A COMPARATIVE STUDY ON X_4 MUTANTS OF COW PEA (*Vigna sinensis* L. Savi.) WITH REFERENCE TO QUANTITATIVE CHARACTERS

BY

E. N NATARAJAN, B Sc, (Ag)

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C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bona fide work carried out by Shri E.N. Natarajan, under my direct supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

(Dr. C.K.N. NAIR) Principal and Additional Director of Agriculture (Research)	16.8.66 (P. KUMARA PILLAI) Vice-Principal & Professor of Agricultural Botany

Agricultural College and Research Institute,
Vellayani, Trivandrum,

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INTRODUCTION

INTRODUCTION

Radiation genetics had its origin in the researches of Muller and Stadler, almost thirty five years ago. The discovery of the mutagenic effect of X-rays by Muller (1927) in Drosophila and the induction of mutations in maize and barley by Stadler (1928) attracted the interests of geneticists and plant breeders alike. The demonstration that radiation are effective in inducing genetic changes in plants gave an added impetus to plant breeding efforts.

Two of the major factors in evolution - recombination and selection - have been extensively used by breeders and refined methods were developed during the first half of this century. Researches during the last thirty years have shown that mutations, the third major factor in evolution, offer an additional tool to modify and improve cultivated plants in a way similar to conventional breeding methods.

Mutation breeding through ionizing radiations has proved to be generally useful in practical plant-breeding. Its usefulness was first reported in Sweden through the brilliant work of Nilson - Ehle, Gustafsson and their associates. They demonstrated in cereals that varieties having higher yield, stiffer straw and earlier ripening habit could be successfully produced by radiations. There after its usefulness in improving several other crop plants was reported from many parts of the world.

In U.S.A., Gregory (1956) by his comprehensive experiment in groundnut (Arachis hypogaea) demonstrated the use of ionizing radiations in crop improvement. Mutation breeding through the use of ionizing radiation has resulted in the development of outstanding varieties of barley, mustard and oil rape in Sweden and of common bean in Michigan. At the Indian Agricultural Research Institute, New Delhi, induction of awning in several New Pusa strains of wheat has been made possible through the use of ionizing radiations.

Cow pea (Vigna sinensis, L. Savi) constitutes one of the prominent members of the pulse group in India. Cow pea due to its adaptability to widely varying soils and climatic conditions and ease of cultivation, has turned up as a choice catch crop in this part of the country. Hence the necessity for further improvement in this crop needs no emphasis.

Cow pea is a diploid, naturally self-pollinated leguminous plant which provides very little genetic variability under natural conditions. If, by some artificial means like the use of ionizing radiations, genetic variability is induced, selection for desirable quantitative economic characters becomes possible.

With this in view, Nair (1964) got the seeds of the 'African' variety of cow pea irradiated with X-rays. He studied the various morphological and physiological mutations in both X_1 and X_2 generations. Kumaran (1965) studied the morphological and cytological behaviour of twenty one X_3 mutants. Eight mutant types were selected from X_3 based on the seed and pod characters for further study.

The present investigation attempts at a comparative study of these eight mutant types for several quantitative economic characters in X_4 generation. This work mainly aims at isolating economic mutants possessing desirable characters like, increased yield of seed and haulms, early flowering, early maturity and higher protein content.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Since the discovery of X-rays by Rontgen in 1895, scientists all over the world started working on the effects of these rays on plants and animals. The effects of radiation, chiefly X-rays and Gamma rays on plants were studied extensively as early as 1908 by Gager, and later by Petry (1922) and others. These earlier workers failed to explain clearly the mutagenic action of radiation.

With the successful demonstration of Muller (1927) in *Drosophila*, and Stadler (1928) in Maize, artificial induction of mutation has received a special impetus in crop and animal breeding programmes. In the earlier years of research, the main interest was centered on the study of morphological and physiological changes caused by radiations and other mutagenic agents.

Attention was later directed to the understanding of the genetic effects produced by these agents. Genetic effects have been produced by means of radiations in a wide range of organisms, often only or mainly with the object of obtaining genetic variants for the use in various researches; for example, in *Neurospora* for the study of biosynthesis

(Beadle and Tatum, 1945), in *Drosophila* for the study of position effect (Stern, 1944) and in *Zea* for the cytological mapping of gene loci (Anderson and Randolph, 1945).

The genetically effective radiations are of two kinds, namely, ionizing and non-ionizing. The ionizing radiations are the alpha, beta, and gamma radiations of radio active substances, X-rays, protons and neutrons. The only effective non-ionizing radiation is ultra-violet light. Doses of X, alpha, beta and gamma rays are commonly measured in roentgen(r) units being the dose of radiation required to liberate one electrostatic unit of change in 0.001293 g. of air. X-rays increase the small rate of spontaneous mutations while all the other radiations have a similar but a lesser effect.

Effects of ionizing radiations

Ionizing radiations cause chromosomal aberrations.

(1) The chromosomal aberrations include dot deletions, rod deletions, dicentric chromosomes, and ring chromosomes. Though it is difficult to detect them, inversions and free translocations, are also produced.

(2) Irradiation at prophase results in chromatid aberrations.

(3) Irradiation in very late prophase or pro-metaphase produces half chromatid or sub-chromatid aberrations.

Radiation frequently cause changes in the chromosome number also. Polyploidy is often induced as a result of inhibition of mitosis by radiation. There are some gene mutations induced by radiation which are genetic changes, characterised by the cytologically visible alterations in the chromosomes. Sometimes these have been called "Point mutations". Effects of ionizing radiations also result in the production of cytoplasmic mutations.

Beneficial new hereditary traits

Ionizing radiations, irrespective of mode of production and of properties, readily induce hereditary changes, which are stable and lead to new traits manifested also in the subsequent generations. For a long period of time induced changes were considered by most workers to lead to a break down of the hereditary material, thus being exclusively 'harmful', if not entirely lethal. It is a fact indeed, that, most of the induced mutations decrease viability in the homozygous state. In organisms like barley (Gustafsson, 1946-1954) or *Antirrhinum* beneficial lethals are not uncommon. The occurrence of beneficial lethals has also been described in *Drosophila* even for the X-chromosome.

Radiation in Plant breeding

In recent years, the geneticists concentrate more on the possible utilization of several mutagenic agents particularly X-rays in artificially inducing economic mutations in a variety of cultivated crops. Two Swedish Scientists, Nilsson Ehle and Gustafsson were the first to put this idea to practical use in crop breeding. They began shooting X-rays at barley seeds in almost lethal doses and in few years found that they could step up nature's mutation rate as much as a thousand fold. A few geneticists and plant breeders in Germany and Russia also recognised early that this method might be used to increase variability in crop plants.

The principles for the induction of possible mutations have now been worked out in a large number of Agricultural species. The Swedish group of workers have chiefly concentrated on barley, where the mutations are easily identified. In the case with the "erectoid" mutants in barley, many displayed features valuable from an agricultural point of view. Wettstein, D. Von (1954), one of the Swedish workers in the field of radiation research says "we have found that by radiation we can get almost anything out of plants we really want". Gustafsson and Olof Tedin (1954), after several years of radiation research conclude, that induced mutation can increase the yielding capacity of a variety or leave this capacity intact and improve upon special characters of importance in agriculture as regards earliness, protein or oil content, baking quality, malting properties, fibre strength and grain size in cereals as well as in peas, lupines, flax, mustard, tomatoes etc.

A brief review of the artificial induction of mutations by X-rays on several crop plants so far investigated is attempted here.

1. Germination

Three years after the discovery of X-rays, Maldiney and Thouvenin (1898) found that germination in *Convolvulus* and *Lepidium* was hastened by irradiation. A similar result was obtained by Pfiffer and Simmermacher (1915) on *Vicia faba*. But Ancel (1924) obtained contradictory results and reported that in no case germination was hastened by irradiation.

Kumar and Joshi (1939) reported that X-irradiation was found to be deleterious to germination in Brassica juncea, Nicotiana tabacum and Pennisetum typhoides. Gustafsson (1941) stated that different kinds of plants react differently to X-irradiation. Of several mutants studied erectoides-4 and erectoides-5, germinated more slowly than the other erectoide types. Jacob (1949) observed a higher germination percentage in irradiated seeds of Jute (Corchorus sp.). Spencer and Cabanillas (1956) reported that X-ray irradiation appeared to promote earlier germination in Indigofera endecaphylla. But reduction in percentage of germination was noted by Lesley and Lesley (1957) in tomato and Matsura et al (1957) in wheat seeds.

Gottschalk and Scheibe (1960) reported that the germinability in leguminous plants was independent of X-ray dose and was supported by the findings of several workers like Kundu et al (1961) in Corchorus sp., Shasthry and Ramiah (1961) in Oryza, Sjodin (1962) in Vicia faba, and Katayama (1963) in Oryza sativa.

Nair (1964) and Kumaran (1965) reported that X-irradiation affected germination in seeds of cow pea (Vigna sinensis). In X_2 and X_3 generations, reduction in germination was observed in certain mutants studied by them.

Reports of the effect of X-irradiation on the germinability of plants in their advanced generations are very few.

2. Effect of radiation on height

Annual report of the Bose Research Institute for the year (1950-51) indicates that tall mutants attaining greater height were obtained in Jute subjected to X-ray treatment. Tedin and Hagberg (1952) reported dwarf mutants in X_3 generation of *Lupinus luteum*. An increase in genetic variability for plant height was observed by Krull and Frey (1954) in oats treated with thermal neutron. Hackbarth (1955) observed in X_2 generation of irradiated *Lupinus albus* a number of dwarf plants with short stems. Matsumura and Fujii (1955) observed dwarf mutants in *Nicotiana tabacum* and *Nicotiana sylvestris*. Occurrence of similar dwarf mutants were reported by Korah (1959) in X_1 and X_2 generations of X-irradiated *Oryza*; Shasthry and Nandhachary (1965) in X_4 generation of irradiated rice NP 130; and Nair (1964) in X_2 of X-irradiated cow pea (*Vigna sinensis*).

Johnston (1961) reported some significant cases of disparity between the selected and untreated lines of oats in X_5 generation as regards height. Mutation breeding in cultivated rice NP 130, yielded mutants showing medium height in M_2 which may prove useful in breeding for lodging resistance (Venkatanadhchary, 1963). Sakai and Suzuki (1964) observed that by mutation, plant height in X-rayed population of rice tended on an average to increase from the control. Nair (1964) found dwarf mutants in X_2 of X-irradiated cow pea. Shasthry and Nadhachary (1965) who worked with X_4 generation of irradiated NP 130 rice suggested that dwarfs are the most frequent of all viable mutations.

3. Effect of radiation on tillering

Venkatanadhchary (1963) reported some mutants showing increased or decreased tillering in cultivated rice NP 130 subjected to X-radiation. Sakai and Suzuki (1964) suggested that X-ray irradiation in rice affected mutation towards a decrease in polygenic characters like number of tillers. Toriyama and Futsuhara (1962) obtained a mutant FU 54 by subjecting the rice variety Fujisaka-5 to X-radiation. This mutant was reported to yield better than the parental variety owing to its higher number of tillers.

4. Effect of radiation on flowering

Report of the Bose Research Institute for the year 1950-51 includes early flowering mutants in Jute subjected to X-ray treatment. Tedin (1954) obtained ten early flowering mutants in sweet lupine (*Lupinus luteus*) after X-irradiation. In some cases earliness in flowering was correlated with the early ripening. Matsumura and Fujii (1955) noted a mutant form flowering two weeks earlier than the control among the X-ray induced mutants of *Nicotiana tabacum* and *Nicotiana sylvestris*.

Earliness in flowering by seventeen days in the mutant forms of X_3 generation in *Sesamum* was observed by Rai and Jacob (1956). Similar results were reported by Gladstones (1958) in *Lupinus digitalis*. Gottschalk (1960) obtained by treating *Pisum sativum* with X-rays, a mutant 46/57 which flowered ten days earlier than the control and also ripened earlier. But Abrams and Velez-Fortuno (1962) observed early, intermediate, and late flowering lines in X_3 and X_4 generations of irradiated Pigeon peas (*Cajanus cajan*).

5. *Effect of radiation on maturity*

Gustafsson (1941) reported that out of several "erectoid" mutants studied, most of them set ears at about the same time as golden barley used as control or one to two days later. He observed only two mutants that ripened one to two days earlier. Akerman (1946) reported that "erectoides 16", a morphological mutant, ripened at least a week earlier than 'maja' barley, the control. Froier (1946) reported variants in irradiated black oats which ripened in some instances a week earlier than the control.

Gustafsson (1947) reported that induction of mutations in oil turnips and soya beans hastened the maturity slightly. Down (1948) obtained early bean by treating Michelite with X-rays. Report of the Bose Research Institute for the year 1950-51 also includes early maturing types in Sesamum subjected to X-ray treatment. Tedin and Hagberg (1952) obtained a large number of early mutants in yellow lupine after X-ray treatment.

Chaudhuri (1953-55) observed five early mutants in irradiated Linum, but no plants in the X_2 and X_3 generations were as early as these mutants. Onnfrijchuck (1953) reported that a genetically stable change affecting maturity had occurred in one "speltoid" mutant since X_2 and X_3 plants ripened several days earlier than the control. Mackey (1954) reported that artificial induction of mutation in polyploid wheat resulted in lines that had matured earlier. Frey (1954) observed some mutants maturing two to six days earlier in oats subjected to X-ray treatment.

Reports of the Chinese American Joint Commission on Rural Reconstruction, Taiwan (1957) indicate that selection in R_4 and R_5 generations for earlier maturity is highly promising in rice subjected to X-ray radiation. Ehrenberg (1961) obtained forty three early mutants in X_3 generation of barley subjected to ionizing radiations and chemical mutagens. Li et al (1961) reported an early 'erectoides' mutant both in Japonica and indica varieties of rice subjected to X-ray treatment. Johnston (1961) noted that disparity in heading date was significant between selected and untreated lines in X_5 generation of barley.

Delayed maturity in some of the mutants of oats was reported by Mackey (1954). Vettle (1959) observed among the Triticale (wheat x rye) hybrids; fewer early and late forms during X_2 and X_3 generations. Boratynska (1962) in his attempt to produce mutants with a short growing season in Ricinus communis subjected to X-ray treatment, failed to obtain any such form. Sakai and Suzuki (1964) noted an apparent increase in the mean values of heading date in X_4 lines of irradiated rice.

6. Effect of radiation on average number of pods, mean length and average number of seeds per pod

Markl et al (1962) observed improvements in some yield characters like average number of fruiting pods and average number of seeds per pod in the X_3

generation of Soya bean treated with X-rays. Matsuo et al (1964) treated rice seeds with X-rays, thermal neutron or diepoxybutane and studied variations of several quantitative characteristics in M_6 generation. They observed significant differences in the mean values of panicle length among treated and between treated and controls. Sakai and Suzuki (1964) observed that X-irradiation in rice affected mutation towards decrease in polygenic characters like number of panicles per plant and length of individual panicle.

7. Effect of radiation on yield

Grain

Gustafsson (1941) conducted preliminary yield experiments with ten induced mutations in barley. He observed three out of the ten mutants to be superior than golden barley, the unirradiated mother strain. Among the three superior mutants, erectoides-3 was found to be better than the best series of golder barley. Tedin and Hagberg (1952) after ten years of their work with X-ray induced mutations in yellow sweet lupine (Lupinus luteus) observed two mutants to be equal to the parent strain as regards grain yield. The following two new varieties were released through mutation breeding programme in Sweden.

"Svalof Primax white Mustard", a selection from an irradiated population was released for large scale production in 1950. Andersson and Olsson (1954) reported that the above gave an increased yield of 4% over the parent population. "Regina II Summer Oil Rape" was released for commercial production in 1953. Celin (1954) reported higher seed yields from some of the mutants in peas (*Pisum sativum*) subjected to X-irradiation. Mackey (1954) reported that mutation breeding in oats resulted in increased yield in combination with delayed maturity.

An increase in the genetic variance in yield of dry pods of X-irradiation was observed by Gregory (1955), in pea nuts (*Arachis hypogaea*). The genetic variance of the X_2 was increased three times when compared to the control. Gregory (1956) after his irradiation work at the North Carolina Experiment Station reported that mutant progenies of pea nuts in M_5 generations were significantly higher in yield than the control. 'Sanilac', a commercial variety originated from an irradiated material of common bean which was observed to be superior in yield as well as resistant to diseases (Down and Anderssen, 1956) was released for commercial production in U.S.A.

Van Emden and Jaarverslag (1959) observed in Soya bean that X_6 lines of Laris and Veda have significantly higher yield than their parental varieties. Jaarverslag (1960) also reported that certain of the X_5 lines of Pea nut (Arachis hypogaea) out yielded the parental variety Matjan. Li et al (1960) obtained promising high yielding lines from Taichung 65 and Liu-chou by subjecting them to X-ray treatment. One mutant line from the latter out-yielded the original variety by more than 30%.

Svejda (1961) reported that the average yield of X_3 and X_4 bulks originating from X-irradiated seeds of Pea (Pisum) variety 'Chancellor' was considerably higher than that of the control. Two bulked samples when tested at ten different locations across canada were found to be 10% higher in yield than that of the original variety. Abrams and Velez-Fortuno (1962) in their radiation research with pigeon peas (Cajanus cajan) reported that many mutant lines had out-yielded the parent both in X3 and X_4 generations. Yields from the late flowering lines were found to be lower than those from the early flowering lines. Out of the two hundred and eightyone morphological mutants observed by Kawai (1963) in rice, six were found superior to their parents in yield. Toriyama and Futsuhara (1964) in rice obtained a mutant FU.54, which yielded better than Fujisaka 5, used as the parent. They concluded that the higher yield observed in Fu 54 was owing to its higher number of tillers. Matsuo et al (1964) studied several quantiative characteristics in M_6 generation of rice treated with X-rays and thermal neutrons. They observed significant differences between M_6 mutants and the control with respect to their weight of rice panicle per stock. They have also reported that mutation of polygenes could occur in plus as well as minus direction with regard to grain yield and a few other quantitative characters.

Contradictory to the above findings, reports from several workers support the view that induction of mutation through radiation lowers the yield in crop plants. Gustafsson (1941) conducted preliminary yield experiments with ten induced mutations in barley. He found seven out of ten mutants to be inferior in comparison with golden barley, the unirradiated mother strain. None of the seven mutations gave a production equal to golden barley. Their inferiority has been undoubtedly confirmed and hence being kept for theoretical purpose only. Gottschalk (1960) obtained a mutant 46/57 by irradiating Pisum sativum which although had several desirable economic characters was lower in yield than the parental form. Johnston (1961) studied the effect of X-irradiation on several quantitative characters in oats. He reported that significant yield variations in X_4 and X_5 generations were only in the direction of lower yield. Sakai and Suzuki (1964) after their comparative study of X_4 lines of irradiated rice and control reported that X-ray irradiation affects mutation towards decrease in most of the polygenic characters including yield.

8. Effect of radiation on the yield of straw.

Levan (1944) produced a peculiar yellowing grain variant of concurrent flax yielding 6% more straw than the parent line. Tedin and Hagberg (1952) reported that, out of the several mutations studied in the irradiated yellow sweet lupine, two were found to be equal to the parent strain as regards green matter production. Caric and Mihaj-lovic (1961) reported an increased straw yield in some wheat and maize hybrids subjected to radiation. They also indicated that yield of straw was not correlated with yield of grain. Boratynska (1962) obtained a gigas mutant having increased vegetative growth in *Ricinus communis* subjected to radiation treatment.

9. Effect of radiation on seed weight

Gustafsson (1941) indicated that the higher yield obtained in 'erectoides' 3 of barley was exclusively due to its higher 1000-grain weight. Krull and Frey (1954) found in oats that thermal neutron treatment had brought about an increase in genetic variability for 100-seed weight.

10. Effect of radiation on the quality of grain

Protein content

Preliminary yield experiments with ten induced mutations in barley by Gustafsson (1941) showed a pronounced negative correlation between yield and protein content. But Papa *et al* (1961) reported that selection for protein and oil content could be more effectively done in irradiated population of soya bean varieties, "Adams and Hawkeye".

MATERIALS AND METHODS

MATERIALS AND METHODS

A. EXPERIMENT

The present investigation attempts at a comparative study of eight mutant types of cow pea (*Vigna sinensis*, L. Savi.) in X_4 generation for certain quantitative characters. Comparisons are made among the eight mutant types themselves, as well as with the control which is an unirradiated sample of the original variety of cow pea (*Vigna sinensis*, L. Savi).

B. MATERIAL

The material taken for the present investigation consisted of eight mutant types obtained from X_3 generation studied by Kumaran (1965). The original material (*Vigna sinensis*, L. Savi) was got irradiated in 1963 by Nair with different dose of X-rays ranging from 1,000 r to 15,000 r using Philips X-ray unit at the Agricultural College and Research Institute, Coimbatore.

Nair (1963-64) studied X_1 and X_2 generations. Kumaran (1964-1965) selected twenty one mutant types from X_2 and studied the morphological and cytological behaviour in X_3 generation.

The list of the eight mutant types selected for the present study with their important characteristics are presented in table I.

C. METHODS

1. Experimental site and design

The present investigation was carried out in the Division of Agricultural Botany, Agricultural College and Research Institute, Vellayani, Kerala during the academic year 1965-66.

The experiment was laid out in Randomised Block Design with nine treatments replicated four times (vide Fig. 1). The size of an individual bed was 6 metres x 1.2 metres. The spacing adopted between rows and between plants in a row was 30 centimetres each. In each bed there were three rows of plants, each row containing 19 plants (A general view of the standing crop is shown in Plate 1).

2. Sowing and culture

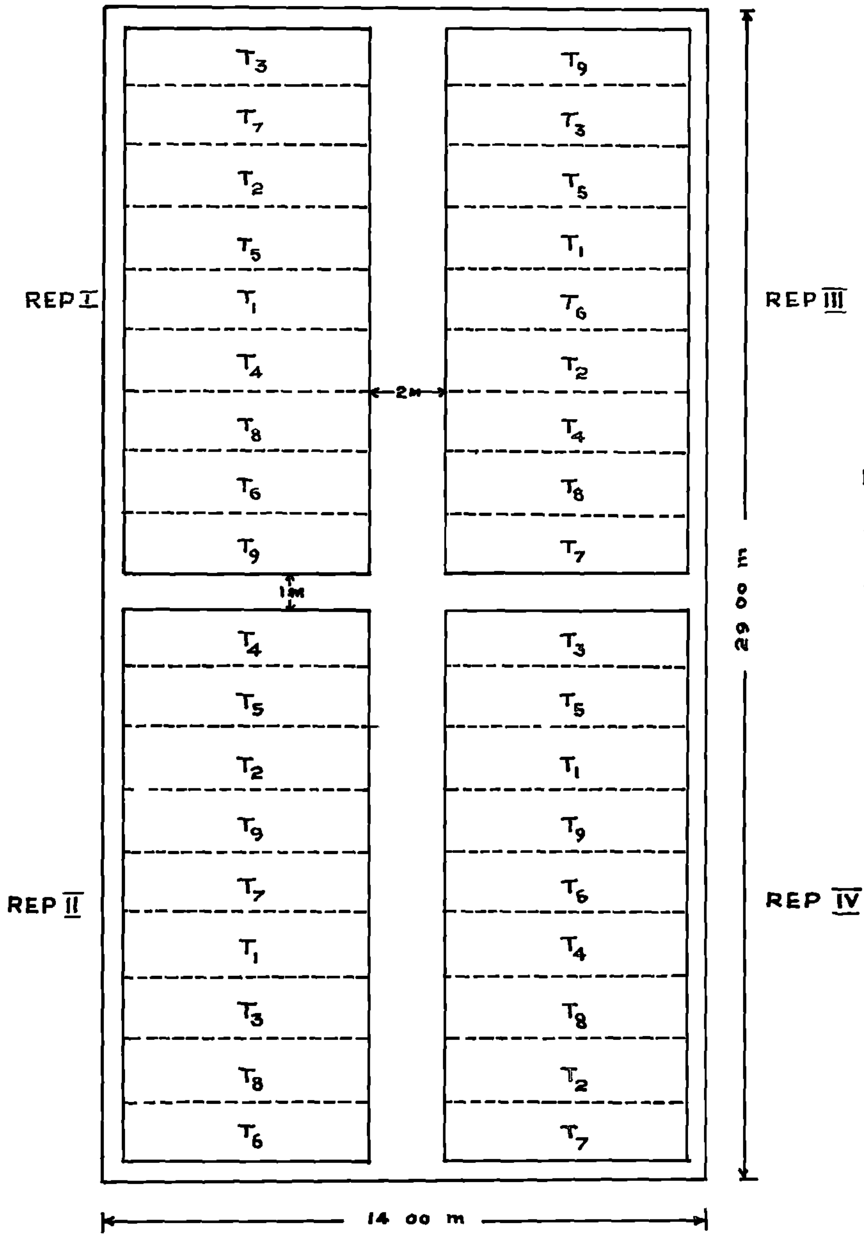
Seeds were dibbled on raised beds in three

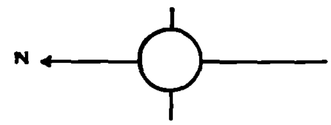
TABLE I

Description of Mutant types of cow pea (*Vigna sinensis*) taken for the present study

Type No.	Description of types	Leaf type	Flower colour	Pod shape	Pod colour	Seed colour and size
1	Control, African type	Small	Light pinkish	Small	Straw	Brown, small
2	White seed type	Small	White	Small	Straw	Straw white, small
3	Light brown	Medium	Pinkish white	Medium	Straw	Light brown, small
4	Reddish with black mottlings	Medium	Pinkish	Small	Straw with pink shaded	Reddish with black mottlings, small
5	Straw brown mottled	Small	Pinkish	Small	Straw	Straw brown mottled, small
6	Large leaved mutant	Large	Dark pinkish	Medium	Pink varigated	Light brown, medium.
7	Ashy violet mottled	Large	Dark pinkish	Long	Straw	Ashy violet mottled, medium.
8	Large brown	Medium	Pinkish	Long	Straw	Brown, medium
9	Straw white with red patches around the eye	Medium	Whitish with pink shade	Long	Light brown with pink shade	Straw white with red patches around the eye, large

Fig. 1. Plan of the layout of the experimental field





RANDOMIZED -

LAY OUT . BLOCK DESIGN

REPLICATIONS : 4

TREATMENTS : 9 (MUTANT TYPES)

AREA . 29 m X 14 m

PLANTED ON 9- 9 - 1965

SINGLE PLOT ENLARGED

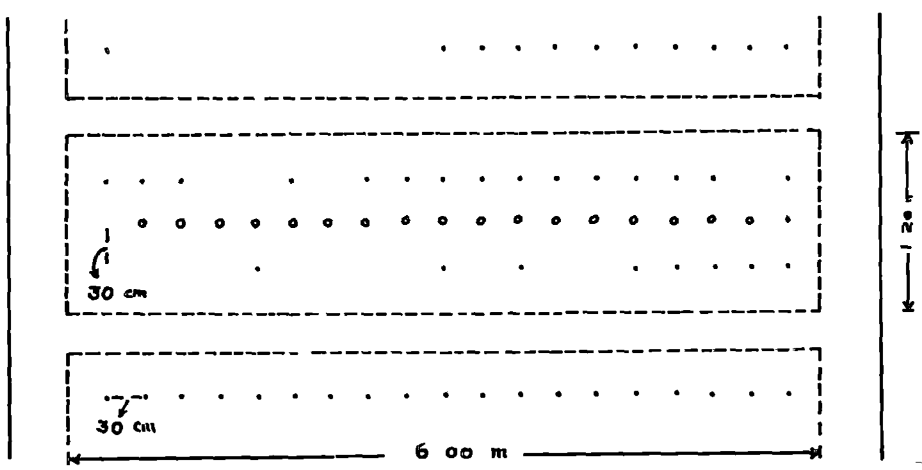


FIG 1

rows. The experimental field received a basal dressing of half-a-ton of Farmyard manure. The crop was grown under irrigated condition. Uniform insecticidal spray was given thrice with Parathion 0.025% against aphids and leaf eating Caterpillars. Fytolon was sprayed against the disease caused by *Choaenophora* sp. which was noted in a mild form.

3. Sampling and observation

Observations for quantitative characters were taken only from eight plants selected at random from the middle row of each plot, keeping the two side rows as border. Thus there were thirty two plants (8 plants x 4 replications) from each type and the total number of plants studied being two hundred and eighty eight (32 x 9).

4. Characters studied

The two hundred and eighty eight plants were individually labelled, studied for the following characters and harvested keeping individual record of all the plants.

(a) Germination

Germination counts were taken for eight days from 4th day of sowing. The percentage of germination was then calculated.

(b) Height of the plant

Height of individual observational plants was measured in centimetres on 30th day and recorded.

(c) Number of branches

All the branches were counted on 30th day after sowing and recorded.

(d) Flowering

The date of first flowering for each individual observational plant was recorded and from then on flower counts were taken every day. Likewise, the date of completion of flowering for each of the observational plant was recorded. From these observations the following were calculated.

(i) The mean number of days taken by each type for onset of flowering from the date of sowing.

(ii) The mean number of days taken by each type for completion of flowering (from the date of sowing).

(iii) The mean period of flowering phase (from onset to completion of flowering).

5. Number of pods per plant

All matured pods having seeds were collected from individual plants and recorded.

6. Mean length of pods per plant

A random sample of five pods per plant was taken and the mean length of pods was measured.

7. Number of seeds per pod

The same random sample taken for the observation No. 6 was shelled, and from that the mean number of seeds per pod was calculated.

8. (i) Yield of pod

Matured pods, from individual observational plants were harvested perioidically, dried and the weight was recorded separately.

(ii) Yield of seed

Weight of seeds after shelling out the pods collected from individual plant was recorded.

9. Weight of haulm

After the final harvest, all the observational plants were up rooted, dried uniformly and their dry weight was recorded.

10. 100-seed weight

Hundred seeds selected at random for each type were weighed and recorded.

11. Analysis of protein

A representative composite sample of seeds from all the four replications of each treatment was powdered after uniform drying. From this a representative sample of two grams of powder for each type was taken for the estimation of nitrogen adopting Kjeldal's method. The protein content was then calculated as follows.

Protein content = Total nitrogen x 6.25

12. Statistical analysis

The whole data were processed, and tabulated plot-wise (for eight plants), treatment-wise (for thirty two plants) and for all the treatments taken together (for two hundred and eighty eight plants) in order to suit the following analytical work.

Analysis of variance was worked out for the different characters studied to find out whether there were any significant differences among the mutants themselves and also with the control.

ANALYSIS OF VARIANCE

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replication	(r - 1)	S.S.R.	S^2R	S^2R/S^2E
Treatments	(v - 1)	S.S.V.	S^2V	S^2V/S^2E
Error	(r-1) (v-1)	S.S.V.R.	S^2E	
Total	(rv - 1)			

Where, r is the number of replications, and v is the number of treatments.

Variance ratios or 'F' ratios for treatments were calculated and compared with the critical value of 'F' for (v - 1) and (r - 1) (v - 1) degrees of freedom at both 5% and 1% levels of significance. The results were then interpreted.

RESULTS

R E S U L T S

The present investigation was carried out for a comparative study of certain quantitative characters of eight X_4 mutants in cow pea. The object of this experiment was to isolate the economic mutants having desirable quantitative characters.

The characters studied are given below:

(1) Germination

(2) Height of the plant

(3) Number of branches

(4) Number of days taken for onset of flowering

(5) Number of days taken for completion of flowering

(6) The exact flowering phase

(7) Number of pods per plant

(8) Length of pods

(9) Number of seeds per pod

(10) Weight of pods per plant

(11) Weight of seeds per pod

(12) Weight of haulm per plant

(13) 100-seed weight

(14) Protein content

1. Germination

Germination counts were taken for eight days from the 4th day of sowing. The percentage of germination was calculated for each type. The data on the germination of seeds for the nine types were analysed statistically and the analysis of variance table is given below.

TABLE - II (a)

Analysis of variance for percentage of germination

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	130.2363	43.4121	2.07
Treatments	8	11,219.2757	1,402.4095	66.91**
Error	24	503.0181	20.9591	
Total	35	11,852.5301		

It was found that there was very high variation in the germination of seeds among the types. The mean germination percentages corresponding to the nine types are given in table II(b).

TABLE - II (b)

Percentage mean of germination

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_5	T_8	T_4	T_7	T_3	T_1	T_6	T_2	T_9
Mean value	90.35	87.98	86.98	83.56	80.83	59.65	43.08	21.20	18.57

C.D. = 6.68

T_5 T_8 T_4 T_7 T_3 T_1 T_6 T_2 T_9

The mean germination percentage varied from 18.57 to 90.35. Type T_5 recorded the maximum germination percentage, followed by T_8, T_4, T_7 and T_3 all of which had significantly higher germination than type T_1 (control). Germination was significantly low in types T_6, T_2 and T_9.

2. Height of the plant

The data on the height of plants for the nine types recorded on tho 30th day were analysed statistically. The analysis of variance table is presented below.

TABLE - III (a)

Analysis of variance for height of plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	4.9224	1.6408	$<$ 1.00
Treatments	8	209.5546	26.1943	2.49**
Error	24	252.5989	10.5249	
Total	35	467.0759		

It was found that there was very high variation in the height of plants among the types.

The mean heights of the plants corresponding to the nine types are given in table III (b).

TABLE - III (b)

Mean height of plants in cm.

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_8	T_3	T_1	T_5	T_4	T_7	T_2	T_6	T_9
Mean value	19.81	17.15	15.91	15.87	15.31	14.56	13.59	12.36	11.27

C.D. = 4.73

T_8 T_3 T_1 T_5 T_4 T_7 T_2 T_6 T_9

The mean heights of the plants in the nine types varied from 11.27 cm. to 19.81 cm. Type T_8 had the maximum mean height followed by T_3, and type T_9 had the minimum height but the differences were not significant from that of T_1 (control). However T_7, T_2, T_6 and T_9 were significantly inferior to T_8.

3. Number of branches per plant

The data on the number of branches recorded on the 30th day were analysed statistically. Table IV(a) shows the analysis of variance for this character.

TABLE - IV (a)

Analysis of variance for number of branches per plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	0.2601	0.0867	< 1.00
Treatments	8	48.0218	6.0027	27.95**
Error	24	5.1534	0.2147	
Total	35	53.4353		

It was found that there was very high variation in the number of branches per plant among the nine types.

The mean number of branches per plant corresponding to the nine types are presented in table IV(b).

TABLE - IV (b)

Mean number of branches per plant

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_8	T_5	T_3	T_7	T_1	T_6	T_4	T_2	T_9
Mean value	5.75	5.69	5.67	5.50	4.75	4.57	4.20	3.69	2.11

C.D. = 0.68

T_8 T_5 T_3 T_7 T_1 T_6 T_4 T_2 T_9

The mean number of branches varied from 2.11 to 5.75. Types T_8, T_5, T_3 and T_7 did not differ significantly among themselves but were superior to T_1 (control). Types T_2 and T_9 were significantly inferior to T_1. Type T_9 was observed to be inferior to all the other types with regard to this character.

4. Number of days taken for onset of flowering

The date of commencement of flowering in all the types was recorded and analysed statistically.

TABLE - V (a)

Analysis of variance for number of days taken for onset of flowering

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	25.7206	8.5735	1.04
Treatments	8	1,418.8715	177.3589	21.52**
Error	24	197.7698	8.2404	
Total	35	1,642.3619		

The types differed significantly regarding the number of days taken for the onset of flowering. The mean number of days taken for the onset of flowering by each type is shown in the table V(b).

TABLE - V (b)

Mean number of days taken for onset of flowering

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_8	T_2	T_5	T_1	T_4	T_3	T_7	T_9	T_6
Mean value	39.35	39.60	40.13	40.35	40.38	40.90	42.35	52.28	57.87

C.D. = 4.18

$\overline{T_8 \quad T_2 \quad T_5 \quad T_1 \quad T_4 \quad T_3 \quad T_7} \quad T_9 \quad T_6$

The onset of flowering in the nine types was found to range from 39th to 57th day after sowing. Type T_6 took the maximum number of days (57) to flower followed by T_9 which took 52 days. T_6 and T_9 were late by 17 days and 12 days respectively from that of T_1 which took only 40 days. All the other types were on par as far as the flower initiation was concerned. (Graphical representation of the variability is presented in Fig. 2).

5. <u>Number of days taken for completion of flowering</u>

The date of final flowering in all the nine types were recorded. The number of days taken for completion of flowering from the date of sowing was calculated and analysed statistically. The analysis of variance for this character is furnished below.

TABLE - VI (a)

Analysis of variance for the number of days taken for completion of flowering

Source of variation	Degree of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	38.0645	12.6882	1.80
Treatments	8	3,890.4478	486.3060	68.65**
Error	24	170.0028	7.0835	
Total	35	4,098.5151		

It was observed that there was significant difference among the types as regards the number of days taken for the completion of flowering.

The mean number of days taken for completion of flowering by the nine types are furnished in table VI(b).

TABLE - VI (b)

Mean number of days taken for completion of flowering

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_7	T_5	T_3	T_4	T_8	T_1	T_2	T_9	T_6
Mean value	79.66	87.16	89.32	90.19	90.22	90.66	93.78	103.39	117.91

C.D. = 3.38

T_7 $\overline{T_5 \quad T_3 \quad T_4 \quad T_8}$ T_1 T_2 T_9 T_6

$\underline{T_4 \quad T_8 \quad T_1}$

The mean number of days taken for completion of flowering among the nine types varied from 80 to 117 days. Type T_7 completed flowering on the 80th day after sowing which was 11 days earlier than that of T_1 (control) whereas T_6 and T_9 took 27 and 13 days more respectively than that of control. All the other types did not differ statistically from the control as regards this character (Graphical representation of the variability is presented in Fig. 2).

6. Exact flowering phase

The exact flowering phase of each type was calculated from the date of onset to the completion of flowering. Table VII(a) shows the analysis of variance for this character.

TABLE - VII (a)

Analysis of variance for duration of flowering

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	176.8764	58.9588	26.82**
Treatments	8	1,363.1348	170.3918	77.50**
Error	24	52.7693	2.1987	
Total	35	1,592.7805		

The types differed significantly in their duration of flowering. The mean duration of the flowering phase corresponding to the nine types are given in table VII(b).

TABLE - VII (b)

Mean duration of flowering phase

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_7	T_5	T_3	T_4	T_1	T_8	T_2	T_9	T_6
Mean value	37.91	47.00	48.44	50.16	50.44	50.88	52.13	52.95	63.03

C.D. = 2.17

T_7 T_5 T_3 T_4 T_1 T_8 T_2 T_9 T_6

The duration of the flowering phase ranged from 38 to 63 days among the types. The type T_7 had a significantly shorter flowering phase than all other types including the control. Its flowering phase was shorter by 12 days than that of T_1 (control). Type T_6 which had the longest flowering phase was longer by 13 days than that of T_1 and 25 days than that of T_7. (Graphical representation of the variability is presented in Fig. 2).

7. Number of pods per plant

The table of analysis of variance for the number of pods per plant is given below.

TABLE - VIII (a)

Analysis of variance for number of pods per plant

Source of variation	Degree of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	356.8424	118.9475	10.76**
Treatments	8	999.3250	122.1656	11.06**
Error	24	265.1891	11.0495	
Total	35	1,621.3565		

Fig. 2. Bar diagram showing the mean number of days taken for onset and completion of flowering and the exact flowering phase of the eight X_4 mutants along with T_1 (control)

MEAN NUMBER OF DAYS TAKEN FOR ONSET AND COMPLETION OF FLOWERING

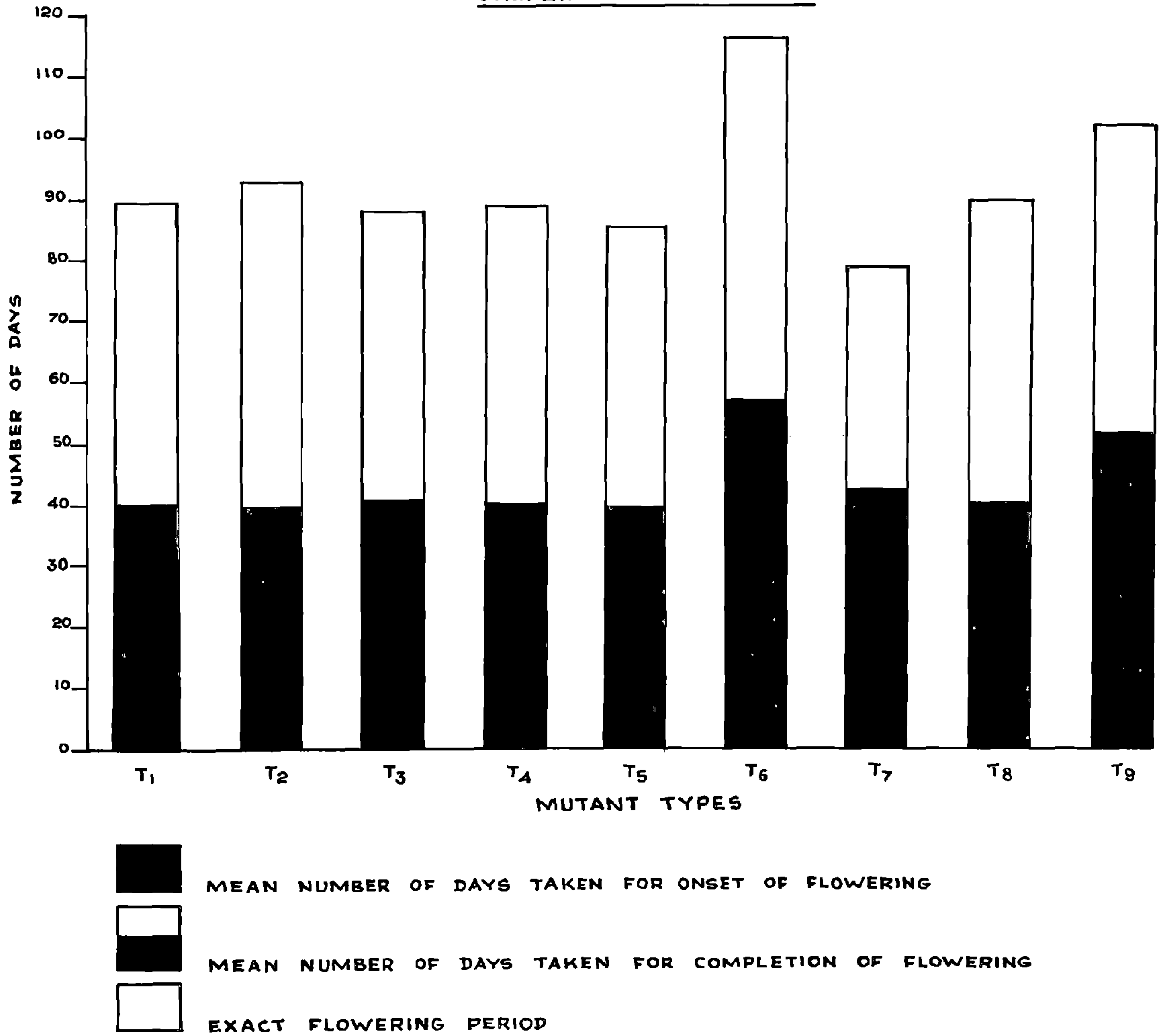


FIG 2

As evidenced from the analysis of variance table the types differed significantly as far as the number of pods per plant was concerned.

The mean number of pods corresponding to the nine types are given below.

TABLE - VIII (b)

Mean number of pods per plant

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_1	T_8	T_7	T_4	T_2	T_5	T_3	T_6	T_9
Mean value	57.91	49.78	49.62	48.41	47.62	46.65	42.59	38.59	34.72

C.D. = 4.85

$$T_1 \quad \underline{T_8 \quad T_7 \quad T_4 \quad T_2 \quad \overline{T_5}}\overline{\quad T_3} \quad \overline{T_6 \quad T_9}$$

The mean number of pods per plant among the nine types varied from 35 to 58. Type T_1 (control) had the maximum number of pods per plant. The number of pods in type T_8, T_7, T_4, T_2 and T_5 did not differ statistically among themselves but was significantly inferior to T_1. Type T_6 and T_9 recorded the lowest number of pods among the nine types studied [Graphical representation of the variability is shown in Fig. 3(c)].

8. Length of pods

The data on the length of pods for the nine types were analysed statistically. The table of analysis of variance is given below.

TABLE - IX (a)

Analysis of variance for length of pods

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	0.4296	0.1432	1.34
Treatments	8	273.3972	34.1747	319.69**
Error	24	2.5661	0.1069	
Total	35	276.3929		

It was found that there was very high variation in the length of pods among the types under study.

The mean length of pods corresponding to the nine types are given below.

TABLE - IX (b)

Mean length of pods in cms.

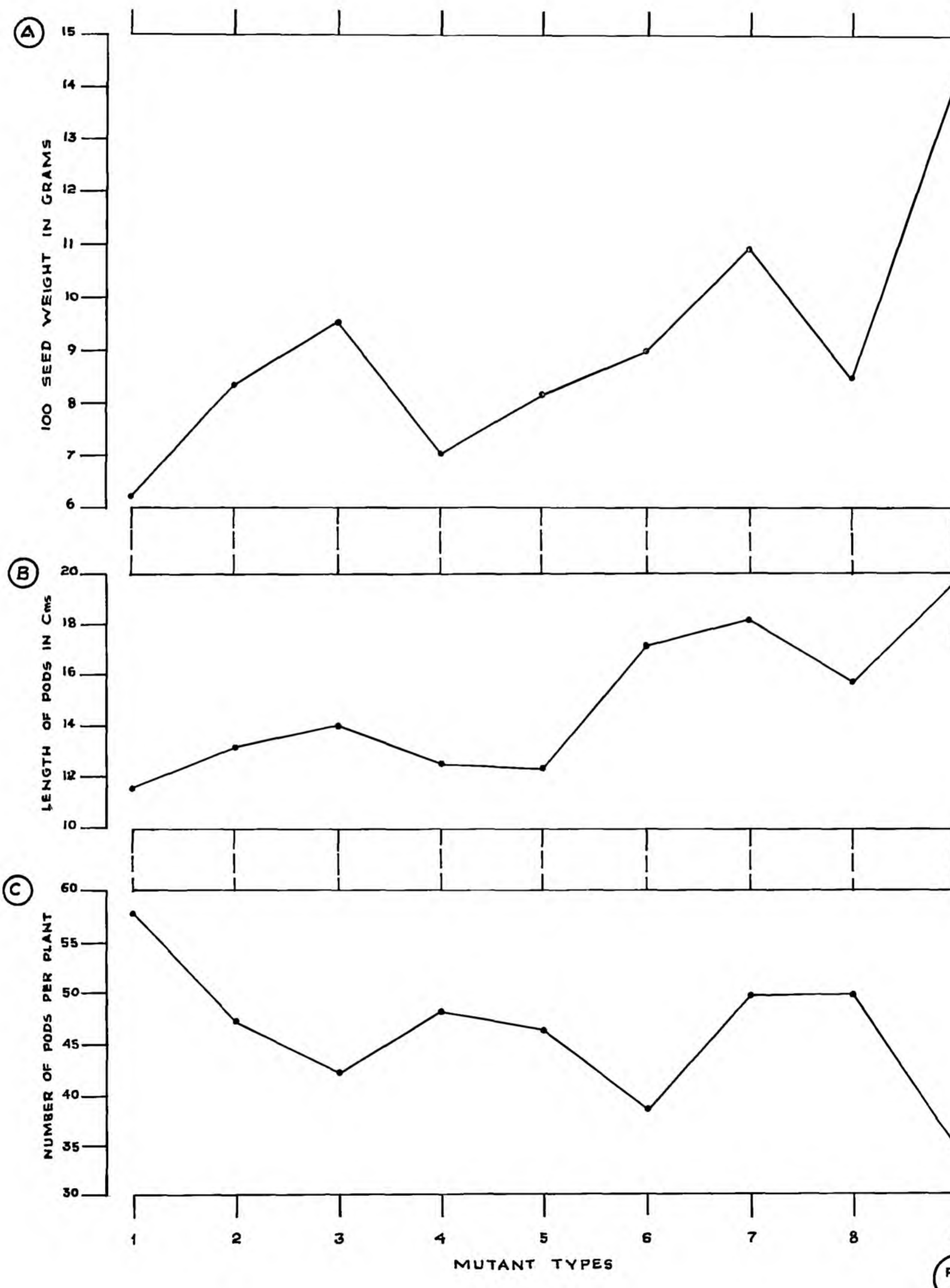
Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_9	T_7	T_6	T_8	T_3	T_2	T_4	T_5	T_1
Mean value	19.81	18.18	17.13	15.83	13.97	13.02	12.53	12.28	11.52

C.D. = 0.48

T_9 T_7 T_6 T_8 T_3 T_2 $\overline{T_4 \quad T_5}$ T_1

It was observed that all the types studied had an increased mean pod length than that of T_1 (control). Type T_9 had the maximum mean length of 19.81 cm. which was 71% more than that of T_1 (control). Type T_7 had the mean length of 18.18 cm. which was 57.8% more than that of the control, followed by the types T_6 and T_8 which had 48.6% and 37.41% more than that of T_1 respectively (Graphical representation of the variability is presented in Fig. 3-b).

Fig. 3 (A - C) Graphical representation of the variability for three of the productive characters in the eight X_4 mutants, along with T_1 (control) studied.


A
100 SEED WEIGHT IN GRAMS
6
7
8
9
10
11
12
13
14
15
B
LENGTH OF PODS IN Cms
10
12
14
16
18
20
C
NUMBER OF PODS PER PLANT
30
35
40
45
50
55
60
1
2
3
4
5
6
7
8
MUTANT TYPES

9. Number of seeds per pod

Number of seeds per pod was counted for the nine types and the data were analysed statistically. The table of analysis of variance is presented below.

TABLE - X (a)

Analysis of variance for number of seeds per pod

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	0.6929	0.2310	< 1.00
Treatments	8	125.8414	15.7302	49.86**
Error	24	7.5723	0.3155	
Total	35	134.1066		

The nine types differed significantly in the character, namely, number of seeds per pod. The table X(b) shows the mean number of seeds per pod corresponding to the nine types studied.

TABLE - X (b)

Mean number of seeds per pod

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_7	T_9	T_6	T_8	T_4	T_2	T_1	T_5	T_3
Mean value	17.85	17.78	16.66	14.91	14.24	13.64	13.39	13.26	12.81

C.D. = 0.82

T_7 T_9 T_6 T_8 T_4 T_2 T_1 T_5 T_3

The mean number of seeds per pod ranged from 12.81 (T_3) to 17.85 (T_7). T_7 and T_9 had the maximum number of seeds per pod followed by T_6 and T_8 which were all superior to T_1 (control).

10. Weight of pods per plant

Pods harvested periodically from all the observational plants were dried and the weight was recorded.

Table XI(a) shows the analysis of variance for the weight of pods per plant.

TABLE - XI (a)

Analysis of variance for weight of pods per plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	874.2871	291.4290	7.22**
Treatments	8	7,661.5426	957.6928	23.71**
Error	24	969.1714	40.3821	
Total	35	9,505.0011		

The analysis of variance table indicates that the difference among the nine types with regard to this character is highly significant.

Table XI(b) represents the mean weight of pods corresponding to the nine types.

TABLE - XI (b)

Mean weight of pods in gm.

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_7	T_8	T_5	T_3	T_6	T_2	T_4	T_1	T_9
Mean value	94.70	73.57	62.92	62.31	61.23	59.83	51.89	49.53	39.11

C.D. = 9.27

T_7 T_8 T_5 T_3 T_6 T_2 T_4 T_1 T_9

The mean weight of pods per plant ranged from 39.11 gm. (T_9) to 94.70 gm. (T_7). Type T_7 had the maximum weight of pods which recorded 94.70 gm. followed by T_8 which had 73.57 gm.

Types T_5, T_3, T_6 and T_2 did not differ statistically from each other in the mean weight of pods per plant but had significantly higher mean weight than T_1 (control). The mean weight of pods in T_9 was significantly lower when compared to T_1.

11. <u>Weight of seeds per plant</u>

The data on the weight of seeds for the nine types were analysed statistically and the analysis of variance table is presented below.

TABLE - XII (a)

Analysis of variance for weight of seeds per plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	370.0257	93.3419	7.34**
Treatments	8	3,123.9636	390.4404	30.68**
Error	24	305.3851	12.7244	
Total	35	3,799.3744		

It was observed that there was very high variation in the weight of seeds per plant among the nine types.

The mean weight of seeds per plant corresponding to the nine types are presented below.

TABLE - XII (b)

Mean weight of seeds per plant in gm.

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_7	T_6	T_5	T_8	T_3	T_2	T_4	T_1	T_9
Mean value	66.77	51.65	48.76	48.09	43.82	42.05	40.88	38.27	31.87

C.D. = 5.21

T_7 T_6 T_5 T_8 T_3 T_2 T_4 T_1 T_9

The mean weight of seeds per plant varied from 31.87 gm. (T_9) to 66.77 gm. (T_7). Type T_7 had recorded the maximum weight of seeds of 66.77 gm. which was 73.6% more than that of T_1 (control). Type T_6 had the mean weight of seeds (51.65 gm.) which was 34.78% more than that of T_1.

Types T_5 and T_8 had 27.27% and 25.53% increased seed weight over the control. Types T_2 and T_4 did not differ from T_1 whereas significant decreased seed weight by 17.4% was observed in T_9 (Graphical representation of the variation in the weight of seeds per plant is presented in Fig. 4).

12. Weight of haulm

The dry weight of individual observational plants was recorded after the final harvest, analysed statistically and furnished below.

TABLE - XIII (a)

Analysis of variance for weight of haulm

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	326.40	108.80	1.308
Treatments	8	5,372.45	671.56	8.0755**
Error	24	1,995.73	83.16	
Total	35	7,694.58		

Table XIII(a) showed that the weight of haulm varied significantly among the types under study.

The mean weight of haulm corresponding to the nine types are presented below.

TABLE - XIII (b)

Mean weight of haulm per plant in gm.

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_6	T_9	T_7	T_4	T_5	T_1	T_3	T_2	T_8
Mean value	90.47	68.59	64.22	59.22	56.87	54.65	54.53	49.69	47.97

C.D. = 13.31

T_6 T_9 T_7 T_4 T_5 T_1 T_3 T_2 T_8

Type T_6 had the maximum weight of haulm (90.47 gm.) which was 65.5% more than that of control and T_9 had the mean weight of haulm (68.59 gm.) which was 25.5% more than that of T_1.

Types T_7, T_4, T_5 and T_3 did not differ statistically among themselves as well as with T_1.

Type T_2 and T_8 though did not differ much from the control had significant lower haulm weight when compared to superior types such as T_6 and T_9 (Graphical representation of the variability is presented in Fig. 4).

13. <u>100-seed weight</u>

TABLE - XIV (a)

Analysis of variance for 100-seed weight

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replications	3	0.0214	0.0071	< 1
Treatments	8	176.3976	22.0497	355.07**
Error	24	1.4915	0.0621	
Total	35	177.9105		

Significant difference was observed among the types in respect of the character under observation.

Fig. 4. Bar diagram showing the mean weight of seeds and haulm per plant in the eight X_4 mutants studied along with T_1 (control)

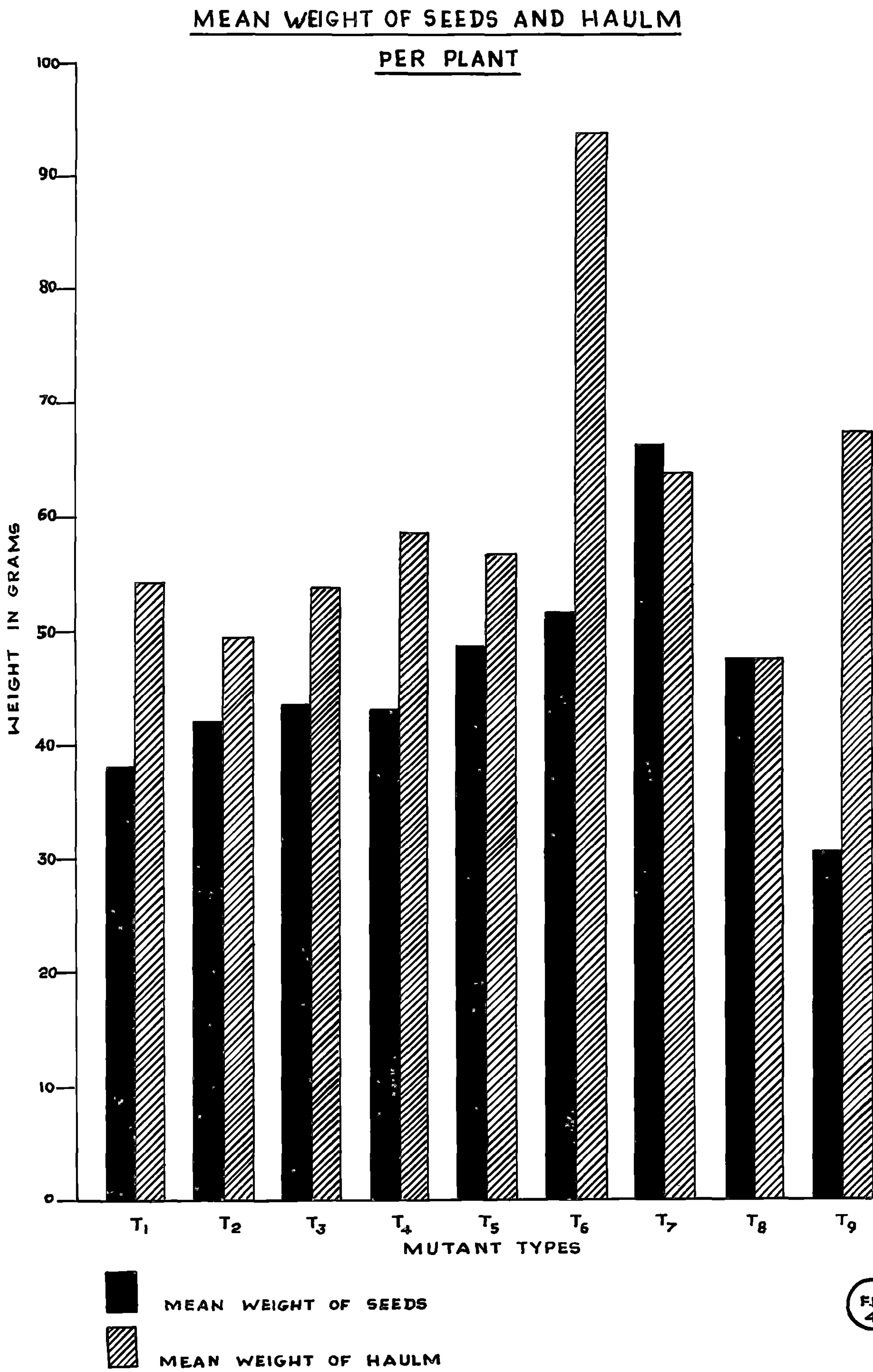

MEAN WEIGHT OF SEEDS AND HAULM
PER PLANT
WEIGHT IN GRAMS
100
90
80
70
60
50
40
30
20
10
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
MUTANT TYPES
MEAN WEIGHT OF SEEDS
MEAN WEIGHT OF HAULM

FIG 4

Table XIV(b) shows the mean weight of 100-seeds corresponding to the nine types.

TABLE - XIV (b)

Mean weight of 100-seeds in gm.

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_9	T_7	T_3	T_6	T_8	T_2	T_5	T_4	T_1
Mean value	14.06	10.98	9.54	8.96	8.41	8.26	8.06	6.98	6.10

C.D. = 0.36

$T_9 \quad T_7 \quad T_3 \quad T_6 \quad \overline{T_8 \quad T_2 \quad T_5} \quad T_4 \quad T_1$

The mean weight of 100-seeds among the nine types varied from 6.10 gm. (T_1) to 14.06 gm. (T_9). All the mutant types recorded significant increase in 100-seed weight than that of control. Type T_9 had the maximum 100-seed weight of 14.06 gm. which was 130.44% more than that of T_1, followed by T_7, T_3 and T_6 which recorded 80%, 56.36% and 46.85% increased weight respectively than that of T_1 (control).

Types T_8, T_2 and T_5 did not differ statistically from each other but had 36.83%, 35.38% and 32.10% increased seed weight respectively, over that of T_1 (control). (Graphical representation of variability is presented in Fig. 3-a).

14. Protein content

The total nitrogen for each type was estimated and then the percentage of protein in each type was calculated and furnished below.

TABLE - XV (a)

Rank	1	2	3	4	5	6	7	8	9
Treatments (Types)	T_8	T_2	T_7	T_4	T_1	T_9	T_6	T_5	T_3
Percentage of Protein on air dry basis	25.10	24.43	24.28	24.01	23.97	23.83	22.87	22.14	20.12

It was observed that the type T_8 had 25.10% protein which was 4.7% more than that of the control which has only 23.97%. In type T_3 the protein content was 20.12% which was 16% lesser than that of T_1. Rest of the types did not differ markedly among themselves as well as from the control.

DISCUSSION

D I S C U S S I O N

Artificial induction of mutations in polygenes responsible for quantitative characters has been an important subject for both plant and animal breeders. There has been a good deal of research which can be traced back to early publications by Stadler (1930), Burgeff in Germany (1943) and Heribert Nilsson in Sweden (1954).

A general conclusion drawn from the earlier studies is that mutagens produce genetic variation in quantitative characters. However, it is still a matter of dabate whether irradiation induced mutations of polygenes occur towards both plus and minus directions or towards either or the other. The problem is of great importance from the stand point of practical utilization of radiation energy for the improvement of quantitative characters in crop plants.

The results obtained in the present investigations on X_4 mutants of cow pea (Vigna sinensis L. Savi) with reference to quantitative characters are discussed and presented below.

Germination

Differential behaviour in germination is usually observed among mutants produced by X-ray irradiation. In the present study, five out of the eight X_4 mutants recorded higher germination percentage and the other three a lower percentage than the control. In the former five mutants germination was quick and in the latter germination was found to be slow.

Workers like Pfiffer and Simmermacher (1915) on *Vicia faba* and Spencer and Cabanillas (1956) in *Indigofera endecaphylla* observed that X-irradiation hastened the germination of seeds. Jacob (1949) reported a higher germination percentage in irradiated seeds of Jute (*Corchorus* sp.).

But reports of Kumar and Joshi (1939) in *Brassica juncea*, *Nicotiana tabacum* and *Pennisetum typhoides* conclude that X-irradiation was deleterious to germination. Reduction in percentage of germination was noted by Lesley and Lesley (1957) in tomato and Matsura *et al* (1957) in wheat seeds.

Since five out of the eight mutant types showed higher germination percentage and also quick germinability, it may be assumed that irradiation produced more of favourable effects in cow pea. However, the reduced germination percentage coupled with slow germinability observed in three mutants suggest that prediction will not always hold good.

Height of the plant

In the present study, the eight X_4 mutants of cow pea showed height variation, though none of them were significantly different from that of control.

Johnston (1961) observed significant height variation between selected X_5 mutants and untreated lines of oats.

However, the behaviour of cow pea was different from that of oats wherein irradiation with X-rays did not seem to exert a marked influence on changing the height of plants.

Excepting types T_8 and T_3, in all other mutants reduction in height was observed though it was not statistically significant.

Mutants showing dwarfness with short stems were reported by many workers like Tedin and Hagberg (1952) in X_3 of Lupinus luteum, Hackbarth (1955) in X_2 of irradiated Lupinus albus, Shasthry and Nandhachary (1965) in X_4 of irradiated rice and Korah (1959) in X_1 and X_2 of Oryza.

Observations made in this study were also similar to the findings recorded by the above authors. Hence it can be said that X-irradiation seems to have exerted a slight influence on shortening the height in these mutants, though not to the extent of calling them as dwarf mutants.

Number of branches

Very little results have been reported so far on the effect of irradiation on branching habit of crop plants.

In the present study, X_4 mutants of cow pea having both larger and smaller number of branches were observed. Out of the eight X_4 mutants studied four produced significantly higher number of branches whereas the other four produced lower number of branches when compared with the control.

Toriyama and Futsuhara (1962) obtained a mutant Fu.54 in rice which had higher number of tillers than its parent. Sakai and Suzuki (1964) noted decreased number of tillers in rice and suggested that X-ray irradiation resulted in a decrease in polygenic characters like number of tillers.

In the light of observations made on X_4 mutants of cow pea as well as the reports of the research in rice, it can be said that the effect of X-irradiation on branching character is highly variable.

Flowering

The onset of flowering was delayed in types T_6 and T_9. All the other types did not vary much from that of T_1 as regards their flower initiation.

Abrams and Velez - Fortuno (1962) observed early, intermediate and late flowering lines in X_3 and X_4 generations of irradiated pigeon peas (*Cajanus cajan*). But works on several crops had shown that earliness in flowering was induced by X-irradiation. Tedin (1954) obtained ten early flowering mutants in *Lupinus luteus*. Matsumura and Fujii (1955) noted in *Nicotiana tabacum* and *Nicotiana sylvestris* that X-ray has induced earliness in flowering by fifteen days in a mutant than its parent.

Earliness in flowering by seventeen days in the mutant forms of X_3 of *Sesamum* was observed by Rai and Jacob (1956). Similar results were obtained by Gladstones (1958) in *Lupinus digitalis* and Gottschalk (1960) in *Pisum sativum* treated with X-rays.

However, the behaviour of cow pea when subjected to X-irradiation is quite contradictory to the observations made in other crops cited above. In the light of observations made in the present study of X_4 mutants of *Vigna sinensis* and also the findings of Abrams and Velez - Fortuno (1962) in X_3 and X_4 of Pigeon peas (*Cajanus cajan*) it can be concluded that X-irradiation in cow pea only tends to delay the onset of flowering.

Duration of flowering phase

Two types, T_7 and T_5 had a shorter flowering phase than T_1 (control). Type T_7 was the one in which flowering phase was observed to be the shortest which differed significantly from all the other types and control. The flowering phase of T_7 was twelve days shorter than T_1, the unirradiated control. The pods in T_7 matured within a shorter period, so much so, the number of periodical harvests was less in this than in the others.

Thus in T_7 the shorter flowering phase leads to uniformity in maturity which is a desirable character.

Two of the eight types (T_6 and T_9) had a significantly longer flowering phase than the control. The flowering phase in T_6 was thirteen days longer than that of T_1 (control). The protracted flowering in types T_6 as well tells on the undesirability in preferring this type since the number of harvests required becomes too many.

Number of pods per plant

In the present observation all the eight X_4 mutants recorded a decrease in total number of pods per plant than that of control. Differences were also observed among the mutants themselves for this character.

The above observation is in line with the reports of Sakai and Suzuki (1964) who reported that X-irradiation in rice resulted in a decrease in polygenic characters like number of panicles per plant.

Thus the larger number of pods in unirradiated parental strain and reduced number of pods observed in the X_4 mutants suggest that mutation through X-irradiation has not resulted in change of polygenic characters towards increase in number of pods in this crop.

Length of pods

The present investigation has revealed that X-ray irradiation affects the length of pods in cow pea very much.

Significant differences in the mean values of panicle length among treated and between treated and controls were observed by Matsuo et al (1964) in M_6 generation of rice. Since the pod length in cow pea and panicle length in rice were similar productive characters, it can be said that the present observations were in line with the findings of the above workers.

In cow pea (*Vigna sinensis*) irradiation with X-rays had produced significantly increased mean length of pods in all the X_4 mutants studied over their unirradiated parent and even among the mutants themselves significant variation was observed for this character. The present study proved beyond any doubt that X-irradiation increases the length of pods in cow pea.

Number of seeds per pod

Except the types T_2, T_5 and T_3 all the other X_4 mutants had higher mean number of seeds per pod than the control.

Irradiation with X-rays therefore seems to exert a favourable influence on the number of seeds per pod.

Similar results were reported by Marki et al, who observed higher number of seeds per pod in X_3 generation of Soya bean treated with X-rays.

100-seed weight

The present observation has conclusively proved the beneficial effects of X-irradiation on increasing the weight of 100-seeds. All the X_4 mutants studied recorded significantly higher seed weight than the unirradiated control. Type T_9 recorded 130.44% followed by T_7, T_3 and T_6 which had 80%, 56.36% and 46.85% more seed weight respectively than T_1, the control.

Krull and Frey (1954) found in oats that thermal neutron treatment had induced genetic variability for 100-seed weight. Gustafsson (1941) observed increased

1000-grain weight in barley and indicated that higher yield obtained in 'erectoid'-3 of barley was exclusively due to its higher 1000-grain weight.

However, results obtained in the present study suggest that 100-seed weight is only one among several characters contributing to higher yields in types T_7, T_6, T_3 and T_8.

Yield of pod and seed

A very high variability for weight of pods and seeds in X_4 mutants of cow pea was observed in the present study. Five (T_7, T_6, T_8, T_5 and T_3) out of eight mutants recorded higher pod and seed weight per plant than T_1, the control.

Results on the effect of X-irradiation in increasing the yield of crop plants have been reported by many workers such as Gregory (1956) in M_6 of Arachis hypogaea, Van Emden and Jaarverslag (1959) in X_6 of Soya bean, Gelin (1954) in Pisum sativum, Svejda (1961) in X_3 and X_4 of Pisum, Abrams and Velez - Fortuno (1962) in X_3 and X_4 of Pigeon peas (Cajanus cajan) and Li et al (1960) in rice.

Out of two hundred and eighty one morphological mutants observed by Kawai (1963) in rice, six proved to be superior in yield than their parents. Effect of X-irradiation towards increasing the yield was best evidenced from the results obtained by Swedish group of workers. 'Svalof Primax White Mustard' and 'Regina II Summer Oil Rape' were the outstanding varieties released for commerical production in Sweden. 'Sanilac' is a commercial variety of common bean that was released in Michigan.

However, in the present observation one of the eight X_4 mutants (T_9) was significantly inferior to all the other types including control, with respect to both pod and seed weight.

Mutants showing lower yield than their parental forms were also observed by some workers like Gottschalk (1960) in *Pisum sativum*, Johnston (1961) in X_4 and X_5 of oats and Sakai and Suzuki (1964) in X_4 of rice. Gustafsson (1941) reported that seven out of ten mutants were inferior to golden barley, the unirradiated mother strain.

Matsuo *et al* (1964) who observed significant differences between M_6 mutants and control with respect to weight of panicle reported that mutation in polygenes could occur in positive as well as negative directions with regard to grain yield.

Since the majority of the X_4 mutants produced better pod and seed yield it can be concluded that mutation through X-irradiation may result in increasing the yield in cow pea.

Weight of haulm

In the present investigation two of the eight X_4 mutants were found to produce higher weight of haulm per plant than the control and other types. Type T_6 yielded 65.5% more and T_9 25.5% more haulm weight than that of T_1 (control).

The above observations are in agreement with the findings of workers like Levan (1944) who reported a mutant in flax yielding 6% increased straw than its parent and Caric and Mihaj-lovic (1961) who observed an increased straw yield in some wheat and maize hybrids subjected to radiation. Similar results were reported by Boratynska (1962) who obtained a gigas mutant having increased vegetative growth in *Ricinus communis* subjected to radiation.

From the foregoing it can be said that X-irradiation has favourably influenced the weight of haulm per plant in cow pea at least in two of the mutants which may prove to be of great economic value.

Protein content

Percentage of protein was more in four of the eight X_4 mutants studied. However, among the superior types, T_8 which recorded maximum protein content had an increase of only 4.7% over T_1 (control). Among the four which had recorded lower percentages of protein, only T_3 was markedly inferior having 16% lesser protein than that of T_1 (control).

Papa et al (1961) reported that selection for protein content could be done more effectively in irradiated, populations of soya bean varieties, 'Adams' and 'Hawkeye'.

A wider range in protein content was also noticed in X_4 mutants under study but the range was more towards the negative side as against the observations on soya bean made by Papa et al (1961).

Hence it can be presumed from the available data that X-irradiation does not seem to bring about chances for effective selection for protein content in cow pea.

<u>Favourable combination of different quantitative characters in some of the X_4 mutants studied (T_7 and T_6)</u>

The productive characters studied in the present investigation were number of pods, length of pod, number of seeds per pod, weight of pod and seed per plant and 100-seed weight. In the eight X_4 mutants studied, one or the other of the several quantitative characters got prominence in any single type. However, a favourable combination of all the productive characters was observed only in two mutant types T_7 and T_6.

Type T_7 had recorded the maximum yield of seed giving an increase of 73.6% over the control. This superiority was due to the favourable combination of all the productive characters such as number of pods per plant, number of seeds per pod, length of pod and 100-seed weight. In addition to this, the shortest flowering phase and uniform maturity of pods in T_7 confirmed beyond doubt that this was the best promising economic type among the X_4 mutants studied.

T_6 recorded the maximum weight of haulm giving an increase of 65.5% over the control. The maximum haulm weight in T_6 was due to its prolonged vegetative phase and profuse vegetative growth. T_6 was second only to T_7 regarding the seed yield. This was due to the favourable influence of X-irradiation on most of the productive characters like length of pod, mean number of seeds per pod and 100-seed weight.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSION

This thesis embodies the results of an investigation carried out in the Division of Agricultural Botany of the Agricultural College and Research Institute, Vellayani during the year 1965-66 to study the behaviour of X_4 mutants of cow pea (Vigna sinensis L. Savi) with reference to certain quantitative economic characters.

Eight mutant types selected from X_3, along with the original (African) variety as control were raised in plots which were statistically laid out and replicated. The X_4 mutants were compared among themselves as well as with the control with a view to isolate the economic types possessing desirable quantitative characters.

(1) It was observed that germination percentage was higher in five types and lower in three, than that of control.

(2) X-irradiation did not seem to exert a marked influence on changing the height of plants. Though the eight X_4 mutants showed variations in height, none of them significantly differed from the control.

(3) Among the eight X_4 mutants studied, four produced more number of branches and two lesser than that of control.

(4) X-irradiation in cow pea only tends to delay the onset of flowering. None of the X_4 mutants flowered earlier than the control. Among the eight types, T_6 and T_9 were significantly late flowering.

(5) T_7 had the shortest flowering phase followed by T_5, which resulted in the uniform maturity of pods in these two types.

(6) T_1 (control) produced the largest number of pods per plant. Significant reduction in the number of pods in all the X_4 mutants suggests that X-irradiation had resulted in changing this polygenic character towards the negative side.

(7) X-irradiation significantly increased the length of pods in all the X_4 mutants studied. The eight mutants showed significant difference even among themselves.

(8) Five of the X_4 mutants recorded a higher mean number of seeds per pod which suggests that irradiation with X-rays exerts a favourable influence on the

number of seeds per pod.

(9) Mutation through X-irradiation had resulted in increasing the pod and seed weight in majority of the X_4 mutants studied. Except T_9 all the mutant types recorded increased pod weight, types T_7 and T_8 recording the maximum. Five of the X_4 mutants had significantly higher seed weight of which T_7 recorded the maximum giving an increase of 73.6% over the control.

(10) X-irradiation has favourably influenced the weight of haulm in two of the X_4 mutants namely T_6 and T_9, of which T_6 registered the maximum haulm weight giving an increase of 65.5% over the control.

(11) The present work has conclusively proved the beneficial effects of X-irradiation in increasing the weight of 100-seeds in all the mutants studied.

(12) Percentage of protein was more in four of the mutants of which T_8 had the maximum, having 4.7% increase over that of T_1 (control). Type T_3 had the least protein content and it was 16% lesser than T_1.

The present investigation has resulted in the isolation of two promising mutants namely T_7 and T_6. The favourable combination of all the productive characters together with a shorter flowering phase and uniform maturity of pods in T_7 suggest that it is a higher yielding type.

T_6 which recorded the maximum weight of haulm due to its prolonged vegetative phase and profuse growth can be developed as a strain suitable for green manuring.

X-ray induced polygenic mutants in cow pea changing quantitative economic characters such as weight of pod and seed, length of pod, weight of haulm and 100-seeds in a positive direction suggests that similar works could be taken up in other leguminous crops in order to induce genetic variability and to select out mutants having a favourable combination of economic characters.

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PLATES

PLATE I

Fig. 1. General view of the Field Trial

Fig. 2. T_1 - A normal cow pea plant of the 'African' variety.

PLATE I

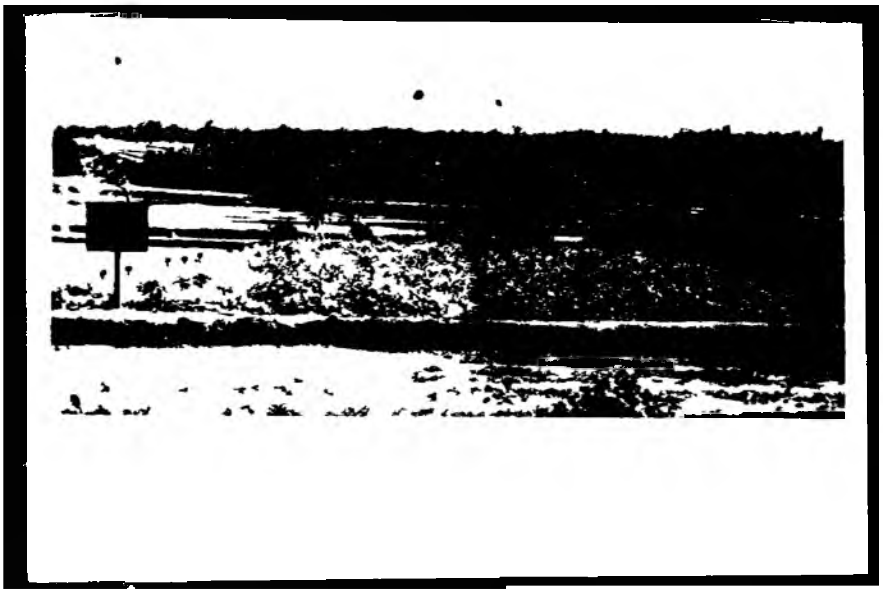

Fig. 1

Fig. 2

PLATE II

Fig. 1. T_2, white seed type

Fig. 2. T_3, light brown

PLATE II

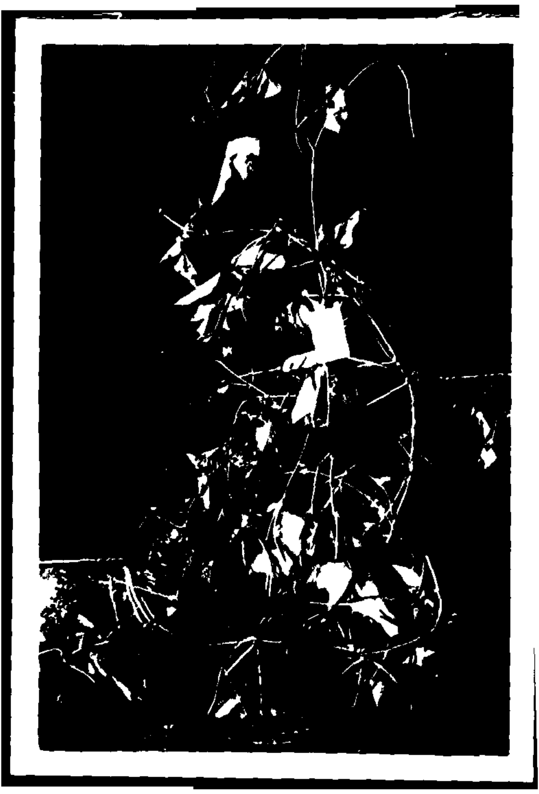

Fig. 1

Fig. 2

PLATE III

Fig. 1. T_4, reddish with black mottlings

Fig. 2. T_5, straw brown mottled

PLATE VI

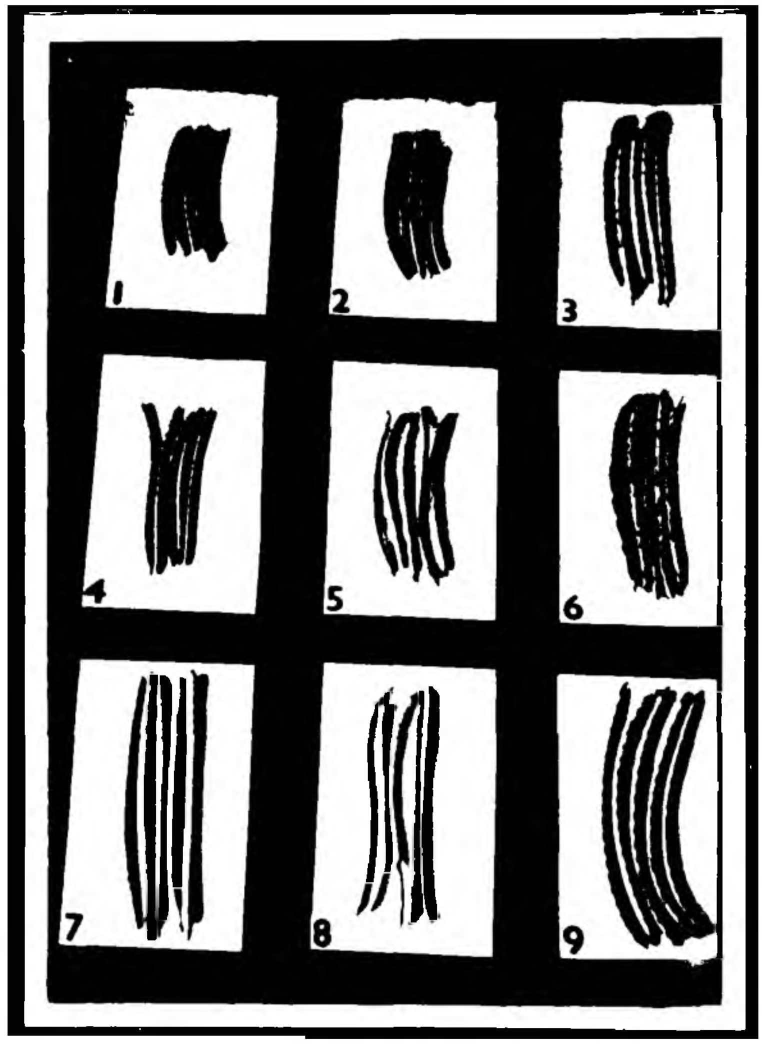

Fig. 1

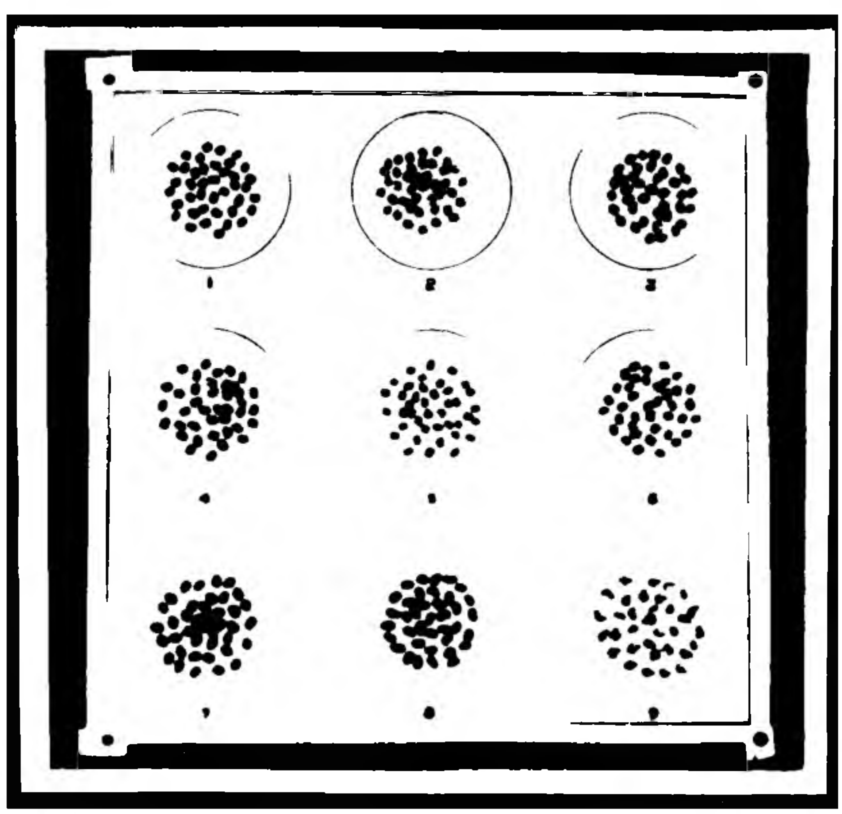

Fig. 2

PLATE VI

Fig. 1. Photograph showing the shape, length and colouration of pods in the eight X_4 mutant types along with the control

Fig. 2. Photograph showing the shape, size and colouration of seeds in the eight X_4 mutant types along with the control

PLATE V

FIG. I

Fig. 2

PLATE V

Fig. 1. T_8, Large brown

Fig. 2. T_9, Straw white with red patches around the eye

PLATE IV

Fig. 1

Fig. 2

PLATE IV

Fig. 1. T_6, Large leaved mutant

Fig. 2. T_7, Ashy violet mottled

PLATE III

FIG. I

Fig. 2