.93 at 40 mM compared to 5.72 in the control.

Heritability estimates in TMV 9 varied from 35.88 at 40 krad treatment to 89.43 at 60 mM compared to 21.79 in the control. In Ah 7911, h^2 values varied from 22.55 at 80 mM treatment to 67.14 at 40 mM against 18.81 in the control.

Genetic advance in TMV 9, ranged from 14.16 at 40 krad treatment to 57.40 at 60 mM treatment against 2.62 in the control. In Ah 7911, GA ranged from 4.92 at 80 mM treatment to 38.37 at 60 mM compared to 4.05 in the control.

d. Number of flowers per plant: In TMV 9, there was decrease in the mean number of flowers due to mutagenic treatments except at 20 krad compared to that of control (Table 28). In Ah 7911, at 30 krad treatment, the mean number of flowers increased to 77.31 compared to 69.06 in

TABLE 28: Effect of mutagenic treatments on number of flowers and shelling per cent in M_3 generation

Variety	Treatment	Number of flowers/plant		Shelling per cent (angles)	
		Mean ± S.E	Per cent on control	Mean ± S.E	Per cent on control
TMV 9	Control	61.93 ± 3.71	100.00	57.23 ± 2.29	100.00
	Gamma 20 krad	62.93 ± 4.13	101.61	58.73 ± 2.53	102.62
	30 krad	53.75 ± 2.65	86.79	57.19 ± 2.16	99.93
	40 krad	54.81 ± 3.16	88.50	60.77 ± 3.12	106.19
	EMS 40 mM	56.02 ± 2.92	90.46	56.75 ± 2.69	99.16
	60 mM	55.26 ± 2.25	89.23	54.70 ± 2.32	95.58
	80 mM	57.09 ± 3.02	92.18	58.76 ± 2.65	102.67
	20 krad+ 40 mM	53.87 ± 2.93	86.99	56.11 ± 1.93	98.04
Ah 7911	Control	69.06 ± 3.06	100.00	58.94 ± 1.89	100.00
	Gamma 20 krad	65.72 ± 2.89	95.16	58.22 ± 2.12	102.25
	30 krad	77.34 ± 3.52	111.99	55.54 ± 2.09	97.54
	40 krad	66.63 ± 2.45	96.48	55.24 ± 1.96	97.01
	EMS 40 mM	57.18 ± 2.78	82.80	58.33 ± 2.32	102.44
	60 mM	56.84 ± 3.21	82.30	59.19 ± 2.65	103.95
	80 mM	73.27 ± 3.56	106.10	56.68 ± 2.57	99.54
	20 krad+ 40 mM	60.84 ± 2.97	88.10	58.49 ± 1.87	102.72

Source	S.E	C.D	S.E	C.D
Variety	0.96	2.38	0.32	0.88
Treatment	1.71	4.75	1.03	2.92
Variety x Treatment	2.43	6.72	0.90	2.48

the control. The mean number of flowers at 40 mM, 60 mM and combination treatment have decreased to 57.18, 56.84 and 60.84 against 69.06 in the control. The GV, GCV, h^2 and GA values are nil.

e. Number of mature pods per plant: In TMV 9, except at 20 krad, the mean number of mature pods in the treated populations were not significantly different from that of control (Table 29).

In Ah 7911, there was reduction in the mean number of mature pods at 20 krad, 60 and 80 mM of EMS treatments compared to that of control.

The genotypic variance had increased in the mutagenic treatments in the varieties except at 40 krad and combination treatment in Ah 7911. There was two-fold increase in GV at 60 mM and 80 mM of EMS and four-fold increase in GV at 40 krad treatment in TMV 9, at 40 mM of EMS treatment in Ah 7911.

The GCV values in TMV 9 ranged from 7.54 in the combination treatment to 13.24 at 40 krad against 1.82 in the control. In Ah 7911, the GCV ranged from 3.86 at 40 krad to 12.85 at 40 mM of EMS compared to 2.70 in the control.

TABLE 29: Mean, variance, heritability and genetic advance for number of mature pods per plant in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	22.6 ± 2.42	100.00	13.26	1.70	1.82	22.19	4.56
	Gamma 20 krad	19.8 ± 2.12	87.61	29.68*	3.87	9.94	39.19	12.81
	30 krad	20.3 ± 2.00	89.82	23.93*	2.63	7.98	32.91	9.43
	40 krad	23.3 ± 2.04	103.10	45.19**	9.51	13.24	63.27	21.69
	EMS 40 mM	20.4 ± 2.75	90.27	18.38	2.95	8.42	48.19	12.04
	60 mM	21.2 ± 1.96	93.81	35.51**	6.69	12.20	56.56	18.91
	80 mM	22.7 ± 2.09	100.44	47.90**	6.69	11.40	41.92	15.30
	20 krad + 40 mM	21.1 ± 2.73	93.36	22.19	2.53	7.54	34.25	9.09
Ah 7911	Control	22.2 ± 1.81	100.00	14.17	1.36	2.70	14.41	3.81
	Gamma 20 krad	18.9 ± 2.05	85.14	23.00*	2.06	7.60	26.89	8.12
	30 krad	23.1 ± 2.39	104.05	20.72	2.11	6.29	30.60	7.17
	40 krad	21.9 ± 2.25	98.65	23.73	1.14	3.86	17.62	11.54
	EMS 40 mM	19.8 ± 2.27	89.19	39.99*	6.47	12.85	48.54	18.44
	60 mM	17.3 ± 2.01	77.93	20.78*	1.55	7.20	22.38	7.01
	80 mM	18.9 ± 2.55	85.14	20.40	1.86	7.22	27.40	7.79
	20 krad + 40 mM	21.2 ± 2.47	95.50	20.69	1.26	5.29	18.25	6.66

*Significant at 5% level

**Significant at 1% level

Source	$S_{\bar{x}}E$	C.D
Variety	1.08	N.S
Treatment	1.04	2.76
Variety x Treatment	1.24	3.41

In TMV 9, heritability estimates varied from 32.91 at 30 krad to 63.27 at 40 krad compared to 22.19 in the control. In Ah 7911, h^2 values ranged from 17.62 at 40 krad to 48.54 at 40 mM against 14.41 in the control.

Genetic advance in TMV 9 ranged from 9.09 in the combination treatment to 21.69 at 40 krad treatment compared to 4.56 in the control. In Ah 7911, GA ranged from 6.66 in the combination treatment to 18.44 at 40 mM of EMS treatment against 3.81 in the control.

Frequency distribution in TMV 9 showed modal value of 20 pods in gamma irradiation and EMS treatments and 25 pods in the combination treatment (Fig.3). In Ah 7911, 60 mM of EMS treatment showed a bimodal curve, the first peak at 10 pods and the second at 20 pods with similar frequency (Fig.4). The treatments 30 krad and 40 krad recorded modal value of 25 pods each.

f. Number of kernels per plant: The mean number of kernels were less than that of control at 20 and 30 krad, 40 mM, 60 mM and combination treatment in TMV 9 and at 20 krad and three concentrations of EMS in Ah 7911 (Table 30).

There was increase in GY due to mutagenic treatments except at 60 mM treatment in TMV 9. The increase in GY in TMV 9 was four-fold at 40 krad and five-fold at 80 mM of

TABLE 30: Mean, variance, heritability and genetic advance for number of kernels per plant in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	37.87 ± 4.61	100.00	46.20	4.59	5.66	17.76	2.19
	Gamma 20 krad	31.31 ± 4.63	82.68	69.20	6.59	4.04	16.92	4.91
	30 krad	33.69 ± 4.62	88.96	77.50	5.91	7.22	38.37	9.21
	40 krad	37.47 ± 4.63	98.94	141.10**	25.60	13.50	54.43	20.52
	EMS 40 mM	33.38 ± 5.39	88.14	62.57	8.19	8.58	39.29	11.07
	60 mM	33.84 ± 4.24	89.36	65.80	3.92	5.85	17.89	5.10
	80 mM	35.40 ± 4.52	93.48	153.10**	30.61	15.63	59.88	17.30
	20 krad+ 40 mM	33.08 ± 5.72	87.35	71.08	9.01	9.07	38.01	11.52
Ah 7911	Control	36.46 ± 3.76	100.00	37.62	3.62	3.49	12.95	2.59
	Gamma 20 krad	30.87 ± 4.46	84.67	42.66	6.63	8.34	46.63	11.75
	30 krad	35.85 ± 4.18	98.33	122.26**	23.22	13.44	56.97	20.90
	40 krad	34.17 ± 4.11	93.72	74.52*	7.91	8.23	31.86	9.57
	EMS 40 mM	32.27 ± 4.13	88.51	126.54**	25.16	15.54	59.64	24.75
	60 mM	27.15 ± 3.85	74.47	64.12	6.56	9.43	30.69	10.76
	80 mM	29.38 ± 4.70	80.58	64.63	4.59	4.63	18.76	4.89
	20 krad+ 40 mM	34.06 ± 5.05	93.42	44.43	4.62	3.74	10.96	2.55

* Significant at 5% level

** Significant at 1% level

Source	S.E	C.D
Variety	1.27	N.S
Treatment	1.42	3.86
Variety x Treatment	2.06	N.S

EMS treatment. In Ah 7911, the increase in GV was five-fold at 30 krad and six-fold at 40 mM of EMS treatment compared to that of control.

The GCV in TMV 9 ranged from 4.04 at 20 krad to 15.63 at 80 mM treatment against 5.66 in the control. In Ah 7911, the GCV was maximum at 40 mM followed by 30 krad treatment.

Heritability estimates in TMV 9 varied from 16.92 at 20 krad to 59.88 at 80 mM of EMS treatment against 17.76 in the control. In Ah 7911, h^2 was maximum of 59.64 at 80 mM treatment followed by 56.97 at 30 krad.

Genetic advance was maximum of 20.52 at 40 krad treatment in TMV 9. In Ah 7911, 40 mM of EMS treatment had resulted in highest genetic advance of 24.73.

g. Pod yield per plant: In TMV 9, the mean pod yield had decreased at 20 krad and EMS 40 mM treatments compared to that of control (Table 31). In Ah 7911, there was reduction in the mean pod yield at 20 krad, three concentrations of EMS and combination treatment.

Genotypic variance had increased in the mutagenic treatments except at 60 mM of EMS treatment in Ah 7911. The increase in GV was two-fold at 80 mM and three-fold at 40 krad treatment in TMV 9. In Ah 7911, there was two-fold

TABLE 31: Mean, variance, heritability and genetic advance for pod yield per plant in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	14.99 ± 1.74	100.00	4.93	1.06	6.88	18.72	5.87
	Gamma 20 krad	12.21 ± 1.75	81.45	8.49	2.23	9.09	43.52	12.35
	30 krad	13.75 ± 1.76	91.73	13.17**	1.82	6.59	35.80	8.48
	40 krad	15.39 ± 1.78	102.67	25.97*	4.43	13.68	51.17	20.15
	EMS 40 mM	13.62 ± 1.92	90.86	8.36	2.11	15.49	25.24	11.04
	60 mM	13.94 ± 1.57	93.00	15.07*	1.73	9.44	34.50	11.42
	80 mM	14.12 ± 1.41	94.20	17.87*	3.31	23.47	55.59	19.80
	20 krad+40 mM	14.08 ± 1.87	93.93	20.88*	2.31	10.80	33.21	12.82
Ah 7911	Control	16.84 ± 1.69	100.00	5.92	0.52	4.28	11.74	3.46
	Gamma 20 krad	13.34 ± 1.71	79.22	16.82*	1.70	9.78	30.34	11.09
	30 krad	15.92 ± 1.85	94.54	15.52*	0.61	4.90	26.31	7.83
	40 krad	16.27 ± 1.71	96.62	17.21*	1.86	8.38	32.41	9.83
	EMS 40 mM	13.60 ± 1.60	80.76	19.59*	3.12	12.98	47.75	18.48
	60 mM	11.07 ± 1.69	65.74	10.93	0.51	6.45	14.01	4.97
	80 mM	13.23 ± 1.85	78.56	11.11	0.85	6.95	22.83	6.84
	20 krad+40 mM	14.70 ± 2.06	87.29	13.59	1.11	7.18	24.60	7.34

* Significant at 5% level

** Significant at 1% level

Source	S.E.	C.D
Variety	0.21	0.58
Treatment	0.42	1.16
Variety x Treatment	0.59	1.63

increase in GV at 20 krad and 40 krad and five-fold increase in GV at 40 mM of EMS treatment. In TMV 9, the GCV was maximum of 23.47 at 80 mM. In Ah 7911, highest coefficient of variability of 12.98 was observed at 40 mM of EMS treatment.

Heritability estimates in TMV 9 was maximum of 55.59 at 80 mM of EMS treatment. In Ah 7911, heritability was highest at 40 mM treatment.

Maximum genetic advance of 20.15 at 40 krad treatment in TMV 9 and 18.48 at 40 mM of EMS treatment in Ah 7911 was observed.

Frequency distribution at 20 krad and 40 krad treatments in TMV 9 showed skewness towards positive direction in M_3 compared to that of M_2. In Ah 7911, the modal value of 18.0 g at 30 krad, 40 krad and combination treatment showed a positive shift in M_3 compared to that of M_2 (Fig. 5 and 6).

h. Kernel yield per plant: In TMV 9, the mean kernel yield at 40 krad and 80 mM treatments were equal to that of control (Table 32). The mean kernel yield at 30 krad, 40 krad and combination treatment in Ah 7911 were not significantly different from that of control.

Increase in genotypic variance was observed in the mutagenic treatments except at 20 krad and 30 krad in

TABLE 32: Mean, variance, heritability and genetic advance for kernel yield per plant in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	10.45 ± 1.40	100.00	6.18	0.19	2.90	4.43	1.25
	Gamma 20 krad	8.82 ± 1.43	84.40	6.68	0.17	4.66	7.57	2.64
	30 krad	9.65 ± 1.42	92.34	5.75	0.10	3.46	5.25	1.55
	40 krad	11.56 ± 1.64	110.62	10.83	0.90	8.25	25.17	8.52
	EMS 40 mM	9.48 ± 1.57	90.72	4.76	0.87	9.83	54.67	14.96
	60 mM	9.11 ± 1.20	87.18	5.07*	0.25	5.51	14.88	4.38
	80 mM	10.24 ± 1.40	97.99	7.97	0.70	8.17	26.32	8.63
	20 krad+40 mM	9.36 ± 1.67	89.57	6.26	0.71	9.03	34.21	10.87
Ah 7911	Control	11.94 ± 1.34	100.00	6.40	0.34	4.88	4.63	1.48
	Gamma 20 krad	9.46 ± 1.51	79.23	7.37	1.18	4.51	7.41	2.53
	30 krad	11.08 ± 1.58	92.80	11.28*	1.27	10.15	33.63	12.13
	40 krad	10.94 ± 1.48	91.62	10.67*	1.38	10.72	38.67	13.73
	EMS 40 mM	9.75 ± 1.34	81.66	12.51**	2.38	15.81	51.46	23.36
	60 mM	8.17 ± 1.51	68.43	8.35	0.52	8.80	18.58	7.72
	80 mM	9.18 ± 1.60	76.88	11.52	1.27	12.28	33.09	14.55
	20 krad+40 mM	10.74 ± 1.70	89.95	8.32	1.13	8.34	15.88	4.00

* Significant at 5% level

** Significant at 1% level

Source	S.E	C.D
Variety	0.54	N.S
Treatment	0.92	2.47
Variety x Treatment	1.24	3.47

TMV 9. In TMV 9, the increase in GV was two-fold at 80 mM and combination treatment and three-fold at 40 krad and 40 mM treatments. In Ah 7911, there was three-fold increase in GV at 30 and 40 krad and 80 mM treatments and six-fold increase at 40 mM compared to that of control. The GCV in TMV 9 ranged from 3.46 at 30 krad to 9.85 at 40 mM compared to 2.90 in the control. In Ah 7911, GCV was maximum of 15.81 at 40 mM treatment.

Heritability estimates were the highest at 40 mM of EMS treatment in the two varieties. Treatment of EMS at 40 mM had resulted in highest genetic advance of 23.36 in Ah 7911 and 14.96 in TMV 9.

i. 100-pod weight: In TMV 9, irradiation at 20 krad and EMS 80 mM treatments resulted in decreased 100-pod weight compared to that of control (Table 33). In Ah 7911, there was reduction in 100-pod weight at all treatments except 40 krad.

Increase in genotypic variance was observed in all treatments in the two varieties. In TMV 9, increase in GV was five-fold at 80 mM and two-fold in the combination treatment. In Ah 7911, there was three-fold increase in GV at 40 krad and four fold increase at 60 mM treatment. In TMV 9, the GCV value was maximum of 10.50 at 80 mM treatment. In Ah 7911, GCV was maximum of 8.62 at 60 mM treatment.

TABLE 33: Mean, variance, heritability and genetic advance for 100-pod weight in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	67.36 ± 4.60	100.00	52.72	3.55	2.80	4.75	1.25
	Gamma 20 krad	62.55 ± 4.11	92.86	68.78	6.06	3.93	26.42	4.17
	30 krad	67.79 ± 4.75	100.64	67.27	4.39	3.92	20.19	2.58
	40 krad	65.93 ± 3.66	97.88	68.86*	9.54	4.69	41.57	6.22
	EMS 40 mM	66.58 ± 4.66	98.84	70.31	3.75	4.99	7.46	1.12
	60 mM	66.35 ± 4.44	98.50	76.43	5.80	3.63	22.78	5.57
	80 mM	62.57 ± 3.12	92.89	158.79**	23.20	10.50	81.62	19.55
	20 krad+40 mM	67.25 ± 5.49	99.84	123.60*	11.07	4.95	26.87	5.28
Ah 7911	Control	75.92 ± 3.99	100.00	74.87	5.99	3.95	3.96	1.61
	Gamma 20 krad	70.11 ± 5.71	92.30	136.23*	12.83	5.11	28.26	5.60
	30 krad	68.89 ± 6.57	90.74	150.39*	6.98	3.84	13.93	2.95
	40 krad	74.50 ± 3.77	98.13	125.36**	27.58	7.05	66.00	11.80
	EMS 40 mM	69.75 ± 4.99	91.87	75.56	9.00	6.48	36.01	4.88
	60 mM	64.00 ± 4.85	84.30	162.91**	30.41	8.62	46.35	13.32
	80 mM	68.01 ± 4.76	89.58	92.71*	8.28	4.23	26.80	4.51
	20 krad+40 mM	68.86 ± 4.28	90.70	95.34*	13.47	5.33	42.38	7.15

* Significant at 5% level

** Significant at 1% level

Source	S.E	C.D
Variety	0.63	1.76
Treatment	1.24	3.47
Variety x Treatment	1.59	4.45

In TMV 9, highest heritability estimate of 81.62 was obtained at 80 mM treatment. In Ah 7911, 40 krad treatment recorded highest h^2 value of 66.00.

At EMS 80 mM treatment in TMV 9 and 60 mM treatment in Ah 7911, high genetic advance of 19.55 and 13.32 respectively was recorded.

j. 100-kernel weight: In TMV 9, irradiation at 40 krad resulted in increased 100-kernel weight compared to that of control (Table 34). In Ah 7911, there was reduction in 100 kernel weight at 20 krad, 60 mM and 80 mM treatments.

There was increase in genotypic variance in the mutagenic treatments except at 30 krad in TMV 9 and 20 krad treatment in Ah 7911. In TMV 9, five-fold increase in GV was observed at EMS 80 mM treatment. In TMV 9, there was considerable increase in GCV at 80 mM, the value being 11.0 compared to 4.13 in the control. In Ah 7911, GCV was high at 40 mM and 30 krad treatments.

In TMV 9, heritability estimates ranged from 14.08 at 30 krad to 75.59 at 80 mM treatment, compared to 9.28 in the control. In Ah 7911, h^2 values varied from 21.03 at 20 krad to 73.99 at 80 mM treatment compared to 16.06 in the control.

In TMV 9, genetic advance varied from 3.21 at 30 krad to 19.70 at 80 mM of EMS treatment compared to 1.48 in the

TABLE 34: Mean, variance, heritability and genetic advance for 100-kernel weight in M_3 generation

Variety	Treatment	Mean ± S.E	Per cent on control	Mean square (between progenies)	GV	GCV	h^2	GA
TMV 9	Control	28.21 ± 1.51	100.00	10.95	1.36	4.13	9.28	1.48
	Gamma 20 krad	28.95 ± 1.75	102.62	14.91	1.92	4.78	38.58	6.12
	30 krad	28.28 ± 2.90	100.25	28.44	1.38	4.16	14.08	3.21
	40 krad	30.63 ± 1.12	108.58	12.65**	2.96	5.62	70.21	9.71
	EMS 40 mM	28.30 ± 2.09	100.32	14.39	2.45	3.36	37.26	5.20
	60 mM	27.30 ± 1.74	96.77	14.53	1.80	4.92	37.17	6.17
	80 mM	29.44 ± 1.84	104.36	41.62**	8.49	11.00	75.59	19.70
	20 krad+40 mM	29.22 ± 2.93	103.58	19.83	1.96	4.80	29.78	5.40
Ah 7911	Control	33.00 ± 2.47	100.00	12.67	1.90	4.17	16.06	2.58
	Gamma 20 krad	30.41 ± 2.02	92.15	15.59	1.11	3.46	21.33	3.29
	30 krad	31.27 ± 2.67	94.76	34.72	4.42	6.73	38.24	8.57
	40 krad	31.65 ± 2.27	95.91	18.36	2.98	4.13	44.90	5.77
	EMS 40 mM	30.69 ± 2.54	93.00	34.60*	5.06	7.33	43.90	10.01
	60 mM	30.57 ± 3.19	92.64	40.32	3.25	5.89	24.16	5.97
	80 mM	30.30 ± 3.02	91.82	13.99	3.45	6.13	73.99	10.86
	20 krad+40 mM	31.04 ± 2.15	94.06	22.09	2.72	5.32	44.56	7.32

* Significant at 5% level

** Significant at 1% level

Source	S.E	C.D
Variety	0.52	1.46
Treatment	0.84	2.35
Variety x Treatment	1.42	3.97

control. In Ah 7911, GA ranged from 3.29 at 20 krad to 10.86 at 80 mM of EMS against 2.58 in the control.

Frequency distributions of 100-kernel weight are shown in Fig. 7 and 8. Unimodal curves with modal value of 30 g were observed in the mutagenic treatments. The curves in M_3 showed a positive shift in the modal value compared to that of M_2 at 40 mM of EMS and combination treatment in TNV 9 and 40 krad of gamma irradiation in Ah 7911. A shift in the negative direction was observed at 80 mM of EMS treatment in Ah 7911.

k. Shelling per cent: The mean shelling per cent in TNV 9 ranged from 54.70 at 60 mM to 60.77 at 40 krad compared to 57.23 in the control (Table 28). Significant increase in shelling per cent was observed at 40 krad treatment in TNV 9. In Ah 7911, mean shelling per cent ranged from 55.24 at 40 krad to 59.19 at 60 mM against 56.94 in the control. The GV, GCV, h^2 and GA values are nil.

Frequency distributions are presented in Fig.9 and 10. Comparison between the curves in M_2 and M_3 revealed a positive shift in the modal value in M_3 generation at 30 krad and 40 krad, 40 mM of EMS and combination treatment in the varieties. Treatments 80 mM in TNV 9 and 60 mM in Ah 7911 also showed positive shift in the modal value in M_3 generation.

TABLE 35: Total correlation coefficients between pod yield and its components in M_3 generation of TMV 9+

Trait	Treatment	Length of primary branch	Number of branches	Number of flowers	Number of pods	Pod yield
Height of main stem	Control	0.148	0.407**	0.285*	0.246*	0.277*
	20 krad	0.622**	0.574**	0.371**	0.208	0.688**
	30 krad	0.813**	0.418**	0.303**	0.304**	0.288*
	40 krad	0.808**	0.469**	0.258*	0.157	0.281*
	40 mM	0.887**	0.673**	0.282*	0.371**	0.361**
	60 mM	0.757**	0.496**	0.111	0.271*	0.174
	80 mM	0.764**	0.406**	-0.701**	0.137	0.197
	20 krad+40 mM	0.808**	0.526**	0.712**	-0.357**	-0.328**
Length of primary branch	Control		0.209	0.150	0.242*	0.204
	20 krad		0.682**	0.492**	0.488**	0.322**
	30 krad		0.607**	0.249*	0.406**	0.375**
	40 krad		0.523**	0.338**	0.306**	0.359**
	40 mM		0.711**	0.419**	0.526**	0.517**
	60 mM		0.577**	0.431**	0.636**	0.460**
	80 mM		0.414**	-0.758**	0.320**	0.334**
	20 krad+40 mM		0.589**	0.132	0.234*	0.212
Number of branches	Control			0.473**	0.438**	0.467**
	20 krad			0.320**	0.500**	0.394**
	30 krad			0.393**	0.418**	0.334**
	40 krad			0.157	0.263*	0.234*
	40 mM			0.383**	0.553**	0.517**
	60 mM			0.263*	0.438**	0.271*
	80 mM			-0.184	0.360**	0.272*
	20 krad+40 mM			0.422**	0.305**	0.286*
Number of flowers	Control				0.551**	0.526**
	20 krad				0.523**	0.334**
	30 krad				0.170	0.845**
	40 krad				0.309**	0.209
	40 mM				0.630**	0.581**
	60 mM				0.577**	0.537**
	80 mM				0.119	0.205
	20 krad+40 mM				0.437**	0.357**
Number of pods	Control					0.908**
	20 krad					0.813**
	30 krad					0.881**
	40 krad					0.904**
	40 mM					0.932**
	60 mM					0.877**
	80 mM					0.824**
	20 krad+40 mM					0.839**

+ Observations were recorded on 360 plants in each treatment from three replications

* Significant at 5% level

** Significant at 1% level

TABLE 36: Total correlation coefficients between pod yield and its components in M_3 generation of Ah 7911+

Trait	Treatment	Length of primary branch	Number of branches	Number of flowers	Number of pods	Pod yield
Height of main stem	Control	0.576**	0.492**	0.168	-0.121	-0.103
	20 krad	0.611**	0.243*	0.154	0.148	0.114
	30 krad	0.857**	0.213	0.155	0.871**	0.229
	40 krad	0.537**	0.321**	0.900**	0.566**	0.707**
	40 mM	0.648**	0.327**	0.199	0.134	0.190
	60 mM	0.681**	0.164	0.945**	0.114	0.983**
	80 mM	0.899**	0.615**	0.301*	0.415**	0.372**
	20 krad+40 mM	0.763**	0.173	0.341**	0.405**	0.663**
Length of primary branch	Control		0.489**	0.140	0.513**	0.574**
	20 krad		0.292*	0.308**	0.269*	0.337**
	30 krad		0.322**	0.155	0.151	0.294**
	40 krad		0.271*	0.309**	0.328**	0.359**
	40 mM		0.426**	0.314**	0.442**	0.492**
	60 mM		0.314**	0.321**	0.367**	0.420**
	80 mM		0.556**	0.267*	0.405**	0.382**
	20 krad+40 mM		0.272*	0.185	0.513**	0.944**
Number of branches	Control			0.211	0.343**	0.269*
	20 krad			0.288*	0.163	0.183
	30 krad			0.281*	0.362**	0.356**
	40 krad			0.363**	0.337**	0.394**
	40 mM			0.282*	0.553**	0.483**
	60 mM			0.348**	0.317**	0.346**
	80 mM			0.218	0.345**	0.347**
	20 krad+40 mM			0.225	-0.802**	-0.113
Number of flowers	Control				0.492**	0.411**
	20 krad				0.308**	0.102
	30 krad				0.305**	0.185
	40 krad				0.435**	0.375**
	40 mM				0.404**	0.380**
	60 mM				0.613**	0.569**
	80 mM				0.477**	0.475**
	20 krad+40 mM				0.170	0.117
Number of pods	Control					0.902**
	20 krad					0.835**
	30 krad					0.834**
	40 krad					0.904**
	40 mM					0.900**
	60 mM					0.926**
	80 mM					0.916**
	20 krad+40 mM					0.902**

+Observations were recorded on 360 plants in each treatment from three replications

* Significant at 5% level

** Significant at 1% level

of Ah 7911. The correlation coefficient of 0.343 was observed between the number of branches and the number of pods in the control population. The correlation coefficient between these two characters in the combination treatment was -0.802.

D. Evaluation of productive mutant lines

Forty plants in M_2 generation which possessed higher pod yield than that of control were selected and their progenies were raised for further study. Of these, five lines, namely No.19 and 20 (TMV 9, EMS 40 mM), 24 and 27 (TMV 9, 30 krad) and 39 (Ah 7911, 20 krad + 40 mM) recorded higher yield than that of control (Table 37). Twenty one plants were selected at random in these five lines in M_3 and their progeny were tested for yield performance. The yield data are furnished in Table 38. The mean pod yield per plant in four selections, 19I/2, 24 II/7, 24 II/8, and 39 II/10 ranged from 23.8 g to 25.5 g, the increase over control being 22.1 to 30.8 per cent.

TABLE 37: Pod yield/plant of mutant lines in M_3 generation

Mutant line number	Mean pod yield g/plant	Percentage on		Mutant line number	Mean pod yield g/plant	Percentage on	
		TMV 9	Ah 7911			TMV 9	Ah 7911
1.	13.2	91.0	95.7	24.	20.8	143.5	150.7
2.	11.6	80.0	84.1	25.	11.3	77.9	81.9
3.	9.7	66.9	70.3	26.	14.5	100.0	105.1
4.	13.3	91.7	96.4	27.	16.9	116.6	122.5
5.	14.5	100.0	105.1	28.	11.5	79.3	83.3
6.	14.5	100.0	105.1	29.	14.9	102.8	108.0
7.	13.4	92.4	97.1	30.	11.0	75.9	79.7
8.	11.5	79.3	83.3	31.	11.0	75.9	79.7
9.	10.5	72.4	76.1	32.	14.0	99.3	104.4
10.	12.9	89.0	93.5	33.	13.2	91.0	95.7
11.	13.7	92.6	99.3	34.	13.0	89.7	94.2
12.	14.2	97.9	102.9	35.	12.2	84.1	88.4
13.	13.6	93.8	98.6	36.	13.1	90.3	94.9
14.	8.8	60.7	63.8	37.	14.1	97.2	102.2
15.	14.2	98.1	102.9	38.	14.0	96.6	101.5
16.	11.0	75.9	79.7	39.	16.0	110.3	115.9
17.	13.2	91.2	95.7	40.	13.0	89.7	94.2
18.	11.0	75.9	79.7	TMV 9	14.5	100.0	105.1
19.	15.8	109.0	114.5	Ah 7911	13.8	95.2	100.0
20.	16.7	115.2	121.0	G.M	13.2	91.0	95.7
21.	13.6	94.0	98.6	S.E	1.59	11.0	11.5
22.	12.5	86.2	90.6	C.D	4.45	30.7	32.3
23.	9.2	63.5	66.7				

TABLE 38: Yield performance of selections from M_3 lines in M_4 generation

S.No.	Selection number	Variety and treatment	Mean yield g/plant	Per cent on TMV 9
1.	19 I/1	TMV 9, EMS 40 mM	22.5	115.4
2.	19 I/2	TMV 9, EMS 40 mM	24.0	123.1
3.	19 I/8	TMV 9, EMS 40 mM	21.5	110.3
4.	20 II/10	TMV 9, EMS 40 mM	20.0	102.6
5.	24 II/5	TMV 9, 30 krad	22.0	112.8
6.	24 II/7	TMV 9, 30 krad	23.8	122.1
7.	24 II/8	TMV 9, 30 krad	25.0	128.2
8.	24 II/10	TMV 9, 30 krad	22.5	115.4
9.	24 III/1	TMV 9, 30 krad	21.5	110.3
10.	24 III/2	TMV 9, 30 krad	20.5	105.1
11.	24 III/8	TMV 9, 30 krad	21.5	110.3
12.	24 IV/5	TMV 9, 30 krad	18.5	94.9
13.	27 I/3	TMV 9, 30 krad	20.5	105.1
14.	27 I/4	TMV 9, 30 krad	22.5	115.1
15.	27 I/6	TMV 9, 30 krad	20.5	105.1
16.	27 I/10	TMV 9, 30 krad	20.0	102.6
17.	27 II/10	TMV 9, 30 krad	20.00	102.6
18.	39 II/6	Ah 7911, 20 krad + 40 mM	17.2	88.2
19.	39 II/7	Ah 7911, 20 krad + 40 mM	21.5	110.2
20.	39 II/9	Ah 7911, 20 krad + 40 mM	23.0	118.0
21.	39 II/10	Ah 7911, 20 krad + 40 mM	25.5	130.8
22.	TMV 9	Control	19.5	100.0
23.	Ah 7911	Control	17.5	89.7
	S.E.		1.4	7.1
	C.D at 5%		3.9	20.1

Discussion

DISCUSSION

The extent of crop improvement is limited to the available inherent variability for the economic characters. The greater the variability, the better will be the scope for improvement. In recent times, plant breeders have attempted to increase the variability for quantitative characters by induced mutagenesis (Dumanovic et al., 1970 in wheat, Raut et al.,1974 in cotton, Conger et al., 1976 in soybeans and Patil and Thakare, 1969 in groundnut). Breeding for higher yield in groundnut has been in progress in several centres and the artificial creation of variability has been attempted using specific varieties and mutagens (Gregory,1968; Levy and Ashri,1975; Patil and Mouli,1978). Induction of variability in locally adapted varieties of groundnut would be rewarding from the point of view of stability of performance of the mutants. Two of the high yielding varieties TMV 9 and Ah 7911 of the Oilseeds Research Centre of the Tamil Nadu Agricultural University were subjected to physical, chemical and combination treatments and the variability observed both in qualitative and quantitative characters are discussed.

A. Studies on germination, survival and seedling height in M_1 generation

The biological effects of the mutagenic treatments were determined from the observation made in the germination, survival and seedling height in M_1 generation.

Progressive decrease in germination with increase in dose of gamma rays and EMS was observed on the two varieties (Table 4). Similar relationship between dose and effect has also been observed in the irradiated material of groundnut (Gregory,1968), cotton (Khalifa,1978), bengalgram (Athwal,1963), Phaseolus vulgaris (Mujeep and Greig,1973) and peas (Sharma,1965) and gamma and EMS treatments in soybeans (Constantin et al.,1976) and EMS treatments in Vicia faba (Hussain et al.,1974). Data have shown that combination treatment caused greater reduction in germination than that of single treatments. Such increase in reduction of germination due to combination treatment was observed in rice (Siddiq and Swaminathan, 1968 and Swaminathan et al., 1970) and Sorghum (Sree Ramulu, 1970).

It may be clear from Table 4, that survival was reduced with increase in doses of gamma rays and EMS. Such inverse relation between dose and survival was observed in groundnut due to X-irradiation (Gregory, 1968) and in cotton due to gamma irradiation (Khalifa, 1978). DES and EMS treatments in soybeans (Constantin et al.,1976) and EMS treatments in Vicia faba (Hussain, et al.,1974) were also found to cause decrease in survival with increase in dose. In the present study, reduction in survival to about 50 per cent was caused by 40 krad of gamma rays and 60 mM of EMS treatment (Table 4 and Fig.2). Identical response

of the two varieties to mutagenic treatments may be evident from the data on survival. Combination treatment was found to reduce the survival to a greater extent than that of single treatments. Combination of gamma rays with DES in barley (Doll and Sandfaer, 1969), gamma rays and X-rays with EMS and nitrosoethylurea in Sorghum (Sree Ramulu, 1970), have caused a greater reduction in survival than that of individual mutagens.

Data on seedling height (Table 5) have indicated growth reduction with increase in doses of gamma rays and EMS. There were several reports on such growth reduction due to mutagenic treatments. In groundnut, irradiation with X-rays (Bhatt et al., 1961; Gregory, 1968) and thermal neutrons and gamma rays (Bhatt et al.,1961) and in soybeans, treatments with physical mutagens such as fission neutrons and gamma rays and with chemical mutagens such as EMS and DES (Constantin et al.,1976) were shown to cause reduction in the seedling growth with increase in dose.

In the present study, the two varieties showed identical response to mutagenic treatments with regard to germination and survival while differential response was indicated by growth reduction. Gamma rays have reduced the height of seedling in TMV 9 to a greater extent than EMS. However, this trend was reversed in Ah 7911 in which EMS

showed greater reduction on seedling height than that of gamma rays. Growth of seedlings in the combination treatment was less than that observed in single treatments and the effect was more pronounced in Ah 7911 than in TMV 9. The increased reduction in growth due to combination treatment was observed in barley (Konsak et al.,1961; Milan et al., 1963 and Mohan Rao, 1972). Differential response of the varieties to mutagenic treatments as observed for seedling growth in the present study has also been reported in groundnut (Bilquez and Martin, 1961; Emery et al.,1970; Levy and Ashri, 1973; Ashri and Levy,1974) and in other crops such as wheat (Walther and Haug,1973), Peas (Gelin et al.,1958, Blixt,1972) and rice (Swaminathan et al.,1970).

Seedling injury as revealed by the reduction in the height of seedling due to mutagenic treatments has been attributed to different causes like auxin destruction (Smith and Kersten, 1942), inhibition of auxin synthesis (Gordon, 1954), changes in enzyme specificity (Cherry and Leesman, 1967; Endo, 1967), inhibition of DNA synthesis (Mikaelson, 1968) and reduction in reactivity to IAA (Miura et al.,1974). The reduction in the seedling growth in the present investigation might have been due to one or more of the factors enumerated above.

B. Studies on qualitative mutations

Mutations which resulted in large phenotypic effects such as chlorophyll and viable mutations in M_2 generation were considered under qualitative mutations. As against these, quantitative mutations were those affecting characters with continuous variation and having small effects. Gaul (1965) critically discussed these mutations involving qualitative and quantitative characters under macro- and micromutation. Gustafsson (1969) used the terms oligomutation (Oligogenic mutation) and poly mutation (polygenic mutation) to denote phenotypically large and small effects respectively.

i) Chlorophyll mutations

The chlorophyll mutation frequency expressed as per cent on M_2 plant basis (Table 6) was 1.44 at 40 krad of gamma irradiation treatment in Ah 7911 which was the maximum observed in the present study.

A comparison of earlier reports on the occurrence of chlorophyll mutation induced by gamma rays and EMS in groundnut (Ashri and Levy, 1974) showed the low magnitude of occurrence of such mutation in the present study. Such differences could have arisen due to differential response of the genotypes besides differences in dose and treatment conditions of mutagenic treatments. The low frequency of chlorophyll mutation might have also been due to phenotypic

buffering as reported in hexaploid wheat (Mackey, 1961). As groundnut is an amphiploid (Gregory et al.,1951 and Raman, 1959) and several traits are controlled by duplicate factors (Gregory et al., 1951 and Hammons, 1963) the masking effect would have reduced the expression of chlorophyll mutations. This trend of reduction in the rate of induced chlorophyll mutations with increasing chromosome number was noticed by Stadler (1929) in Triticum and Avena and later by Muntzing (1942) in tetraploid barley, Levan (1944) in flax, Froier (1946) in wheat and oats and by Smith (1950), Mackey (1954) and Natarajan et al., (1958) in wheat and by Bhaskaran and Swaminathan (1962) in wheat and barley.

The data on chlorophyll mutation frequency have shown that the two varieties were identical in their response to gamma rays and EMS. Combination treatment in TMV 9, was found to induce chlorophyll mutation in greater frequency than that of single treatments. Synergism calculated on the basis of formula suggested by Sharma and Swaminathan (1969) indicated less than additive effect in the combination treatment, Constantin et al. (1974) reported greater than additive effect at the higher doses of gamma rays and neutrons plus EMS and less than additive at lower doses in barley. Instances of increased mutation frequency

in the combination treatment have been reported in peas (Mehandjiev, 1969), french bean (Marghittu, 1973) and Vicia sativa (Debelji and Ptashenchuk, 1973).

The spectrum of chlorophyll mutations induced by mutagenic treatments consisted of albina, alboviridis, chlorina, xantha and viridis (Table 7). The spectrum was found to vary according to the mutagen, dose employed and variety. While all the three concentrations of EMS have induced albina and viridis in Ah 7911, such mutants were observed in TMV 9 at 40 mM of EMS only. Gamma irradiations have induced xantha in Ah 7911 and not in TMV 9. EMS treatments were found to induce chlorina in TMV 9 and not in Ah 7911. Earlier reports have shown the occurrence of xantha and virescent mutants after X-irradiation in groundnut (Patil and Bora, 1963). Chlorina was observed from a cross between X-ray induced virescent mutant and spontaneous 'krinkle leaf' mutant (Patil, 1973). Xantha, albina and virescent mutants have been induced by individual treatments of gamma rays and EMS (Ashri and Levy, 1974). Three major genes were found to control chlorophyll development in groundnut (Patil, 1973).

2. Viable mutations

Data on viable mutation frequency on M_2 plant basis (Table 8) have shown its occurrence upto 0.66 per cent in TMV 9 and 0.51 per cent in Ah 7911 at 40 mM of EMS treatment.

Lower frequency of viable mutations was observed at higher concentrations of EMS. A comparison of chlorophyll and viable mutations indicated the occurrence of the latter at a lower frequency than that of the former. EMS, particularly at lower concentrations of 40 mM was found to induce higher frequency of viable mutation in the two varieties. The response to mutagenic treatment was different in wheat. Radiation in wheat especially at higher levels of ploidy induced higher frequency of viable mutations (Kawai, 1969). In 6 x wheat ionising radiation were reported to be more efficient in inducing viable mutations than that of chemical mutagens (Mackey, 1968). The results were interpreted as indicating that alkylating agents were more efficient than radiation for inducing point mutations but less efficient for inducing chromosome aberrations which give rise to phenotypic changes in polyploid plants. Swaminathan (1965), however, reported cases where EMS was as effective as gamma rays in inducing chlorophyll mutations and mutations at the speltoid suppressor locus Q in breadwheat.

Polyploids may be expected to tolerate chromosomal aberrations to a greater extent than diploid species. Thus the possibility of greater proportion of viable mutations in tetraploid and hexapoloid wheat has been demonstrated (Mackay, 1961). However, low frequency of viable mutation observed in the present study may be due to haplontic or diplontic selection (Swaminathan, 1977) or because the

induced mutations may be semidominant or recessive. M_3 mutants are ordinarily considered homozygous for the selected trait. However, it cannot be assumed that all the variants should prove homozygous in progeny tests particularly since epistatic interaction among genes are common.

Spectrum of viable mutations induced by various treatments consisted of mutations involving height (dwarfism), kernel size, testa colour and growth habit. Mutations resulting in increase in the number of kernels per pod, alteration of morphological features of pod and leaf size and shape have also been noticed.

As a result of gamma irradiation at 30 krad in Ah 7911 and TMV 9, two drastic mutants were isolated. In mutant-1 and -2, the height was reduced accompanied by reduction in the expression of other characters such as 100-pod weight and 100-kernel weight (Table 11). The pod and kernel yield was also reduced in these mutants. Reduction in height accompanied by drastic reduction in other plant parts such as leaflets, pods and seeds have been reported in the dwarf mutants of groundnut (Shehori and Ashri, 1970). The frequency of these recessive mutations was low in all mutation experiments. In groundnut also similar reports have appeared (Loesch and Hammons, 1968). Gaul (1964) concluded that three most important causes for

the shortage of recessives were the association of mutations with chromosome aberrations, modified genetic transmission and pleiotropy involving undesirable traits. In the present study, the characteristics of mutant-1 and -2 have shown the possibility of pleiotropic effect of the same gene involving undesirable traits which has reduced the pod and kernel characters besides reduction in height. While Shchori and Ashri (1970) observed monogenic recessive inheritance, Patil and Mouli (1975) have shown that dwarfism in groundnut was controlled by a pair of recessive factors. Though the drastic mutants in the present study were not superior to control in economic characteristics, it might be possible to derive better genotypes in crosses with high yielding cultivars. Such mutants in peas (Gottschalk, 1972) and wheat (Konsak, 1976) have been found to yield desirable recombinants in crosses between mutants as well as with normal plants. Dwarf mutants have been very frequently observed in cereals such as wheat (Reitz and Salmon, 1968) and barley (Yamaguchi et al., 1974). They were characterised by short plant height and at the same time in many instances reduced plant organs indicating growth rate reduction in many or all plant parts throughout their entire life cycle. However, there were examples in Sorghum and sugarcane in which plant parts or organs were disproportionately reduced in size (Hansel et al., 1963; Jagatheesan and William, 1976).

Mutation for increased kernel size without involving major changes in other plant parts has been observed in the population derived from Ah 7911 subjected to 20 krad of gamma irradiation. Thus, mutants-3 and -4 were morphologically indistinguishable from the parent variety except for bold kernels. These mutant-3 and -4, however, were not superior to the parent variety in their yielding ability.

Mutations involving alterations in testa colour have been observed in the populations raised from gamma irradiation at 30 krad, EMS treatments at 40 mM and 80 mM and combination treatment (Mutant-7 to -15). Purple and brown testa occurred in the mutagen treated populations of the two varieties. Brown testa appeared to be a new variant. Among the other testa colour mutants observed were those with red, variegated and white testa, compared to the rose testa of the parental varieties. These testa colour mutants would be more of academic interest than of economic importance. The genetic factors affecting testa colour have been shown to be characterised by the interaction of five primary loci, although certain additional loci might be involved in other specific instances (Hammons, 1963; 1973). Krapovickas and Rigoni (1952) reported that purple testa was incompletely dominant to flesh and that dark purple depended upon atleast two pairs of genes with cumulative effect.

Harvey (1967) also found purple testa to be incompletely dominant to flesh and although the dominant gene (R) was not required for the development of purple testa, that gene did modify its expression. Because of the interaction of many testa colour genes and the difficulty of classifying colours of varying intensity, the genetic explanations of the inheritance of some colours have been inconsistent. In the present study it appears that the purple testa colour observed might have been due to mutation of the modifiers which affect the expression of this character. Mutations for seed coat colours have also been reported in other crops such as french bean (Moh, 1971) and black gram (Ramaswamy, 1973).

Mutations involving growth habit were found to be induced by EMS and combination treatment. Semispreading types of mutants occurred in the two varieties while spreading types of mutants were observed in TMV 9. The characteristics of mutant-16 and -17 with semispreading growth habit (Table 16) have shown increased pod and kernel size besides higher pod and kernel yield than that of control. Thus, these two semispreading types of mutants could be of considerable economic importance. Two mutants with spreading growth habit, namely mutant-21 and -22 were isolated in a population derived from TMV 9 subjected to 40 mM of EMS treatment. These spreading type of mutants have shown considerable increase in their yielding ability besides having increased pod and kernel size.

The genetics of growth habit in groundnut have been reviewed by several authors in recent years (Hammons, 1973; Coffelt, 1974; Ashri, 1975). Three different plasmons and three different nuclear loci have been identified. The plasmons interact differently with plasmon sensitive nuclear genes thereby determining whether the plants will be erect or trailing (Ashri, 1976). Levy and Ashri (1978) have isolated one true breeding trailing mutant, an extreme form of spreading type, from bunch cultivars, which has been interpreted as segregation of hetero-plasmons arising from plasmon mutations. The observed semi-spreading and spreading types of mutants in the present study might have arisen as a result of probable plasmon mutation.

Such mutations for growth habit have been reported in other plant species. Prostrate, spreading, sparse and rosette like types have been induced in many plants. Mutants with altered growth rythm showing enhanced or reduced growth rate at particular growth stages (Tedin, 1954; Lamprecht, 1958, Jain et al., 1962; Porsche, 1963) form a particular group of growth habit mutants. Yagyu and Morris (1957) reported a semideterminant tomato mutant.

In the present study, mutation affecting single trait, testa colour was observed in mutant-7 to -12. There were mutations for two traits, namely growth habit and kernel size in mutant-16, -17, -21 and -22. Mutations involving

three traits namely growth habit, kernel size and testa colour were observed in mutant-15. Such simultaneous mutations for two or more traits were reported to be due to pleiotropic effects (Ashri and Levy, 1974) and EMS produced relatively higher proportions of such mutants. Present observations have shown the occurrence of simultaneous mutations for two or more traits in EMS and combination treatment. Gottschalk (1968) has shown that instances in which pleiotropic gene action were assumed could be due to simultaneous mutation of neighbouring genes as revealed by test of crossing over in hybridisation experiments.

Mutations involving various plant characters have been found in groundnut. Gregory (1968) observed twenty four classes of viable mutants by X-irradiation of MC-4 variety. Such viable mutants have also been reported in other polyploids such as "broad leaved" mutant in tobacco (Patel and Swaminathan, 1961) "Photo-insensitive" mutant in MCU 5 cotton and "Short branched" mutant with clustering habit in H 14 cotton variety (Raut, et al., 1974).

C. Studies on quantitative mutations

Induction of mutations in the quantitative characters are detected in the successive generations of mutagen treated material through mean and variance comparisons (Scossiroli,1977). In the present study, the nature and extent of variability

induced in M_2 and M_3 generations by physical and chemical mutagens and their combination are discussed with particular reference to economic characters.

1. M_2 and M_3 generations

In the M_2 generation, there was decrease in the mean values of eight out of eleven characters, namely height of main stem, number of branches, flowers, mature pods, kernels, pod yield, kernel yield and 100-pod weight (Tables 19,21 to 24) in the treated populations compared to that of control. Such decreases in mean values due to mutagenic treatments have been observed in groundnut (Gregory, 1968), bread wheat (Bhatia and Swaminathan, 1962; Borojevic, 1965), durum wheat (Scossiroli, 1966) and in diploids like soybeans (Rawlings et al., 1958), barley (Gaul, 1964) and Arabidopsis (Brock, 1965). Several explanations have been given for the shift in the mean values of quantitative characters due to mutagenic treatments (Gregory, 1961; Brock, 1965 and Gaul and Aastveit, 1966). Mutations in a quantitatively inherited character would depend on the number of genes involved, the relative proportion of genes with positive and negative effects and the degree to which the genes of the parental genome operate as a balanced set (Brock, 1965). This explanation of Brock might be considered appropriate. The increase in the proportion of genes with negative effects over that of positive effects arising as a result of mutagenic treatments would have resulted in the reduction of mean values of several characters in M_2 in the present observation.

In the M_3 generation, the mean values of several characters approached that of control while there was reduction in the mean values in the M_2 generation. For example, number of branches in the gamma irradiation treatments in Ah 7911 (Table 27), pod and kernel yield at 40 krad of gamma irradiation treatment in TMV 9 (Table 31 and 32) were found to be equal to that of control. It might have been the effect of selection exercised in M_2 generation. Such a possibility has been indicated from selection resulting in the means approaching that of control in bread wheat, tobacco, cotton and autotetraploid barley (Swaminathan, 1963). Mean values of quantitative characters equal to that of control and a greater variability in M_3 and M_4 than in M_2 was found in wheat (Trujillo and Betancourt, 1972).

Mutagenic treatments have resulted in increase in variability for several economic characters in the M_3 generation. EMS treatment at 40 mM concentration in Ah 7911 was found to increase the variability of number of kernels and kernel yield six times and that of pod yield and number of mature pods five times and three times respectively compared to that of control (Tables 29 to 32). EMS at 80 mM treatment in TMV 9 had increased the variability of 100-pod weight and 100-kernel weight five times that of the control (Tables 33 and 34). Gamma irradiation at 40 krad was found to increase the variability of kernel yield and

100-pod weight in Ah 7911 three times compared to that of control. Such irradiation at 40 krad in TMV 9 had resulted in four times increased variability for number of mature pods and number of kernels and three times increase in variability for pod and kernel yield. Earlier reports have shown that the variance for pod yield in groundnut has been increased by radiation four times over that measured in the control progenies (Gregory, 1955). A four-fold increase in genetic variance for number of kernels per spike was reported in wheat (Borojevic, 1965). Such increase in variance in mutagenic treatments was also observed in diploids. Rawlings et al., (1958) found approximately five fold increase in variance in irradiated soybeans for yield and seed size and Brock and Latter (1961) reported an induced genetic variance 4 to 5 times larger than that of control for flowering time in substerranean clover.

Induced variability in quantitative characters was also shown by the frequency distribution curves. Mutant plants with large phenotypic deviations were not included for assessment of variability of quantitative characters. Symmetrical distribution for pod yield (Fig. 5 and 6) in M_3 and 100-kernel weight (Fig. 7 and 8) in M_2 and M_3 generations might be interpreted as due to individual changes of approximately equal number of plus and minus effects. Brock (1965) showed that asymmetry was reduced

in the frequency distribution by removing obvious morphological mutants. Gregory (1965) observed that the more completely all mutant plants of large phenotypic deviation were removed from the population the more symmetrical it became in genetically uncorrelated quantitative characters. Bateman (1959) reviewing Oka et al., (1958) and Sakai and Suzuki (1964) came to the opposite conclusion that not only were genetic changes induced unidirectional in effect but of negative sign. The observations in the present study, however, have shown that the interpretation of Gregory (1968) that the number of negative and positive mutations in the polygene system are nearly equal and that it is the magnitude of phenotypic effect of a mutation which gives the negative effects and not its unidirectional nature might be more appropriate. Such phenotypic distribution for number of kernels in Triticum aestivum was shown to indicate the variability in X_3 generation caused by the appearance of plus and minus variants (Borojevic and Borojevic, 1968).

Increase in genotypic variability for quantitative characters contributing to yield in M_3 generation but not in M_2 might have been due to the fact that mutated genes were not homozygous in M_2 for all loci but segregated further. Such increase in variability in the M_3 generation of T. aestivum and T. durum was demonstrated in irradiated population (Scossiroli, 1965) and also in the M_3 generation in bread wheat, tobacco, cotton and autotetraploid barley

(Swaminathan, 1963). Palemsema (1966) while studying the progress of selection for various quantitative characters under different selection pressures in the progenies raised from X-irradiation of seeds of wheat concluded that selection started in M_3 was more effective than the one started in M_2. The observed increase in variability for economic characters in the M_3 generation of the present study has shown that it might be more appropriate to start selection in M_3 than in M_2.

Increase in doses of EMS was found to result in increase in genotypic variance, heritability and genetic advance for number of mature pods and pod yield in TMV 9 (Tables 29 and 31) and for kernel yield in Ah 7911 (Table 32) in the M_3 generation. However, such increase was not proportionate to the increase in doses. For example, maximum values for these genetic parameters were observed at 60 mM for number of mature pods in TMV 9 and at 40 mM for kernel yield in Ah 7911. A similar non-linear trend of increase in genetic parameters for number of kernels was observed in Ah 7911 (Table 30) with the increase in dose of gamma rays. In this case the increase in the genetic parameters at 30 krad was higher than that at 40 krad treatment. Such increase in genetic variability not proportionate to the dose of X-ray treatments was reported for plant height, heading date and panicle length in rice (Kao et al., 1960). Such dose-variance relation was also reported in polyploid

like breadwheat (Scossiroli, 1965, 1977). The increase in variability which was not proportionate to the dose as observed in the present study could have arisen as a result of elimination of detrimental or unadaptable mutants through gametic or zygotic selection (Scossiroli, 1965), or perhaps due to artificial selection.

The data on heritability and genetic advance for economic characters have shown that there was considerable increase due to mutagenic treatments in the M_3 generation. High heritability and genetic advance for number of mature pods, number of kernels and pod yield were observed at 40 krad of gamma irradiation treatment in TMV 9 and 40 mM of EMS treatment in Ah 7911. EMS at 80 mM concentration was found to enhance the heritability and genetic advance for 100-kernel weight in the two varieties. Such high values of genetic parameters for 100-pod weight were observed at 80 mM of EMS treatment in TMV 9 and 40 krad of gamma irradiation in Ah 7911.

Selection exercised for number of mature pods and pod yield in the population derived from 40 krad treatment in TMV 9 and for number of kernels at 40 mM of EMS treatment in Ah 7911 might result in high yielding types in view of the high heritability accompanied by relatively high genetic advance for these characters. Results of path analysis studies in groundnut have been found to be in conformity with

the observations of the present study as shown by the significant direct contribution to pod yield by number of mature pods in semi-spreading and erect types and 100-kernel weight in spreading types (Badwal and Harbans Singh,1975). Selection for 100-kernel weight at 80 mM of EMS treatment in TMV 9 might also result in improvement for this character in view of its high heritability and relatively high genetic advance. Sangha and Sandhu (1970; 1975) have also reported such high heritability and genetic advance for 100-kernel weight in groundnut. Possible gain from selection exercised in characters showing high heritability and genetic advance have been indicated from the earlier observations in groundnut (Gregory, 1955; Loesch, 1964) and in other polyploid crops such as cotton (Chandramathy, 1978) and wheat (Scossiroli et al., 1966; Goud, 1967) and diploids like barley (Borojevic, 1966) Gaul, et al., 1969) and Arabidopsis (Brock et al., 1972). The characters 100-kernel weight and number of pods in groundnut in which high heritability and genetic advance have been observed were reported to be more dependable for selection on the basis of phenotypic performance (Sangha and Sandhu, 1975).

3. Studies on character association

Mutation involving quantitative characters result in the alteration of association of certain characters which existed in the parental variety. A knowledge of alterations involving the association of yield with its component

characters may be useful in formulating selection procedures in the treated populations. Total correlation co-efficients obtained from M_3 generation in the population derived from gamma rays, EMS and combination treatment and that of control are presented (Tables 35 and 36) and discussed here.

The study related to the association of five characters, namely, height of main stem, length of primary branch, number of branches, number of flowers and number of pods with pod yield in the two varieties. In the control population of the two varieties there was significant positive association between pod yield on one hand and number of branches, number of flowers and number of pods on the other. However, genetic difference between the two varieties may be evident from the difference in the association in two instances. Height of main stem was found to be positively associated with number of pods and pod yield in TMV 9 while they were uncorrelated in Ah 7911. Significant positive association between length of primary branch and pod yield was observed in Ah 7911 and not in TMV 9.

Comparison of the correlation co-efficients obtained from control and treated population has shown that in a few instances the relationship between the characters was enhanced, for example height of main stem with length of primary branch in the gamma irradiation, EMS and combination treatments in TMV 9 pointing to a common effect of mutations

on associated traits (i.e, pleiotropic effect as observed in wheat (Scossiroli, 1966). In certain cases as for example association between number of pods and pod yield in the two varieties and length of primary branch and number of pods in TMV 9 no alteration was observed. In a few instances as in the case of association between number of branches and pod yield at 20 krad and combination treatment in Ah 7911, there was definite increase in correlation pointing to a break of relationship which existed in the control population. Non-alteration of the positive association between pod number and pod yield in the treated populations of the present study is in conformity with the earlier observations (Sathiamoorthy et al.,1978).

The negative association between a vegetative character like height of main stem and reproductive character like number of pods and pod yield in the combination treatment in TMV 9 provides opportunity for effecting selection of plants with shorter height and increased yield. Likewise, the negative correlation between number of branches and number of pods in the population derived from combination treatment in Ah 7911 indicated the possibility of selection of plants with less number of branches and more yield. Such desirable changes in plant architecture not ordinarily attainable by recombination breeding has been made possible due to mutagenic treatments. This may be clear when compared with the positive relationship between number of branches

and number of pods reported in the segregating populations of intervarietal crosses (Lin, 1966). Mutagen induced alterations in character association as in the present study has been observed in other crops such as cotton (Chandramathy, 1978), tobacco (Scarascia-Mugnossa, 1968), wheat (Scossiroli et al., 1966), green gram (Krishnaswami, 1977), peas (Dudits and Sutka, 1970) and rice (Rao and Siddiq, 1976).

D. Evaluation of productive mutant lines

Forty plants with increased pod number and yield were isolated in M_2 generation from out of population of 23,523 plants. Their progenies were tested in M_3 generation. The yield data (Table 37) indicated that in five lines there was significant yield increase over control. Twenty one plants were selected at random in these five lines and further tested in M_4 generation. It may be seen from Table 38 that in four selections, 19I/2 (TMV 9, EMS 40 mM), 24II/7 and 24II/8 (TMV 9, 30 krad) and 39II/10 (Ah 7911, 20 krad+40 mM), there was significant increase in yield ranging from 22.1 to 30.8 per cent over control.

Following successful experiments of Gregory (1955), the usefulness of mutation as a tool for groundnut improvement has been demonstrated (Patil, 1973a; Patil and Thakare, 1969 and Patil and Mouli, 1978). Inspite of the difficulty of detecting positive yield mutants, there is no

doubt about their existence and number of mutant cultivars with increased yield have been released in many crops (Sigurbjornsson and Micke, 1974).

Results in the present study have shown the occurrence of high yielding mutants in groundnut which may be utilised in appropriate breeding programme.

Summary

SUMMARY

The effects of gamma rays and EMS individually and in combination on two locally adapted groundnut varieties, TMV 9 and Ah 7911 were studied to find out the frequency and spectrum of induced mutations in qualitative characters, induced variability for quantitative characters and their influence on character associations.

1. In the M_1 generation, germination, survival and seedling height, decreased with increase in dosage of physical and chemical mutagens. Combination treatment resulted in greater reduction than that of single treatments. The two varieties were identical in their sensitivity to mutagenic treatment with reference to germination and survival while they differed significantly with regard to seedling height.

2. Qualitative mutations in M_2 consisted of chlorophyll and viable mutants. The spectrum of chlorophyll mutation showed differential response of the two varieties to mutagenic treatments. Combination treatment in TMV 9 and higher dose of gamma rays in Ah 7911 resulted in less than additive values for chlorophyll mutation.

3. Induced viable mutations included mutation for dwarfism, kernel size, testa colour and growth habit. Two mutants having semi-spreading growth habit possessed desirable features of short stature, higher pod and kernel yield, bold kernels and increased shelling per cent over control.

Mutations for testa colour consisted of brown, purple, red, white, variegated and purple lining around micropyle compared to rose testa in the control.

4. The expression of quantitative characters in M_2 generation in the populations obtained from gamma rays, EMS and combination treatments was in most instances lower in the treated than in the untreated populations.

5. In the M_3 generation, the mean values for different vegetative characters and yield attributes in the populations derived from different mutagenic treatments were in several instances equal to that of control. Genotypic variance for economic characters increased two to six-fold over control in different mutagenic treatments. The significance of these observations are discussed.

6. Increase in variance, heritability and genetic advance for number of kernels observed in gamma irradiation treatments in Ah 7911 was not consistent with dose. Similar increase in genetic parameters for number of mature pods and pod yield in TMV 9 and kernel yield in Ah 7911 was observed in EMS treatments.

7. The effect of mutagenic treatments on the character association was studied in the M_3 generation. Negative associatio between height of main stem and pod yield in TMV 9 and between number of branches and number of pods in Ah 7911 was observed in the combination treatment against the positive association in the respective parent populations. The positive association

between number of flowers on one hand and number of pods and pod yield on the other which existed in the control population of TMV 9 was not observed in 80 mM of EMS treatment. The possibility of selection for yield with improved plant architecture from mutagen treated populations was indicated by the altered character association.

8. Mutant selections with improved yield have been identified by further progeny testing in M_3 and M_4 generations.

References

REFERENCES

Ashri, A. 1968. Morphology and inheritance of sterile brachytic dwarfs in peanuts, Arachis hypogaea L. Crop Sci. 8:413-415.

_____. 1972. Mutations and physiological reactions to several chemical mutagens in peanuts, Arachis hypogaea L. Induced Mutations and Plant Improvement. (Proc. Panel), FAO/IAEA, Vienna, 1972, 253-264.

_____. 1975. Natural cytoplasmic divergence and induction of plasmon mutation in peanuts, Arachis hypogaea L. Final Research Report ARS., U.S.D.A., Beltsville, MD., USA. pp.32.

_____.1976. Plasmon divergence in peanuts (A. hypogaea): A third plasmon and locus affecting growth habit. Theor. appl. Genet. 48: 17-21.

_____., and Goldin, E. 1965. The mutagenic activity of diethyl sulfate in peanuts. Radiat. Bot. 5: 431-441.

_____. and Herzog, Z. 1972. Differential physiological sensitivity of peanut varieties to seed treatments with diethyl sulphate and ethyl methane sulphonate. Radiat. Bot. 12: 173-178.

_____. and Levy, A. 1974. Mutation yields and types obtained in peanuts Arachis hypogaea by treating mature seeds with ethyl methane sulphonate and gamma rays and developing embryos with ethyl methane sulphonate. Polyploidy and Induced Mutations in Plant Breeding. (Proc. Panel, 1974), IAEA, Vienna, 1-12.

Athwal, D.S. 1963. Some X-ray induced and spontaneous mutations in Cicer. Indian J. Genet., Pl. Breed. 23: 50-57.

Avadhani, K.K. and Ramana Rao, 1968. Studies on the effects of diethyl sulphate on TMV 2 groundnut (Arachis hypogaea L.) Indian J. Sci. Ind. 2: 77-88.

Badwal, S.S. and Harbans Singh, 1973. Effect of growth habit on correlations and path coefficients in groundnut. Indian J. Genet. Pl. Breed. 33: 101-111.

Bateman, A.J. 1959. Induction of polygenic mutation in rice. Int. J. Radiat. Biol. 1: 425-427.

Bhaskaran, S. and Swaminathan, M.S. 1962. Chromosome aberrations, changes in DNA content and frequency and spectrum of mutations induced by X-rays and neutrons in polyploids. Radiat. Bot. 1: 166-181.

Bhatia, C.R. and Swaminathan, M.S. 1962. Induced polygenic variability in bread wheat and its bearing on selection procedures. Z. Pflanzenzucht. 48: 317-326.

Bhatt, B.Y., Bora, K.C., Gopal Ayyengar, A.R., Patil, S.H., Rao, M.S., Sharma, H.K., Subbiah, K.C. and Thakare, R.C. 1961. Some aspects of irradiation of seeds with ionising radiations- "Effects of ionising radiations on seeds" - Karlsruhe, 1960. Vienna, 1961, 591-607.

*Bilques, A.P. and Martin, J.P. 1961. Difference varietale de sesibilete aux rayons X ches L' arachide. J. Agr. Trop. Botan. Appl. 8: 30-43.

*_____., Magne, C. and Martin, J.P. 1965. Bilan de sin annes de recherches sur L'emplides rayonnements ionisants pour l'amelioration des plantes an Senegal (The use of Induced Mutations in Plant Breeding). Radiat. Bot. 5 (Suppl): 585.

Blixt, S. 1961. Quantitative studies of induced mutations in peas. IV. Chlorophyll mutations. Agric. Hort. Gen. 18: 219-227.

_____. 1972. Mutation genetics in Pisum. Agr. Hort. Genet. 30: 1-293.

Borojevic, K. 1965. The effect of radiation and selection after irradiation on the number of kernels per spike in wheat. The use of Induced Mutations in Plant Breeding. Radiat. Bot. 5 (Suppl.): 505-513.

_____. 1966. Studies on radiation induced mutations in quantitative characters of wheat (Triticum vulgare) Mutations in Plant Breeding (Proc. Symp. IAEA/(FAO) Vienna, 1966, 15-38.

Borojevic, K. and Borojevic, S. 1968. Response of different genotypes of Triticum aestivum ssp. vulgare to mutagenic treatments. Mutations in Plant Breeding. (Proc. Panel) FAO/IAEA, Vienna, 1968, 15-46.

Brock, R.D. 1965. Induced mutations affecting quantitative characters. The use of Induced Mutations in Plant Breeding. (Rep. FAO/IAEA. Tech. Meeting Rome, 1964). Pergamon Press, Oxford, 443-450.

_____. and Latter, B.D.H. 1961. Radiation induced quantitative variation in subterranean clover. (Proc. Australian Conf.) Radiat. Biol. 3: 205-215.

_____, Shaw, H.P. and Callen, D.F. 1972. Induced variation in quantitatively inherited characters. Induced Mutations and Plant Improvement. (Proc. Meeting, Buenos Aires, 1970). IAEA, Vienna, 317-322.

Chandramathi, P.S. 1978. Maximisation of genetic variability in intervarietal hybrids of Gossypium hirsutum L. Ph.D. Thesis, Tamil Nadu Agri. Univ. Coimbatore, 1978.

Cherry, J.H. and Leesman, K.J. 1967. Comparison of nucleic acids in maize shoots and pea epicotyls. Amer. J. Bot. 54: 181-188.

Coffelt, T.A. 1974. Interspecific growth habit in an interspecific cross population of peanuts. J. Hered. 65:160-162.

Conger, B.V., Skinner, L.N. and Skold, L.N. 1976. Variability for components of yield induced in soybeans by seed treatment with gamma irradiation, fission neutrons and EMS. Crop Sci. 16: 233-236.

_____, Konzak, C.F. and Nilan, R.A. 1977. Methods of applying pre- and post-treatments. Manual on Mutation Breeding. IAEA, Vienna, 1977. p. 45.

Constantin, M.J., Conger, B.V., Chowdhury, J.B. and Ramage, R.T. 1974. Chlorophyll deficient mutants in barley: Effects of chemical mutagens on irradiated and non-irradiated seeds after various periods of presoaking. Polyploidy and Induced Mutations in Plant Breeding. (Proc. Panel) FAO/IAEA, Vienna, 1974, 53-62.

_____, Klobe, W.D. and Skold, L.N. 1976. Effects of physical and chemical mutagens on survival, growth and seed yield of soybeans. Crop Sci. 16: 49-52.

Cooper, W.E. and Gregory, W.C. 1960. Radiation induced leaf spot resistant mutants in the peanut (Arachis hypogaea L.) Agr. J. 52: 1-4.

Debelji, G.A. and Ptashenchuk, V.N. 1973. Recessive chlorophyll mutants in seed progeny of M_1 plants of Vicia sativa. Genetika 9: 45-49.

Doll, H. and Sandfaer, J. 1969. Mutagenic effect of gamma rays, diethyl sulphate, ethyl methane sulphonate and various combinations of gamma rays and chemicals. Induced Mutations in Plants (Proc. Symp. Pullman, 1969) IAEA, Vienna, 195-205.

*Dudits, D. and Sutka, J. 1970. Genetic change of characters by mutations in peas. Protein growth by plant breeding. Ed. Balint, A. Akademaikiado, Budapest.

Dumanovic, J., Ehrenberg, L. and Denic, M. 1970. Induced variation of protein content and compositions in hexaploid wheat, Improving plant protein by nuclear techniques (Proc. Symp. Vienna, 1970) IAEA, Vienna, 107-119.

Emery, D.A. 1972. Effect of re-irradiation on radio resistance in peanuts (Arachis hypogaea L.) Radiat. Bot. 12: 137-150.

_____., Gregory, W.C. and Loesch, Jr.P.J. 1964. Breeding value of X-ray induced macromutant I. Variations among normal appearing F_2 families segregated from crosses between macromutants of peanuts (Arachis hypogaea L.) Crop Sci. 4: 87-90.

_____., _____. and _____. 1965. Breeding value of the radiation induced macromutant. II. Effect of mutant expression and associated backgrounds on selection potential in Arachis hypogaea L. The use of Induced mutations in plant breeding. Radiat. Bot. 5 (Suppl.): 339-353.

_____., Beardman, E.G. and Stucker, R.E. 1970. Some observations on the radio sensitivity of certain varietal and hybrid genotypes of cultivated peanuts. Radiat. Bot. 10: 267-272.

Ando, T. 1967. Comparison of the effects of gamma rays and maleic hydrazide on enzyme systems of maize seeds. Radiat. Bot. 7: 35-40.

Frdier, K. 1946. Genetical studies on the chlorophyll apparatus in oats and wheat. Hereditas 32: 297-406.

*Gaul, H. 1957. Die Verschiedenen Bewuchsysteme der mutation shaufigkeit bei Pflanzen angewendt auf Dosis. Effktkurven, Z. Pflanzenzucht. 38: 63.

_____.1964. Mutation in plant breeding. Radiat. Bot. 4: 155-232.

_____.1965. The concept of macro- and micro-mutations and results on induced micromutations in barley. The use of Induced Mutations in Plant Breeding (Rep. FAO/IAEA Tech. Meeting, Rome, 1964). Pergamon Press, Oxford, 408-426.

*_____. and Aastveit, K. 1966. Induced variability of culm length in different genotypes of hexaploid wheat following X-irradiation and EMS treatment. Proc. 5. Yogoslav Symp. Res. Wheat. Novi. Sead. Savrem. Poljopr. 1: 263-276.

_____., Ulonska, E., Winkel, C.Z. and Braker, G. 1969. Micromutations influencing yield in barley. Induced Mutations in plants. (Proc. Symp. Pullman, 1969) IAEA, Vienna, 375-398.

Gelin, O., Ehrenberg, L. and Blixt, S. 1958. Genetically conditioned influences on radiation sensitivity in peas. Agr. Hort. Genet. 16: 78-102.

*Gilles, A. and De Vinck, A. 1959. Recherches radio-genetiques Ches Arachis hypogaea L. Agricultura, 7: 533-541.

Gordon, S.A. 1954. Occurrence, formation and inactivation of auxins. Ann. Rev. Pl. Physiol. 5: 341-378.

Gottschalk, W. 1968. Simultaneous mutations of closely linked genes. A contribution to the interpretation of "Pleiotropic" gene action, Mutations in Plant Breeding. II. (Proc. Panel, Vienna, 1967), IAEA, Vienna, 97-109.

Gottschalk, W. 1972. Combination of mutated genes as an additional tool in plant breeding. Induced Mutations and Plant Improvement. (Proc. Study Group meeting, Buenos Aires) IAEA, Vienna, 199-215.

Goud, J.V. 1967. Induced polygenic mutations in hexaploid wheats. Radiat. Bot. 7: 321-331.

Gregory, W.C. 1955. X-ray breeding of peanuts (Arachis hypogaea L. Agron. J. 47: 396-399.

_____. 1956 a. The comparative effect of radiation and hybridization in plant breeding. Peaceful uses of Atomic Energy (Proc. Conf. Geneva, 1956) 12: 48-51. UN, New York.

_____. 1956 b. Inductions of useful mutations in the peanut. Genetics in Plant Breeding. Proc. Brookhaven Symp. Biology. 9: 177-190.

_____. 1956 c. Radio sensitivity studies in peanuts (Arachis hypogaea L.) Proc. Intern. Genet. Symp. Tokyo and Kyoto, 1956. Cytologia (Suppl.): 243-247.

_____. 1957. Progress in establishing the effectiveness of radiation in breeding peanuts- Proc. 9th Oak Ridge Reg. Symp. "Radiation in Plant Breeding", 1957. 36-48.

_____. 1960. The peanut, NC 4-x, a milestone in crop breeding. Crop and Soil 12: 12-13.

_____. 1961. The efficacy of mutation breeding. Mutation and Plant Breeding. U.S.Nat. Akad. Sci. Nat. Res. Council Pub. No. 891: 461-486.

_____. 1965. Mutation frequency, magnitude of change and the probability of improvement in adaptation. The use of induced mutation in plant breeding. (Rep. FAO/IAEA, Tech. meeting, Rome, 1964) Pergamon Press, Oxford. 429-441.

_____.1968. A radiation breeding experiment with peanuts. Radiat. Bot. 8: 81-147.

_____, Smith, B.W. and Yarbrough, J.A. 1951. Morphology, genetics and breeding. pp. 28-88. In: The Peanut - A symposium, The Natl. Fertilizer Assoc. Washington, D.C.

*Gustafsson, A. 1940. The mutation system of the chlorophyll apparatus. Lunds. Univ. Arsak. 36: 1-40.

_____. 1969. A study on induced mutations in plants. Introductory address. Induced Mutations in Plants. (Proc. Symp. Pullman, 1969) IAEA, Vienna, 9-31.

_____. and Gadd, I. 1965. Mutations and crop improvement V. Arachis hypogaea L. Hereditas, 53: 143-164.

*Hammons, R.O. 1953 a. Arachis hypogaea. Behaviour of induced mutant sup. J. Elisha Mitchell Sci. Soc. 69: 84-85.

_____. 1953 b. Arachis hypogaea. Behaviour of the induced mutant. North Carolina State College, Raleigh, N.C. Ph.D. Thesis, pp. 76.

_____. 1963. White testa inheritance in the peanut. J. Heredity. 54: 139-142.

_____. 1973. Genetics of Arachis hypogaea. In: C.T.Wilson Ed., Peanuts-culture and uses. Ch.4. pp.135-173, American Peanut Research and Education Association Inc., Stillwater, Oklahoma.

Hansel, H., Ross, J.G. and Huang, C.C. 1963. Irradiation induced mutations in a colchicine-reactive genotype on sorghum. Crop Sci. 3: 242-245.

Harvey, Jr. J.G. 1967. The inheritance of seed coat colour in peanuts. Ph.D.Thesis. Univ. Georgia: 33 pp, Univ. Microfilm, Ann. Arbor. Mich. (Diss.Abstr.28(6):272-B).

Hussain, H.A.S., Heakel, M.Y. and Fayed, A. 1974. Effects of EMS treatments on M_1 performance and M_2 chlorophyll mutations in Vicia faba L. Egyptian J. Genet. Cytol. 3: 299.

Jain, H.K., Sur, S.C. and Raut, R.N. 1962. Genetic studies in tomato. I. Induced variability for uniform fruit ripening and other characters. Indian J. Genet. Pl.Breed. 22: 81-87.

Jagatheesan, D. and William Jebadhas, A. 1976. A rare 'dwarf' mutant in sugarcane. Sci. Cult. 42: 233-234.

Johnson, A.W., Robinson, H.F. and Comstock, R.E. 1965. Estimates of genetic and environmental variability in soybeans. Agron. J. 47: 314-318.

*Kao, K.N., Mu, C.H., Chang, W.T. and Oka, H.I. 1960. A biometrical genetic study of irradiated populations on rice, genetic variances due to different doses of X-rays. Bot. Bull. Acad. Sin. N.S.I. 101-108.

Kawai, T. 1969. Relative effectiveness of physical and chemical mutagens. Induced Mutations in Plants. (Proc. Symp. Pullman, 1969) IAEA, Vienna, 137-152.

Khalifa, H. 1978. Radio sensitivity of some Gossypium species. Regional seminar on the utilisation of induced mutations for crop improvement in Africa. (Unpub. Proc. Symp. 1978) Ibadan, Nigeria) IAEA/FAO.

Konzak, C.F. 1976. A review of semidwarfing gene sources and a description of some new mutants useful for breeding short stature wheats. Induced mutations for cross breeding (Proc. Advisory Group Vienna, 1975) IAEA, Vienna, 79-93.

_____, Nilan, R.A., Harle, J.R. and Heiner, R.E. 1961. Control of factors affecting the response of plants to mutagens. Brookhaven Symp. Biol. 14: 128-157.

Krapovickas, A. and Rigoni, V.A. 1952. (Review of general progress in Argentina Agriculture) IDIA. Nos. 59-60. Cited by Hammons, 1973.

Krishnaswami, S. 1977. Studies on induced mutations in green gram Vigna radiata (L.) Wilczek. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Lamprecht, H. 1958. Über Grundlagen der gene für die Gestaltung hoherer Pflansen, Agri. Hort. Genet. 16: 145-195.

Levan, A. 1944. Experimentally induced chlorophyll mutations in flax. Hereditas 30: 225-230.

Levy, A. and Ashri, A. 1973. Differential physiological sensitivity of peanut varieties to seed treatment with the mutagens. Ethidium bromide, MNNG and Sodium azide, Radiat. Bot. 13: 369-374.

_____. and _____. 1975. Ethidium bromide-An efficient mutagen in higher plants. Mutation Res. 28: 397-404.

_____. and _____. 1978. Induced plasmon mutations affecting growth habit of peanuts. Mutat. Res. 51: 347-360.

Levy, A., Ashri, A. and Rubin, B. 1979. Ethidium bromide uptake by peanut seeds and its relationship to varietal sensitivity and mutagenic efficiency. Environmental and Experimental Botany, 19: 49-57.

*Lin, H. 1966. Studies of the genetic behaviour of quantitative characters in the hybrid progenies of Virginia and Spanish peanut. J. Agri. Ass. China. 53: 1-7.

Loesch, Jr. P.J. 1961. Inheritance studies of X-ray mutant and the effect of mutated background genotype on mutant expression in Arachis hypogaea L. Dissertation Abstr. 1961: 22. Order No. 61-1629[illegible]800.

_____. 1964. Effect of mutated background genotype on mutant expression in Arachis hypogaea L. Crop Sci. 4: 73-78.

_____. and Hammons, R.O. 1968. Inheritance of macromutants (MO 4-18.5 kR). Radiat. Bot. 8:94-108.

*Lush, J.L. 1949. Heritability of quantitative characters in farm animals. Proc. Intern. Cong. Genet. 8th. Stockholm, 1948, 356-375.

*Mackey, J. 1954. Mutability in diploid and polyploid level. Proc. Intern. Cong. Genet. 9th Congr. Bellagio, Italy, 1953. Caryologia 6: (Suppl. pt.2) 697-698. Caryologia

_____.1961. Methods of utilizing induced mutation in crop improvement. Mutation and Plant Breeding. Natl. Acad. Sci. U.S-Natl. Res. Council, publ. 891, pp.336-363.

_____.1968. Mutagenesis in vulgare wheat. Hereditas 59: 505

*Marghittu, V. 1973. The effect of combined action of gamma rays and diethyl sulphate on french beans. Analele Universitatti din Craiova. III a. 4: 137-143,

*Mehandjiev, A. 1969. Effects of combined action of gamma rays and diethyl sulphate on garden peas. Genetika i selekcija., 2: 39-53.

Mikaelson, K. 1968. Effects of fast neutrons on seedling growth and metabolism in barley. Neutron irradiation of seeds II (Tech. Rep. Series No.92) IAEA, Vienna, 63-70.

Miura, K., T.Hashimoto and Yamaguchi, H. 1974. Effect of gamma irradiation on cell elongation and auxin level in Avena coleoptiles. Radiat. Bot. 14: 207-215.

Moh, C.C. 1971. Mutation breeding in seed coat colours of beans Phaseolus vulgaris L. Euphytica 20: 119-125.

Mohan Rao, P.K. 1972. Biological effects of combination treatments with ionising radiations (X-rays) and diethyl sulphate (DES) in barley. Mutation Res. 16: 322-327.

Mujeeb, K.A. and Greig, J.K. 1973. Gamma irradiation induced variability in Phaseolus vulgaris L. CV. Blue Lake. Radiat. Bot. 13: 121-126.

Muntzing, A. 1942. Frequency of induced chlorophyll mutations in diploid and tetraploid barley. Hereditas 27: 273-308.

Natarajan, A.J., Sikka, S.M. and Swaminathan, M.S. 1958. Polyploidy, radio sensitivity and mutation frequency in wheats. Proceedings International Conference on the peaceful uses of Atomic Energy, 2nd Conference, Geneva, 1958. United Nations Vol. 27: 321-331.

Nilan, R.A., Konsak, C.F., Heiner, R.E. and Froese-Gertsen, E.E. 1963. Chemical mutagenesis in barley, Genetics I. Proc. First Intern. Barley Genet. Symp., Wageningen, 35-54.

Norden, A.J. 1973. Breeding of the cultivated peanuts. Peanuts-culture and uses. 175-208. American Peanut Research and Education Association, Inc.

Oka, H.I., Hayashi, J. and Shiojiri, I. 1958. Induced mutations of polygenes for quantitative characters in rice. J. Hered. 49: 11-14.

Osborne, T.S. and Lunden, A.O. 1961. The cooperative plant and seed irradiation program of the University of Tennessee. Intern. J. Appl. Radiation, Isotopes 10: 198-209.

Palemsoma, D.L. 1966. The progress of selection for quantitative traits under different pressures after X-irradiation of seeds in Triticum aestivum spp. Vulgare. Proc. Fifth Yugoslav Symp. Rad. Res. in wheat, Savremena Poljoprivreda. 12: 225-261.

Patel, K.A. and Swaminathan, M.S. 1961. Mutation breeding in tobacco. Tobacco Sci. 5: 67-69.

Patil, S.H. 1966. Mutation induced in groundnut by X-rays. Indian J. Genet. Pl. Breed. 26: 334-48.

_____. 1973. Chlorina, a new chlorophyll deficient character in groundnut. Indian J. Genet. Pl. Breed. 33:82-87.

_____. 1973 a. Trombay groundnut selections for increased oil content and yield. Indian J. agric. Sci. 43: 370-376.

_____. and Bora, K.C. 1961. Meiotic abnormalities induced by X-rays in Arachis hypogaea. Indian J. Genet. Genet. Pl. Breed. 21: 59-62.

_____. and _____. 1963. Radiation induced mutations in groundnut. 1. Chlorophyll mutations. Indian J. Genet. Pl. Breed. 23: 47-49.

_____. and Mouli, C. 1975. Genetics of dwarf mutant in groundnut. Theor. Appl. Genetics. 46: 395-400.

_____. and _____. 1978. Selection of extreme form of fastigiata with high productivity in groundnut. Indian J. agric. Sci. 48: 351-358.

_____. and Thakare, R.G. 1969. Yield potential of X-ray induced Trombay groundnut mutants. Proc. Symp. 'Radiations and Radiomimetic substances in mutation breeding'. 1969. Food and Agric. Comm. Dept. Atomic Energy. Govt. of India. 375-378.

*Porsche, W. 1963. Mutations versuche mit weissen Lupinen (Lupinus albus L) Rontgen-Bestrahlung der Sorte. "neutra", Zuchter 33: 33-39.

Raman, V.S. 1959. Studies in the genus Arachis. VI. Investigation on 30-chromosomed interspecific hybrids. Indian Oilseeds J. 3: 157-161.

Ramaswamy, N.M. 1973. Investigations on induced mutagenesis in blackgram (Phaseolus mungo L). Ph.D. Thesis, Tamil Nadu Agric. Univ.

Rao, M. and Siddiq, E.A. 1976. Studies on induced variability for amylose content with reference to yield components and protein characteristics in rice. Environmental and Experimental Botany. 16: 177-188.

Raut, R.N., Sharma, B., Pokhriyal, S.C., Singh, M.P. and Jain, H.K. 1974. Induced mutations: Some basic findings and applied results. Indian J. Genet. Pl. Breed. 34A:311-315.

Rawlings, J.O., Hamway, D.G. and Gardner, C.O. 1958. Variation in quantitative characters of soybeans after seed irradiation. Agron. J. 50: 524-528.

Reitz, L.P. and Salmon, S.C. 1968. Origin, history and use of Norin-10 wheat. Crop Sci. 8: 686-689.

Sakai Kan-Ichi and Suzuki Akio. 1964. Induced mutation and pleiotropy of genes responsible for quantitative characters in rice. Radiat. Bot. 4: 141-151.

Sanga, A.S. and Sandhu, R.S. 1970. Genetic variability and correlation studies in groundnut (Arachis hypogaea L.) J. Res. PAU, Ludhiana. 7: 143-150.

_____. and _____. 1975. Variability and correlation studies in spreading groundnut. Oilseeds J. 5 (2): 5-8.

Sathiamoorthy, M.R., Natarajan, S.T., Ramachandran, T.K. and Thangavelu, S. 1978. Shift in association of metric traits in mutants of groundnut (Arachis hypogaea L.) Madras agric. J. 65: 470-471.

*Scarascia-Mugnozza, G.T. 1968. Mutation breeding in sexually propogated plants. Fifth Congress of the European Association on research in plant breeding. Milano, Pavia, 1968; 187-217.

Scossiroli, R.E. 1965. Value of induced mutations for quantitative characters in plant breeding. The use of Induced Mutations in Plant Breeding. (Rep. FAO/IAEA. Tech. Meeting, Rome, 1964). Pergamon Press, 443-450.

_____. 1966. Wheat mutagenesis in quantitative traits (Wheat genetics Symp., Lund) Hereditas (Suppl) 2: 85-101.

_____. 1977. Mutations in characters with continuous variation. Manual on Mutation Breeding (Tech. Report. Ser. No.119) IAEA, Vienna, 1977, 118-125.

_____, Palenzona, O.C. and Scossiroli-Pallegrini,S. 1966. Studies on the induction of new genetic variability for quantitative traits by seed irradiation and its use for wheat improvement. Mutation in Plant Breeding. (Proc. Panel, Vienna, 1966) IAEA/FAO, Vienna, 197-229.

Sharma, B. 1965. Influence of some chemical and physical mutagens on growth and development of peas in the first generation. Fl. Breed. Abst. 36 (3): 5350.

Sharma, R.P. and Swaminathan, M.S. 1969. On the combined effects of physical and chemical mutagens. Radiations and Radiomimetic substances in Mutation Breeding (Proc. Symp. Bombay, 1969) Dept. Atomic Energy, India, 70-78.

Sheheri, Y. and Ashri, A. 1970. Inheritance of several macromutations induced by diethyl sulphate in peanuts, Arachis hypogaea. Radiat. Bot. 10: 551-555.

Shivaraj, A., Gangaprasada Rao, N., Ramana Rao, B.V. and Razvi, M.A. 1962. Effects of fast neutrons on seeds of groundnut. Indian Oilseeds J. 11: 24-30.

_____, and Ramana Rao, B.V. 1963. A note on the effects of fast neutrons and gamma rays on groundnut. Indian Oilseeds J. 7: 156-157.

Siddiq, E.A. and Swaminathan, M.S. 1968. Induced mutations in relation to the breeding and phylogenetic differentiation of Oryza sativa. Rice Breeding with induced mutations. (Tech. Rep. Series. No.86) IAEA, Vienna, 25-51.

Sigurbjornsson, B. and Micke, A. 1969. Progress in mutation breeding. Induced mutations in plants. (Proc. Panel. Pullman, 1969) FAO/IAEA, Vienna, 673-698.

_____. and _____. 1974. Philosophy and accomplishments of mutation breeding. Polyploidy and Induced Mutation in Plant Breeding. (Proc. Panel Bari, 1972) FAO/IAEA, Vienna, 303-345.

Sivasubramaniam, S. 1978. Studies on induced mutations in peanut (Arachis hypogaea L.) Ph.D.Thesis, Tamil Nadu Agric. Univ. pp.125.

Smith, L. 1950. Effects of atomic bomb irradiations on seeds of cereals, J. Hered. 41: 125-130.

Smith, G.F. and Kersten, H. 1942. Root modifications induced in Zea mays seedlings by irradiating dry seeds with soft X-rays. Biol. Abstr., 17: 294.

Sree Ramulu, K. 1970. Mutations in Sorghum. Mutation Res. 10: 197-205.

*Stadler, L.J. 1929. Chromosome number and mutation rate in Avena and Triticum. Proc. Natl. Acad. Sci. Wash. 15:876-881.

Stucker, R.E., Emery, D.A. and Gregory, W.C. 1968. Estimating genetic parameters in a radiated autogamous population: I. Components of radiation induced quantitative variation (NO 2-20 kR) A Radiation Breeding Experiment with Peanuts. Radiat. Bot. 8: 81-147.

Swaminathan, M.S. 1963. Evaluation of the use of induced micro and macro-mutations in the breeding of polyploid crop plants. Estratto da: L'energia nucleare in agricoltura, 243-277.

_____. 1965. A comparison of mutation induction in diploids and polyploids. The Use of Induced Mutations in Plant Breeding. (Rep. FAO/IAEA Tech. Meeting, Rome, 1964) 619-641.

_____.1977. The detection of induced mutations. Manual of Mutation Breeding, IAEA, Vienna, 1977. 138-141.

_____, Siddiq, E.A., Sing ,C.B. and Pai, R.A.1970. Mutation breeding in rice in India. Rice Breeding with Induced Mutations II. (Tech. Rep. Series No.102) IAEA, Vienna; 25-43.

*Tedin, O. 1954. X-irradiation of Lupinus luteus. Acta Agric. Scand. 4: 569-573.

Trujillo Figueroa, R., Betancourt Rios, M.J. 1972. Estudio sobre la variabilidad inducida por etil metansulfonato (EMS) in caracteres cuantitativos de plantas hermanas de mutantes drasticos en trigo (T. vulgare) con propositos de selection. Induced Mutations and Plant Improvement (Proc. Study Group meeting, Buenos Aires, 1970) IAEA, Vienna, 405-423.

Walther, F. and ... Hang, A. 1973. Radiobiological investigations in cereals. VII. Relationship between radical content and radio sensitivity in caryopses of radiosensitive and radioresistant wheat cultivars. Radiat. Bot. 13: 19-25.

Yagyu, P. and Morris, R. 1957. Cytogentic effects of X-rays and thermal neutrons on dormant tomato seeds., Genetics 42: 222-238.

Yamaguchi, H., Tano, S. and Tatara, A. 1974. Mutations induced in germinating barley seed by diethyl sulphate treatment at the interphase. Polyploidy and Induced Mutations in Plant Breeding. (Proc. Panel FAO/IAEA, Bari, 1972). IAEA, Vienna, 1974, 393-399.

Yarbrough, J.A. 1949. Arachis hypogaea L. The seedling ite cotyledons, hypocotyl and roots. Amer. J. Bot. 36: 758-772.

*Original not seen.