

**STUDIES ON THE NATURE OF VARIATION IN
SEGREGATING GENERATIONS OF IRRADIATED AND
UNIRRADIATED F₂ SEEDS IN RICE**

THESIS

BY

JOHN EARLE MASSAR

Submitted to



**HIMACHAL PRADESH KRISHI VISHVA VIDYALAYA
PALAMPUR - 176062 (H. P.)**

IN

Partial fulfilment of the requirements for the degree of

**MASTER OF SCIENCE IN AGRICULTURE
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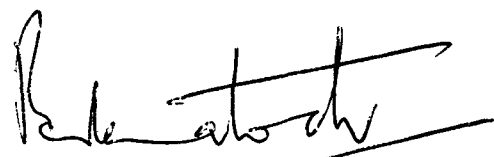
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This is to certify that the thesis entitled "Studies on the nature of variation in segregating generations of irradiated and unirradiated F_2 seeds in rice" submitted for the degree of Master of Science (Agriculture) in the subject of Plant Breeding of Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, is the bonafide research work carried out by Shri John Earle Massar son of Shri H.C. Lister under my supervision and that no part of this thesis has been submitted for any other degree.

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

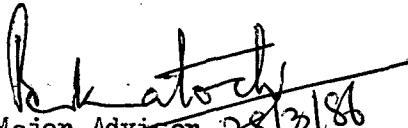
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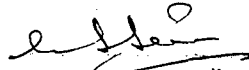

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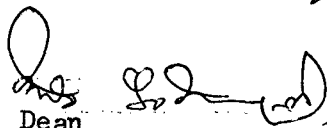
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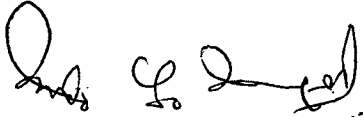
This is to certify that the thesis entitled "Studies on the nature of variation in segregating generations of irradiated and unirradiated F_2 seeds in rice" submitted by Shri John Earle Massar son of Shri H.C. Lister to the Himachal Pradesh Krishi Vishva Vidyalaya, in partial fulfilment of the requirements for the degree of Master of Science (Agriculture) in the subject of Plant Breeding has been approved by the Students' Advisory Committee after an oral examination on the same, in collaboration with the External Examiner.


Major Advisor 28/3/86


External Examiner 28/3/86


Head of the Department 28.3.86


Dean 21.4.86
College of Agriculture


Dean 25.4.86
Post-Graduate Studies

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Dedicated
to
my Parents
~ ~ ~ ~ ~
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(John Earle Massar)

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Name of the student : John Earle Massar

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A B S T R A C T

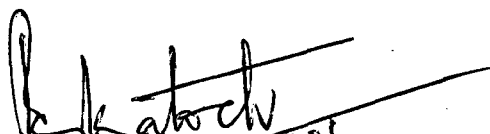
Dry F_2 seeds of two crosses of rice viz. Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 were irradiated with 25 kR gamma-rays. The experimental material for the trial during kharif, 1983 comprised F_2 , F_2M_1 of the two crosses alongwith their parents. During kharif, 1984, the experimental material comprised of F_3 , F_3M_2 and the parents of the above crosses. The study was undertaken to assess the magnitude of induced variability for yield and some quantitative characters and to study the spectrum and frequency of macro-mutations induced.

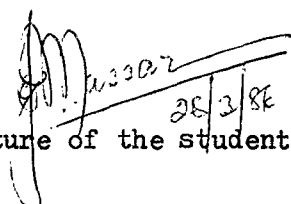
In the cross Himalaya-1 x Phul Patas 72, the mean values for panicle length, fertility percentage, and yield per plant decreased and for number of tillers per plant increased significantly in F_2M_1 as compared to the F_2 , however, for plant height and 100-grain weight, no differences were observed. In the cross Himalaya-1 x China 988, significant decrease in F_2M_1 as compared to F_2 for plant height, panicle length, fertility percentage, 100-grain and yield per plant was observed where as for number of tillers per plant no difference was observed.

The spectrum of chlorophyll mutations in both the crosses, comprised mostly of albina followed by xantha, striata, xantha-alba, and viridis. In both the crosses, the overall frequency based on M_1 plant progeny was higher than that calculated on the basis of M_2 seedlings. In the cross Himalaya-1 x Phul Patas 72, the mean values in F_3M_2 for days to heading, plant height, number of tillers per plant, panicle length, 100-grain weight and yield per plant remained unchanged,

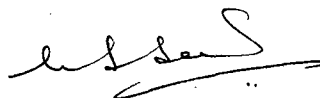
whereas, significant decrease was observed for fertility percentage as compared to the F_3 . In the cross Himalaya-1 x China 988, the means in $F_3 M_2$ remained unaffected when compared with F_3 for all characters studied except for yield per plant where it decreased significantly. Significant variations have been observed within F_3 and $F_3 M_2$ progenies of the two crosses for all characters except for fertility percentage in both F_3 and $F_3 M_2$ of the cross Himalaya-1 x China 988. However, no significant differences in variances were observed when the irradiated population ($F_3 M_2$) was compared with the unirradiated population (F_3) in the two crosses except for yield per plant in the cross Himalaya-1 x ~~Phul Patas 72~~ ^{China 988}. In the cross Himalaya-1 x Phul Patas 72, moderate to high estimates of heritability and genetic advance for days to heading and yield per plant in F_3 and days to heading and plant height in $F_3 M_2$ were observed. In the cross Himalaya-1 x China 988, these estimates were moderate to high for plant height and yield per plant in F_3 and for days to heading, plant height and yield per plant in $F_3 M_2$. Selection in these populations may therefore lead to improvement of different characters.

A few progenies in different populations which have higher yield in comparison to the highest yielding progeny of the recommended variety have been identified. These progenies are also superior for one or more yield components. Selection of these progenies from different populations and further evaluating them in yield test may lead to the development of high yielding genotypes in rice.


Signature of
Major advisor 28/3/86


Signature of the student 28/3/86

Countersigned


Head of the Department.

C O N T E N T S

<u>Sr.No.</u>	<u>Title</u>	<u>Pages</u>
I	INTRODUCTION	1 - 3
II	REVIEW OF LITERATURE	4 - 13
III	MATERIAL AND METHODS	14 - 21
IV	EXPERIMENTAL RESULTS	22 - 60
V	DISCUSSION	61 - 74
VI	SUMMARY	75 - 78
	LITERATURE CITED	i - viii

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INTRODUCTION

INTRODUCTION

Rice (Oryza sativa L.) is considered to be the native of South-east Asia, which includes India and China. It is the principal food of nearly half of the mankind. Hence, higher yields coupled with improved nutritional quality is of prime importance.

Rice is the major kharif crop of Himachal Pradesh, next only to maize, occupying an area of approximately 92.8 thousand hectares during 1983-84 with a production of 111.5 thousand tonnes and an average of 1200 kg/ha. (Anonymous, 1984). In Himachal Pradesh, rice is grown at elevations ranging from 300 metres to 2250 metres. The rice growing season is relatively short, temperature fluctuates extremely and the crop is exposed to low temperature, particularly at flowering stage causing low temperature damage coupled with neck blast. Although good progress has been made in the development of rice varieties in Himachal Pradesh, yet the losses in yield caused by blast, low temperature and drought etc. are regular features. Development of varieties resistant to blast and tolerant to drought and low temperature with acceptable grain quality offers the possibility of increasing the rice yields in the state.

The presence of sufficient genetic variability in a population is a pre-requisite for the success of a breeding programme. The idea of producing artificial mutations and utilizing them for improving cultivated plants was indicated as early as 1901 by De-Vries. Muller (1927) in Drosophila and Stadler (1928) in maize and barley discovered that mutations can be induced artificially by irradiation. Mutation induction is a real and proven way to create variation within a crop variety. Artificial

mutagenesis offers a possibility for induction of desired attributes, perhaps some of those that either cannot be found naturally or have been lost in evolution. It is an established fact that mutagens, beside causing changes in major genes, also induce mutations at loci governing the quantitative characters. These micro-mutations can be detected in the form of increased variance in M_2 generation. Since most of the economic traits show polygenic inheritance, more information on the induction of genetic variability in them through mutation is needed.

Pure breeding homozygous genotypes have generally been used in mutation breeding experiments. Lately, the importance of ^umutagenesis in increasing the recombination rate with a possibility of adding induced variability to that inherent in a cross has been realised and heterozygous and heterogeneous populations of different crop species have been exposed to mutagens. Gregory (1956) hypothesized that the variation induced by irradiation might be cumulative with that of hybridization.

The present investigation was therefore undertaken to make a comparative assessment of the effects of gamma irradiation (25 kR) on the amount of induced variability in some quantitative characters following the treatment of F_2 seeds in two rice crosses, viz. Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 with the following objectives.

1. To assess the magnitude of induced variability for yield and some quantitative traits in segregating generations.

2. To study the spectrum and frequency of macro-mutations induced by gamma rays.
3. To explore the possibilities of isolating desirable phenotypic mutants.

REVIEW OF LITERATURE

Chapter - 2

REVIEW OF LITERATURE

Swaminathan (1965) classified mutations into two major groups, those which can be detected in a group of plants and their testing requires biometrical analysis are called micro-mutations, while those which can be recognised by a study of individual plants, involving gross change in the phenotype are called macro-mutations. A micro-mutation is a mutational event which causes only small modification of the phenotype of a trait.

The relevant literature on different aspects studied during the course of present investigation is reviewed briefly under the following headings:

- A. Macro-mutations and phenotypic mutants
- B. Micro-mutations and polygenic-variability
- C. Mutation frequency and spectrum.

A. Macro-mutations and phenotypic mutants

In many cases, induced macro-mutants may not be suitable for being released directly for cultivation, but they may prove excellent initial breeding materials (Gustafsson and Tedin, 1954). The great merit of such mutants is that the variability would be available in a well adapted variety.

Syakudu et al. (1958) and Yamagata and Syakudu (1960) obtained early and late maturing varieties in R_2 from four irradiated varieties of rice with gamma-rays. The change in latter type occurred more frequently than the former.

Futsuhara et al. (1967) reported the development of a rice variety 'Reimei' by irradiating the seeds with gamma-rays. Reimei has short culm and is resistant to lodging. Similarly, development of short statured and lodging resistant mutant varieties has also been reported by Marie and Tinarelli (1972) and Ree (1973).

Mutants that ripened earlier thanⁿ the parent variety have been reported by many workers in rice including Jodon (1958), Kawai (1963), Rajagopalan (1968), Viado et al. (1970), Haq et al. (1971), Swaminathan et al. (1971), Woo and Chang (1971), Bari and Awan (1974), Somoto and Kanai (1975), Awan and Cheema (1976), Rutgers (1977) and Sharma *et al.* (1985).

Awne mutants have been reported by Siddiq and Swaminathan (1968), Swaminathan (1970), Ratho and Jachuk (1971) in different varieties of rice.

Tanaka (1968) concluded after studying R_2 and R_3 generations that mutants with early or late heading dates showed the least frequency and each mutant line showed concurrent or combined changes in three characters on an average.

Gill et al. (1969) obtained an open spikelet mutant in M_2 progeny following gamma-irradiation of seeds of the cross Jhona 349 x Taichung Native-1. According to them it seems to be a monogenic recessive character.

Swaminathan et al. (1970) isolated a dwarf mutant, Tromby Rice - 1 (TR-1) from GEB variety after gamma-irradiation, which produced larger grains and flowered 15-20 days earlier.

Mohanty (1970) developed a new variety 'Jagannath' by treating T. 141 with X-rays, which is resistant to drought and shattering.

Radiation induced chlorophyll mutations in rice have been reported by several workers (Imai, 1935; Khanna, 1935; Ehrenberg et al; 1956; Bora and Rao, 1958; Matsuo et al; 1958; Yamaguchi, 1962; Swaminathan et al, 1962; Tanaka, 1968; Basu and Basu 1969; Miah and Awan, 1971 and Chakrabarti, 1975).

Saini and Gagneja (1971) treated the F_2 seeds of the cross between Jhona 349 x Taichung Native-1 with gamma-radiations and isolated a mutant in F_3 , which was shorter strawed and earlier maturing than Basmati 370. This mutant had longer grains but similar cooking quality as Basmati 370, Saini and Kumar (1973) also isolated a mutant from the cross Jhona 349 x Taichung Native-1, which is insensitive to photoperiod and temperature. It is early maturing, and has shorter straw and grain of better cooking quality.

Chao (1973) reported that the yielding capacity of the indica short statured strains, induced in Taiwan Native varieties after irradiation was equal to that of the improved varieties T(N)-1 and IR-8. Ram (1974) also isolated dwarf mutants with higher yields than the parental varieties from the irradiated tall varieties (NP-49, NP-114 and NP-8) and dwarf varieties (IR-8, Jaya and Padma).

Phenotypic and physiological mutants for maturity, plant height extra large glumes, awnedness, grain pubescence and grain dimensions have been reported by Bhatia (1973) and Kaushik (1974).

Bhan and Kaul (1974) reported a long-grained, strong culmed true breeding mutant with pleiotropic effects on genes governing other quantitative characters in Jhona 349 following treatment with gamma rays.

Saini et al. (1977) reported the recovery of a mutant following gamma-irradiation, which was 72 cm shorter than the parent variety Basmati 370, earlier by ten days and 83.7% higher yielding.

Mutant varieties with short stature, early maturity and improved tillering, grain yield and protein content were reported by Shaikh (1981).

Awan and Cheema (1981) compared the semi-dwarf mutants obtained through gamma-irradiation with the tall indica parent variety Basmati 370 and reported that reduction in height was associated with reduction in panicle components of yield, the degree of change differing between mutants and characters. The mutants were true breeding.

Malik (1982) isolated two rice mutants in the M₂ generation of Basmati 370 following gamma-irradiation. Basmati A 54 is a high yielding, semi-dwarf, matures 28 days earlier than Basmati 370 and has superior agronomic and quality traits. BMS-1 is a semi-dwarf mutants with 15-20 tillers per plant, reduced grain size, partially naked grains, 35-40% pollen sterility, alternate branching from every stem node and erect leaves.

B. Micro-mutations and polygenic variability

The variability caused by micro-mutations is polygenic in nature and of great importance to plant breeders. A better understanding of the mutation processes in such genetic systems and the nature of induced variability is of utmost importance in the application of induced mutations to plant breeding problems, as it tends to shift the mean of the homozygous lines.

The first analysis of induced mutation for quantitative traits in rice based on biometrical analysis was published by Oka et al. (1958). They observed increased variances for plant height and heading date in X-ray irradiated population over the control, though the means remained unchanged. This suggested that polygenic mutations with plus and minus effects occur equally frequently in both directions. However, these results were criticized by Bateman (1959), who reported that not only the variance but also mean values for plant height and days to heading increased significantly after irradiation. In his opinion the overall effect of polygenic mutations was unidirectional and no plus and minus mutations around the control mean could be obtained.

Increased variances for different quantitative characters were reported by several workers. Variances were increased for heading date, plant height and panicle length (Kao et al., 1960); flowering date, length and rigidity of culm, leaf width and grain length (Boroughs, 1962); plant height, plant weight, tiller number, panicle length and grain yield (Sakai and Suzuki, 1964); awn length, number of effective tillers and grain size (Venktanadachari, 1963); panicle length, grain number per panicle and 100-grain weight (Vairavan et al. 1973); tiller number, panicle length, grains per panicle and yield per plant (Mallick et al., 1979) in rice following mutagenic treatments. Increased variances accompanied by the shift in the means were also observed for various quantitative characters in rice, following physical and chemical mutagenic treatments (Sato, 1966; Roy and Jana, 1971; Jana and Roy, 1973; and Chakraborty and Sen, 1979).

Ota et al. (1962) irradiated dry seeds of Hamayu variety of rice with gamma-rays and found that variance increased with the increasing

dose, while the means did not differ much in irradiated and non-irradiated lots.

Miah and Yamaguchi (1964) treated the seeds of two rice varieties and their F_1 seeds and suggested that manifestation of mutated characters was modified by background genotype, and it was apparent that we could select more desirable variants by the irradiation of hybrid seeds in comparison to irradiation of the seeds of pure varieties.

Saini and Sharma (1970) studied the radiation induced variation for days to heading, plant height, tillers per plant and yield per plant in varieties Jhona 349 and Taichung Native-1 and the F_2 of the crosses between them. The mean values remained unchanged in the irradiated populations compared with the control. There was, however, an increase in genetic variance following irradiation. Hybridization combined with irradiation resulted in greater genetic variance than irradiation of parental types.

Ganashan (1971) selected a high yielding mutant line M_1 273, with shorter culm, relatively darker green leaves and an erect growth habit, from the progeny of gamma-irradiated seed of H_4 , a Ceylonese variety.

Chand et al. (1974) have found the highest phenotypic and genotypic co-efficients of variance and highest expected genetic advance for grain yield per plant. High broad sense heritabilities were recorded for spikelet numbers per panicle, number of panicle bearing tillers, days to heading and yield per plant. Most variation occurred at 15-20 kR doses with normal grain moisture.

Virk et al. (1978) treated the rice varieties Jhona 349 and Taichung Native-1 and their F_1 hybrids with different doses of gamma rays. A significant increase in variation was observed after exposure. The

magnitude of two types of variations i.e. induced variation in pure breeding lines and variation from hybridization segregation were almost the same for yield but was greater for plant height and tiller number in case of hybridization segregation.

Deng (1981) showed that in early mutants from the M_2 of ^{60}Co gamma-irradiated rice Taiying 1, the heritability values were in the order of 100-grain weight > heading date > plant height > grain number per panicle > grain weight per plant > panicle length > panicle number per plant.

Savov (1983) reported that considerable variation in height was found in the M_2 of six crosses of wheat varieties following irradiation of F_1 and F_2 grains with 5-15 kR gamma-rays. Upto 12.6% of mutants, depending on dosage and cross combination, had short culms. Plant with short and strong culms, upright leaves, productive spikes and good resistance to rust were obtained after irradiation of F_2 grains.

Zhou (1983) reported that in the M_2 derived from grains treated with 2 kR gamma-rays, heritability values for panicle length, panicle number, grain set per panicle, grain number per panicle; and fertility were higher in the late maturing mutants than in the early maturing mutants. In the M_3 , the heritability values for 1000-grain weight and heading date were 94.1 and 88.8% respectively in the early mutants, while 83.1 and 74.6% for panicle length and fertility in the late mutants.

C. Mutation frequency and spectrum

Chlorophyll mutations are the most important group of mutations, which have great significance in methodology investigation of mutation breeding programmes. However, chemical frequency might be more closely

correlated to gene mutation than the parameters like growth reduction and plant lethality, which have a major physiological component associated with induced genetic changes (Brun, 1954; Kaplan, 1954; Blixt et al. 1960 and 1964).

Different methods have been suggested for measuring the frequency of chlorophyll mutations per 100M₁ plants (Gustafsson, 1947). However, Gaul (1960) observed that the number of chlorophyll mutations per 100M₁ seedlings provide the best index for measuring mutation frequency, as it is proportional to the initial mutation rate and the size of the mutated sector. Similar observations were also made by Eriksson (1965), Jacobson (1966) and Sethi (1968).

Sharma (1968) reported a linear increase in chlorophyll mutation frequency with increase in dose of Ethyl methane sulphonate (EMS) and gamma-rays.

Ram and Zaman (1972) treated IR-8 with gamma-rays and found that both albina and xantha types were lethal and died after 10-15 days. Albina died a week earlier than xantha, whereas, green-striata (white bands on green leaves) and albina-striata (green bands on white base) survived and gave normal seed setting and normal plants in the R₃ generation.

Mehra (1975) reported that the frequency of chlorophyll mutations induced by gamma-rays was the highest in the main panicles, followed by lateral-I and lateral-II panicles.

Nayar and Ninan (1978) studied the frequency and spectrum of gamma-rays induced variation in rice variety Jaya and found that exposure of dry seeds to three doses of gamma rays reduced panicle length in the M₂ and M₃ generations. There were no differences for this trait between dose or between the seven panicle categories studied. High estimates for

genetic advance and heritability indicate that this trait can be improved through mutation breeding.

Reddy et al. (1979) treated dry seeds with gamma-rays followed by chloral hydrate, ethanol and methanol or mixtures of these chemicals and reported that chemicals gave rise to more chlorophyll deficient mutants in the M_2 generation than did treatment with gamma-rays alone.

Wu and Zhang (1983) reported that the frequency and range of mutation in the M_2 following irradiation of grains with gamma-rays, were correlated closely and positively with the dose of radiation and negatively with the M_1 seedling survival rate and fertility.

Alteration in the spectrum of chlorophyll mutations is another genetic effect, usually taken as the most important measure of mutagen specificity in higher plants. Chemical mutagens, especially alkylating agents, produced higher frequency of viridis type than radiations with which produce albina type with greater frequency (Ehrenberg et al., 1959; Favret, 1960; Konzak et al., 1961; Sharma, 1968). Nanda and Misra (1975) observed that albina mutants occurred with greater frequency, following gamma-rays and EMS treatments.

Seetharam and Nayar (1978) reported that chlorophyll mutants arising from seeds of an indica selection treated with EMS alone were mainly of the tigrina type, while those arising from gamma-rays treatment alone were mainly of the albina and xantha types.

Nallathambi and Raja (1982) treated the grains of rice variety CO 37 with gamma-rays and EMS separately and in combination. Mutation frequency could be estimated equally well as number of mutants per 100 M_1 spikes or number of mutants per 100 M_2 plants. Treatment with

gamma-rays gave higher mutation frequency than did EMS. Combination treatment induced mutations in higher frequency. The gamma-rays treatment produced albina, xantha and striata mutations, whereas EMS and combined treatments produced these types and virescens. Albina and xantha were the most frequent mutations overall but combined treatments produced more albina mutations than did the separate treatments.

MATERIAL AND METHODS

MATERIAL AND METHODS

The present investigation was carried out at the experimental area of the Department of Plant Breeding, Himachal Pradesh Krishi Vishva Vidyalaya, Palampur during the kharif seasons of 1983 and 1984. The experimental material for the study during kharif 1983 comprised of F_2 irradiated and unirradiated seeds of two crosses alongwith the parent varieties as described below:

1. F_2 and F_2M_1 generations, kharif 1983

The F_2 seeds of the two crosses in rice, viz., Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 were treated with gamma rays. 500 dry seeds of F_2 's of each cross stabilized at 13 per cent moisture content were irradiated with 25 kR gamma rays in ^{60}Co gamma rays cell from the Division of Genetics, Indian Agricultural Research Institute, New Delhi. Untreated 500 F_2 seeds of each cross and 100 seeds of each parent were used as control.

The F_2 seeds of the two rice crosses, along with their F_2 irradiated seeds and parents, were sown on a moist filter paper treatment wise, in separate petridishes during 1983. The temperature was maintained at 30°C during germination. Sprouted seeds were transferred to the finely prepared nursery trays. Thirty days old seedlings were transplanted in the field at 20 cm x 15 cm spacing to raise the F_2 and F_2M_1 generations during kharif 1983 alongwith the parents.

Following observations were recorded on 100 competitive plants of each of the F_2 's and F_2 irradiated populations and on 20 plants of each of the parental populations.

1. Plant height (cm)
2. Number of tillers per plant
3. Panicle length (cm)
4. Spikelet fertility (%)
5. 100-grain weight (g)
6. Grain yield (g)

At maturity, the selected plants were harvested individually, keeping the main panicle separately and bulking the remaining panicles of each plant. The remaining plants in each treatment were harvested and bulked. The main panicles were studied in the laboratory for panicle length, and number of fertile and sterile spikelets. One hundred grains were counted and weighed for each plant individually. The weight of grains from the main and other panicles of the plant was recorded for yield per plant.

Statistical analysis

The data recorded on various quantitative characters in F_2 and F_2M_1 generations were analyzed statistically using following formulae.

$$\text{Mean } (\bar{x}) = \frac{\sum_i^m X_i}{n}$$

Where, $X_i = i^{\text{th}}$ observation of a given character

$n =$ total number of observations

$$\text{Variance } (S^2) = \frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n - 1}$$

$$\text{Standard error} = \sqrt{\frac{S^2}{n - 1}}$$

Where, x_1 and n are the same as above and

$$S^2 = \text{Variance of the sample}$$

Significance of difference between any two treatments for observations recorded in percentages was done by using Z-test.

$$Z = \frac{2 \arcsin \sqrt{x_1} - 2 \arcsin \sqrt{x_2}}{\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where, x_1 and x_2 are observed values (expressed in decimal fraction) and n_1 and n_2 the number of observations in two treatments being compared. The standard error of percentage was calculated as follows:

$$\text{S.E. of percentage} = \sqrt{\frac{pq}{n}}$$

Where, p is the percentage expressed in decimal fraction, $q = 1 - p$ and n is the number of plants.

The significance of difference of any two treatment means for other observations was tested by using Student's t-test.

$$t = \frac{m_1 - m_2}{S \sqrt{1/n_1 + 1/n_2}}$$

Where, t = calculated value of t at respective degrees of freedom

m_1 = sample mean of one treatment

m_2 = sample mean of the other treatment

n_1 = sample size of one treatment

n_2 = sample size of the other treatment

S = Pooled standard deviation and

$$S = \sqrt{\frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{n_1 + n_2 - 2}}$$

Where, S_1^2 and S_2^2 are the variances of the two samples of sizes n_1 and n_2 .

The experimental material during kharif 1984 comprised of F_3 and F_3M_2 of the two crosses alongwith the parent varieties as described below:

2. F_3 and F_3M_2 generations, kharif 1984

The Seeds from randomly selected normal looking 40 F_2M_1 plants, 40 F_2 plants from each of the two crosses and 5 plant bulk for each parent were sown in the nursery beds for raising the seedlings of F_3 , F_3M_2 and parental populations, respectively. Fifteen, one month old seedlings of each of the 40 F_3 's and 40 F_3M_2 's progenies, alongwith 75 plants for each parent per replication were transplanted in a randomized block design with three replications. The row to row and plant to plant spacings were kept as 20 cm x 15 cm. Chlorophyll mutations and other variations, if any, were recorded at seedling stage. Two rows of purple-leaved dwarf variety R x T-47 were transplanted on either side of each replication to eliminate border effects. The field was checked regularly and gap filling was done from the balance nursery within 10 days of transplanting.

Fertilizers were applied at the rate of 100 kg N and 50 kg P_2O_5 and 50 kg K_2O per hectare. Half the dose of N and whole of P_2O_5 and K_2O were applied through German Mixture at the time of last puddling before transplanting and the remaining nitrogen was top-dressed through urea in two equal split doses 30 and 60 days after transplanting. Adequate water supply was maintained throughout the growing period of the crop.

The following Observations were recorded on five normal looking randomly selected plants in each progeny replication wise.

1. Days to heading: Number of days taken from sowing to panicle emergence.
2. Plant height (cm): Measured from the ground level to the tip of the main panicle, excluding awns, if any.
3. Tillers per plant: Number of panicle bearing tillers were counted and recorded at the time of maturity.
4. Panicle length(cm): The length of main panicle of each selected plant was measured from the panicle base to its tip, excluding awns, if any.
5. Fertility percentage: The main panicles were threshed seperately and the number of sterile and ferti/e spikelets in each of them were counted and fertility percentage calculated.
6. 100-grain weight(g): 100-grains were counted from the yield of each plant and their weight recorded.
7. Grain yield per plant (g): The grain yield of the selected plants was weighed and recorded.

Chlorophyll mutants in the progeny of $F_2 M_1$ plants ($F_3 M_2$) were counted and the number of mutant seedlings recorded in the progeny on population basis. The identification and classification of chlorophyll mutants were done according to Gustaffson (1947).

Chlorophyll mutation frequency

The chlorophyll mutation frequency in $F_3 M_2$ was calculated by using the following formula:

$$\text{Mutation frequency on } M_2 \text{ seedling basis (\%)} = \frac{\text{No. of mutated seedlings}}{\text{Total no. of } M_2 \text{ seedlings}} \times 100$$

Statistical analysis: Each individual family i.e. F_3 , F_3M_2 and parents of each crosses were analysed separately as per the analysis of variance given by Panse and Sukhatme (1967).

Analysis of variance for individual family

Source of variation	d.f.	Mean squares	Expectations of mean squares
Replication	(r - 1)	-	-
Progenies	(p - 1)	MS_1	$\sigma^2 + r \sigma_g^2$
Error	(r - 1)(p - 1)	MS_2	σ_e^2
Total	rp - 1		

The genotypic and phenotypic variances were computed by the formulae,

$$\text{Genotypic variance } (V_g) = \frac{MS_1 - MS_2}{r}$$

$$\text{Phenotypic variance } (V_p) = V_g + \sigma_e^2$$

Where,

MS_1 = mean square due to progenies

MS_2 = mean square due to error

r = number of replications

Phenotypic and genotypic variances were further used to compute various genetic parameters as follows:

1. Phenotypic coefficient of variation (PCV)

$$PCV\% = \frac{\sqrt{V_p}}{\bar{x}} \times 100$$

2. Genotypic coefficient of variation (GCV)

$$\text{GCV}\% = \frac{\sqrt{V_g}}{\bar{x}} \times 100$$

Where \bar{x} = mean of the character.

3. Heritability

Heritability in broad sense h_{bs}^2 was estimated as the ratio of genotypic variance to total phenotypic variance.

$$h_{bs}^2 = \frac{V_g}{V_p}$$

4. Genetic advances

$$\text{GA} = \sqrt{V_p} \times h_{bs}^2 \times k$$

Where, k = constant whose value at 5% selection intensity is 2.06.

h_{bs}^2 = heritability in broadsense

V_p = Phenotypic variance

Pooled analysis of variances

For comparing the mean values and testing the significance of variances within and between families, analysis of variance was done for all the quantitative characters as per standard procedure for pooled analysis and the total treatment variance was partitioned due to different components as follows

Source of variation	d.f.	Expectations of mean squares
Replication	2(r-1)	-
Treatments	3(t-1)	$\sigma_e^2 + r \sigma_t^2$
Himalaya 1 Vs PP 72/CH 988	1	
F ₃ Vs F ₃ M ₂	1	
F ₃ and F ₃ M ₂ Vs Parents	1	
Error	6 (r-1)(t-1)	σ_e^2
Total	11 (rt-1)	

Standard error and critical differencesStandard error of mean

$$SE(m) = \pm \sqrt{\frac{\sigma_e^2}{r}}$$

The critical difference for comparing two treatment means was calculated by using the formula as

$$C.D. 5\% = \sqrt{\frac{2 \times \sigma_e^2}{r}} \times t \text{ at } 5\% \text{ for error degrees of freedom.}$$

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The results obtained from the experiments conducted to study the nature of variation in segregating generations of irradiated and unirradiated F_2 seeds in rice are presented below generation-wise.

F_2 and F_2M_1 generation

The observations on the effect of gamma rays on F_2 seeds (F_2M_1), as measured by plant height, number of tillers per plant, panicle length, fertility percentage, 100-grain weight and grain yield per plant are presented in Table-1.

Plant height:

In cross Himalaya-1 x Phul Patas 72, both F_2 and F_2M_1 showed a significant increase over the shorter parent i.e. Himalaya-1 and a significant decrease over the taller parent i.e. Phul Patas 72. The F_2 and F_2M_1 showed an increase of 4.68 per cent and a decrease of 1.30 per cent, respectively over the mid-parent values

In cross Himalaya-1 x China 988, only F_2 showed a significant increase over the shorter parent i.e. Himalaya-1, whereas, both F_2 and F_2M_1 showed a significant decrease over the taller parent i.e. China 988. There is an increase of 2.40 per cent in F_2 and a decrease of 16.52 per cent in F_2M_1 over the mid-parent value for plant height.

The mean plant height in 25 kR gamma rays induced F_2 generation (F_2M_1) decreased significantly as compared to the mean of F_2 generation in both the crosses.

Number of tillers per plant:

In cross Himalaya-1 x Phul Patas 72, both F_2 and F_2M_1 exhibited a significant decrease over the better parent i.e. Himalaya-1 but a

significant increase over the poor parent i.e. Phul Patas 72. The F_2 and F_2M_1 showed a decrease of 13.06 and 2.92 per cent, respectively over the mid-parent value. The number of tillers increased significantly following 25 kR gamma-irradiation as compared to the untreated F_2 population.

In cross Himalaya-1 x China 988, significant and non-significant decrease over the two parents i.e. China 988 and Himalaya-1 respectively was observed in both F_2 and F_2M_1 . A decrease of 14.06 per cent and 13.19 per cent was observed in F_2 and F_2M_1 over the mid parent respectively. No significant difference was observed between F_2M_1 and F_2 for number of tillers per plant.

Panicle length:

The F_2 and F_2M_1 of the cross Himalaya-1 x Phul Patas 72 exhibited significant decrease over Phul Patas 72 but the difference was not significant when compared to Himalaya-1. The F_2 and F_2M_1 showed a decrease of 3.21 per cent and 4.10 per cent respectively over the mid-parent value. No significant difference was observed between the means of panicle length of F_2M_1 and F_2 .

In the cross Himalaya-1 x China 988, the F_2 and F_2M_1 showed a significant decrease over the better parent i.e. Himalaya-1, whereas, no significant difference in F_2 and F_2M_1 was observed when compared with China 988. F_2 and F_2M_1 showed a decrease of 1.85 per cent and 7.59 per cent, respectively over the mid parent value. A significant decrease in panicle length of F_2M_1 over F_2 was observed.

Fertility percentage:

In cross Himalaya-1 x Phul Patas 72, both F_2 and F_2M_1 showed a significant decrease for fertility percentage over Himalaya-1. However, only F_2M_1 showed a significant decrease in fertility percentage over Phul Patas 72. A decrease in fertility percentage of 18.41 and 55.51 per cent in F_2 and F_2M_1 respectively was observed over the mid parent value.

In cross Himalaya-1 x China 988, the F_2 and F_2M_1 exhibited a significant decrease for fertility percentage over both the parents. However, there was decrease in the fertility percentage of 27.43 and 60.88 per cent in F_2 and F_2M_1 respectively over the mid-parent value.

In both crosses, fertility percentage decreased significantly in F_2M_1 as compared to the F_2 populations.

100-grain weight:

Significant increase in 100-grain weight were observed in both untreated and treated F_2 populations of the cross Himalaya-1 x Phul Patas 72 over parent Himalaya-1, whereas, the differences were non-significant over Phul Patas 72. There is an increase of 7.69 per cent in F_2 and 11.54 per cent in F_2M_1 over the mid-parent value. No significant difference for 100-grain weight between F_2M_1 and F_2 was observed.

In cross Himalaya-1 x China 988, there were significant increase for 100 grain weight in F_2 and F_2M_1 populations over Himalaya-1, whereas, only F_2M_1 population showed a significant decrease over China 988. In F_2 and F_2M_1 populations an increase of 7.49 per cent and 0.88 per cent, respectively over mid-parent value was observed. 100-grain weight decreased significantly in F_2M_1 as compared to the F_2 mid-parent value.

Table 1 : Mean values and standard errors for different characters in parents, F_2 and F_{2M_1} generations.

Varieties/ Treatments	Plant height (cm)	Number of tillers per plant	Panicle length (cm)	Fertility (cm)	100- grain weight(g)	Yield per Plant (g)
1.	2.	3.	4.	5.	6.	7.
Himalaya-1	62.6±0.96	7.05±0.67	22.31±0.21	82.90±1.39	2.06±0.02	9.08±1.29
Phul Patas 72	121.8±2.88	3.20±0.27	24.48±0.25	64.41±2.77	2.09±0.05	8.15±0.67
Mid parent value	92.2±1.52	5.13±0.36	23.40±0.16	73.65±1.55	2.08±0.03	8.62±0.73
F_2 (Himalaya x Phul Patas 72)	96.5±1.63	4.46±0.17	22.65±0.24	60.99±2.03	2.24±0.05	6.71±0.43
Increase/Decrease over Mid parental value(%)	+4.66	-13.06	-3.21	-18.41	+7.69	-22.16
Increase/Decrease over Ist parent(%)	+54.15**	-36.74**	+1.52	-27.52**	+8.74*	-26.10*
Increase/Decrease over 2nd parent(%)	-20.77**	+39.38**	-7.48**	-6.71	+7.18	-17.67
F_{2M_1} (25 kR)	91.0±1.58	4.98±0.18	22.44±0.27	32.77±2.50	2.32±0.05	2.34±0.23
(Himalaya-1 x Phul Patas 72)						
Increase/Decrease over mid parent value(%)	-1.30	-2.92	-4.10	-55.57	+11.54	-72.85
Increase/Decrease over Ist parent (%)	+45.37**	-29.36**	+0.58	-60.47**	+12.62*	-74.23**
Increase/Decrease over 2nd parents(%)	-25.29**	+55.63**	-6.33**	-49.12**	+11.00	-71.29**

contd

Table 1 contd

1.	2.	3.	4.	5.	6.	7.
Himalaya-1	66.7 \pm 1.32	6.50 \pm 0.66	23.14 \pm 0.26	64.21 \pm 1.51	2.07 \pm 0.03	9.54 \pm 1.08
China 988	91.9 \pm 1.95	7.30 \pm 0.54	21.09 \pm 0.40	80.90 \pm 1.87	2.47 \pm 0.03	9.87 \pm 0.98
Mid parent value	79.3 \pm 1.18	6.90 \pm 0.43	22.12 \pm 0.24	82.56 \pm 1.20	2.27 \pm 0.02	9.71 \pm 0.73
F ₂ (Himalaya-1 x China 988)	81.2 \pm 1.37	5.93 \pm 0.24	21.71 \pm 0.21	50.91 \pm 2.32	2.44 \pm 0.03	5.57 \pm 0.40
Increase/Decrease over mid parent value (%)	+2.40	-14.08	-4.85	-27.43	+7.49	-42.64
Increase/Decrease over 1st parent (%)	+21.74 ^{**}	-8.77	-6.18 ^{**}	-28.86 ^{**}	+17.87 ^{**}	-42.64 ^{**}
Increase/Decrease over 2nd parent (%)	-11.64 ^{**}	-18.77 [*]	+2.94	-25.95 ^{**}	-1.21	-43.57 ^{**}
F ₂ M ₁ (25 kR) (Himalaya-1 x China 988)	66.2 \pm 1.22 ^{**}	5.99 \pm 0.28	20.44 \pm 0.21 ^{**}	32.30 \pm 0.03 ^{**}	2.29 \pm 0.03 ^{**}	1.64 \pm 0.18 ^{**}
Increase/Decrease over mid parent value (%)	-16.52	-13.19	-7.59	-60.88	+0.88	-83.11
Increase/Decrease over 1st parent (%)	-0.75	-7.85	-11.67 ^{**}	-61.64 ^{**}	+10.63 ^{**}	-82.82 ^{**}
Increase/Decrease over 2nd parent (%)	-27.97 ^{**}	-17.95 ^{**}	-3.08	-60.07 ^{**}	-7.29 ^{**}	-83.38 ^{**}

^{**}, ^{*} - Significant increase or decrease of F₂ and F₂M₁ over parents at 5% and 1% level respectively

^{**}, ⁺ - Significant increase or decrease of F₂M₁ over F₂ at 5% and 1% level respectively.

Yield per plant:

In cross Himalaya-1 x Phul Patas 72, both F_2 and F_2M_1 populations showed a significant decrease in yield per plant over the better parent i.e. Himalaya-1, whereas, only F_2M_1 population had significant decrease over Phul Patas 72. There is a decrease of 22.16 per cent and 72.85 per cent in F_2 and F_2M_1 populations, respectively over the mid parent value.

In cross Himalaya-1 x China 988, significant decrease of yield per plant in both F_2 and F_2M_1 populations over the two parents was observed. There is a decrease of 42.64 and 82.11 per cent for yield in F_2 and F_2M_1 populations respectively over the mid-parent value.

In both the crosses, a significant decrease for grain yield per plant was observed in 25 kR gamma-irradiated F_2 populations as compared to normal F_2 's.

Regarding the effect of irradiation on induction of variability in M_1 generation of F_2 seeds, it has been observed that in both the crosses, viz. Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988, the variance (Table-2) for plant height and yield per plant decreased as compared to the unirradiated F_2 . However, the decrease was significant only for yield per plant. The variation increased significantly for fertility percentage and 100-grain weight in F_2M_1 as compared to the F_2 , whereas, the increase was non-significant for tillers per plant. For panicle length the variance increased in F_2M_1 in cross Himalaya-1 x Phul Patas 72 whereas it decreased in Himalaya-1 x China 988, but the differences were not significant.

Table 2. Variances for different characters in F_2 and F_2M_1 generations of two rice crosses

Treatment	Characters	Plant height	Number of tillers per plant	Panicle length	Fertility percentage	100-grain weight	Yield per plant
F_2	(Himalaya-1 x PP 72)	266.264	2.998	5.662	411.441	0.203	18.196
F_2M_1	(Himalaya-1 x PP 72)	250.396	3.373	7.049	623.876*	0.299*	5.440**
F_2	Himalaya-1 x China 988	188.499	5.824	4.517	539.129	0.063	15.988
F_2M_1	Himalaya-1 x China 988	148.579	8.050	4.323	770.829*	0.106*	3.116**

* Significant increase or decrease in F_2M_1 over F_2 at 5% level

** Significant increase or decrease in F_2M_1 over F_2 at 1% level

F₃ and F₃M₂ generation

Spectrum and frequency of chlorophyll mutations in F₃M₂

The most striking effect of the physical mutagens is the occurrence of chlorophyll mutations in the progenies of the treated populations. The frequency of these mutations calculated on the basis of M₂ seedlings and M₁ plant progeny are given in Table 3.

The overall chlorophyll mutation frequency observed in the 25 kR induced F₃M₂ generation of cross Himalaya-1 x Phul Patas 72 was 3.09 per cent, whereas, that of cross Himalaya-1 x China 988 was 1.26 per cent on M₂ seedling basis. The same was 27.83 per cent in cross Himalaya-1 x Phul Patas 72 and 30.61 per cent in cross Himalaya-1 x China 988 on M₁ plant progeny basis.

The spectrum of chlorophyll mutations comprised Albina, Xantha, Striata, Xantha-alba and viridis as given in Table 3.

Albina: This type of chlorophyll mutation occurred most frequently in both the crosses, Himalaya-1 x Phul Patas 72 with 86 albinas and Himalaya-1 x China 988 with 18 albinas, having frequencies of 1.97 and 0.39 respectively.

Xantha: 14 xanthas with a frequency of 0.32 were observed in the F₃M₂ of the cross Himalaya-1 x Phul Patas 72 and 13 xanthas with a frequency of 0.28 were observed in the F₃M₂ of the cross Himalaya-1 x China 988.

Striata: In the cross Himalaya-1 x Phul Patas 72, 16 striatas with a frequency of 0.37, and in the cross Himalaya-1 x China 988, 14 striatas with a frequency of 0.30 were observed in the F₃M₂.

Table 3 : Spectrum and frequency of Chlorophyll α mutations induced by gamma rays (25 kR) in F_3M_2 generation of two crosses of rice.

Crosses	Himalaya-1 x Phul Patas 72	Himalaya-1 x China 988
Treatment	F_3M_2 (25 kR) gamma rays	F_3M_2 (25 kR) gamma rays
Total number of seedlings	4370	4608
<u>Albina</u> Spectrum	86	18
Frequency (%)	1.97	0.39
<u>Xantha</u> Spectrum	14	13
Frequency (%)	0.32	0.28
<u>Striata</u> Spectrum	16	14
Frequency (%)	0.37	0.30
<u>Xantha-alba</u> Spectrum	13	9
Frequency (%)	0.30	0.20
<u>Viridis</u> Spectrum	6	4
Frequency (%)	0.14	0.09
Total	135	58
Overall frequency (%) (M_2 seedling basis)	3.09	1.26
Overall frequency (%) (M_1 plant progeny basis)	27.83	30.61

Xantha-alba: In the cross Himalaya-1 x Phul Patas 72, 13 xantha-albas with a frequency of 0.30 were observed, whereas 9 xantha-albas with a frequency of 0.20 were observed in the cross Himalaya-1 x China 988.

Viridis: Viridis occurred less frequently in both the crosses. Six viridis with a frequency of 0.14 were observed in the F_3M_2 of the cross Himalaya-1 x Phul Patas 72 whereas, only 4 viridis with a frequency of 0.09 were observed in the cross Himalaya-1 x China 988.

Analysis of variance

Results of individual analysis of variance for various characters studied in the two crosses are presented in Table 4.

There were no significant differences within the parent varieties used in two crosses for different characters studied. Within F_3 and F_3M_2 progenies of the two crosses there were significant differences for all the characters, viz., days to heading, plant height, number of tillers per plant, panicle length, fertility percentage, 100-grain weight and yield per plant except for fertility percentage in both F_3 and F_3M_2 of the cross Himalaya-1 x China 988.

Range and mean performance of progenies

The range and mean values of individual progenies of parents, F_3 's and F_3M_2 's for different characters studied are presented in the Table 5-10.

In case of F_3 population of the cross Himalaya-1 x Phul Patas 72, the range for days to heading was 87.2 to 109.0 days with mean days to heading as 97.1. Progeny numbers 17, 32 and 29 took significantly less

Table 4 : Analyses of variance for different characters in parents, F_3 and $F_{3/2}$ of the two crosses.

Varieties and Treatments	Source	d.f.	Mean squares						
			Days to heading	Plant height	No. of tillers/plant	Panicle length	Fertility (%)	100-grain weight	Yield per plant
Himalaya-1	Progenies	4	29.0	19.0	0.8	0.3	9.5	0.006	4.67
	Error	8	8.2	14.1	0.2	0.5	2.8	0.005	1.74
Phul Patas 72	Progenies	4	6.0	82.6	0.7	1.5	15.2	0.082	4.41
	Error	8	2.6	46.1	0.3	3.5	27.2	0.044	1.22
F_3 normal	Progenies	39	81.3**	289.7**	3.1**	2.0*	149.4**	0.126**	6.54**
Himalaya-1 x PP 72	Error	78	18.9	119.9	0.9	1.2	39.8	0.032	1.69
$F_{3/2}$	Progenies	39	77.2**	379.9**	3.3**	2.0*	106.1*	0.163**	5.27**
(Himalaya-1 x PP 72)	Error	78	21.6	69.9	1.0	1.24	64.5	0.040	1.34
Himalaya-1	Progenies	4	15.4	5.3	0.2	0.4	32.4	0.000	0.93
	Error	8	5.8	10.0	0.2	0.5	10.8	0.002	0.70
China 988	Progenies	4	11.3	10.0	1.8	0.2	11.8	0.001	2.22
	Error	8	3.0	3.91	1.4	0.3	9.4	0.004	1.065
F_3	Progenies	39	47.6**	338.5**	2.4*	1.8*	58.8	0.087**	10.14**
(Himalaya-1 x China 988)	Error	78	24.5	48.7	1.4	1.0	67.4	0.031	0.78
$F_{3/2}$	Progenies	39	60.3**	493.9**	2.4**	2.4**	73.4	0.092**	7.58**
(Himalaya-1 x China 988)	Error	78	18.9	37.5	1.0	0.8	55.9	0.039	0.70

* Significant at 5% level

** Significant at 1% level

number of days to heading, whereas, progeny numbers 34, 25 and 40 took more number of days as compared to the mean of the progenies of this population. In the F_3M_2 progenies of this cross, the range for days to heading was 89.9 to 109.2 days with an average number of days to heading as 97.1. Progeny numbers 20 and 12 were significantly earlier whereas, progeny numbers 3 and 31 were significantly late in days to heading as compared to the mean of the population.

The F_3 progenies of the cross Himalaya-1 x China 988 had a range of 86.3 to 101.4 days with a mean number of days to heading as 95.2. Only progeny numbers 20 and 37 were significantly earlier in days to heading as compared to the mean of the population. In case of F_3M_2 of this cross, the range for days to heading was 82.1 to 101.8 days and the mean number of days taken for heading was 92.9. Progeny numbers 6, 12 and 16 took significantly less number of days for heading, whereas, progeny numbers 23, 29, 36 and 37 took significantly more number of days for heading compared to the overall mean i.e. 92.9 days.

Plant height:

In case of F_3 of the cross Himalaya-1 x Phul Patas 72, the range for plant height was 62.2 to 103.1 cm with a mean value of 82.7 cm. Only the progeny numbers 7 and 37 were significantly dwarf and tall respectively over the mean of the population. The F_3M_2 of progenies of this cross had a range of 56.9 to 101.9 cm with a mean of 77.9 cm. Progeny numbers 13, 14 and 37 had significantly less plant height, whereas, progeny numbers 1, 7, 18, 20, 23, 26, 38 and 40 had significantly more plant height as compared to mean plant height of the population.

In F_3 of the cross Himalaya-1 x China 988 the range for plant height was 51.6 to 92.7 cm with a mean value of 78.1 cm. Progeny numbers 1,3, 10, 12, 13 and 24 were significantly shorter, whereas, progeny numbers 22, 25, 28, 35, 39 and 40 were significantly taller than the mean plant height. In case of F_3M_2 progenies of this cross, the plant height varied from 51.0 to 91.0 cm with an average of 74.1 cm. Progeny numbers 1, 6, 7, 11, 16, 17, 22, 23, 29, 30 and 34 were significantly shorter in plant height, whereas, progeny numbers 2, 4, 12, 13, 14, 15, 20, 21, 25, 27, 32, 35, 37 and 39 were significantly taller as compared to the population mean.

Number of tillers per plant

In different progenies of the F_3 population of the cross Himalaya-1 x Phul Patas 72, the number of tillers per plant ranged from 3.3 to 8.4 with a population mean of 5.0. Progeny number 18 had significantly less, whereas, progeny number 2, 29 and 33 had significantly more number of tillers per plant as compared to the average of the population. In the F_3M_2 of this cross the range was from 4.0 to 8.0 with mean number of tillers per plant as 5.6. Progeny numbers 13, 22, and 40 had significantly more number of tillers per plant as compared to the mean.

The range and mean for number of tillers per plant in F_3 of the cross Himalaya-1 x China 988 were 4.6 to 8.5 and 6.6, respectively and there were no significant differences among progenies of this population. In F_3M_2 of this cross, the range was 3.2 to 7.8 with mean as 6.0. Progeny number 36 had significantly less whereas, progeny number 3 had significantly more number of tillers per plant as compared to the overall average of the population.

Panicle length

In case of F_3 population of the cross Himalaya-1 x Phul Patas 72, the range for panicle length was 19.8 cm to 23.7 cm with a mean value of 21.3 cm. Only progeny number 13 had a significant increase in panicle length over the mean of the population. In the F_3M_2 of this cross a range of 19.5 cm to 23.2 cm with the mean panicle length of 21.2 cm was observed. Progeny numbers 19 and 38 showed significant increase in panicle length over the population mean.

The F_3 population of the cross Himalaya-1 x China 988 had a range of 19.3 cm to 22.7 cm and a mean of 20.9 cm. Only progeny number 33 showed a significant increase for panicle length as compared to the population mean. In the F_3M_2 of this cross, the range was 18.9 cm to 22.6 cm with a mean panicle length of 21.0 cm. Progeny numbers 19 and 38 had significantly less panicle length, whereas, progeny numbers 27 and 31 had significantly more panicle length as compared to the mean of the population.

Fertility percentage:

In case of F_3 population of the cross Himalaya-1 x Phul Patas 72, the range for fertility percentage was 31.8 to 62.6. Progeny numbers 12 and 18 were significantly less fertile, whereas, progeny numbers 4, 6, 37 and 39 were significantly more fertile over the mean of the population (50.3 per cent). The F_3M_2 population of this cross had a range of 33.2 per cent to 62.7 per cent with a mean of 47.7 per cent. Progeny number 16 was significantly less fertile, whereas, progeny number 12 was significantly more fertile as compared to the average of the population.

No significant differences were observed in the progenies of both F_3 and F_3M_2 populations of the cross Himalaya-1 x China 988.

100-grain weight

In F_3 population of the cross Himalaya-1 x Phul Patas 72, the range and mean for 100-grain weight were 1.75 g to 2.70 g and 2.25 g. Progeny numbers 28 and 39 had significantly less 100-grain weight, whereas, progeny numbers 2, 19, 20 and 37 had significantly more 100-grain weight as compared to the mean of the population. The F_3M_2 population of this cross had a range of 1.73 g to 2.92 g with a mean value of 2.24 g. Progeny numbers 3, 11, 18 and 30 had significantly less, whereas, progeny numbers 13 and 40 had significantly more 100-grain weight over the population mean.

In case of F_3 population of the cross Himalaya-1 x China 988, the range for 100-grain weight was 2.24 g to 3.06 g with mean as 2.46 g. Only progeny numbers 25 and 35 had significantly more 100-grain weight than the overall mean of the population. The range and mean of the F_3M_2 of this cross were 2.00 g to 2.85 g and 2.40 g respectively. Progeny number 29 had significantly less, whereas, progeny numbers 2 and 10 had significantly more 100-grain weight as compared to the average 100-grain weight of the population.

Yield per plant

In case of F_3 of the cross Himalaya-1 x Phul Patas-72, the range and mean for yield per plant were 3.47 g to 9.87 g and 6.43 g respectively. Among the progenies of the population, only progeny number 9 had significantly higher yield as compared to the mean of the population. In F_3M_2 of this cross, the range for yield per plant was

4.28 g to 10.39 g with a mean value as 6.21 g. In this population, progeny numbers 6, 12 and 20 had significantly higher yields than the overall average of the population.

In the F_3 population of the cross Himalaya-1 x China 988, the yield per plant ranged from 4.48 g to 12.68 g with a mean yield of 7.22 g. Progeny nos. 22, 25, 33, 35, 36 and 39 had significantly higher yields than the overall average yield of the population. In F_3M_2 population, the range for yield per plant was from 2.87 g to 9.99 g with a mean value of 6.11 g. Progeny numbers 5, 12, 13, 15, 18, 28, 35 and 37 were significantly higher yielding as compared to the average yield of the population.

Variability and genetic parameters:

Various genetic parameters viz., genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PCV), heritability in broad sense (H_{bs}) and expected genetic advance (GA) were calculated only in those treatments and characters for which the variances were significant.

These are presented in Tables 11 - 17 characterwise.

Days to heading: In the cross Himalaya-1 x Phul Patas 72, the F_3 population had a higher GCV (4.70%) as well as the estimates of heritability (52.45%) and expected GA (6.81%) than the F_3M_2 where the values were 4.63%, 46.17% and 6.03% respectively. However, F_3M_2 had a higher PCV (6.82%) than the F_3 (6.49%).

In the cross Himalaya-1 x China 988, the F_3M_2 showed a higher genotypic coefficient of variation (3.8%), estimates of heritability (44.1%) and genetic advance (5.1%) but a lower phenotypic coefficient of variability

Table 5 : Mean values of different progenies for various characters in parents of the cross Himalaya-1 x Phul Patas 72

Varieties	Days to heading	Plant height (cm)	No. of tillers/plant	Panicle length (cm)	Fertility (%)	100-grain weight(g)	Yield/Plant (g)
<u>Himalaya-1</u>							
P ₁	97.5	55.1	3.7	20.7	59.8	2.05	8.23
P ₂	93.2	56.8	4.7	21.3	64.2	2.11	9.68
P ₃	90.3	60.0	5.1	21.4	63.9	1.99	9.30
P ₄	97.0	53.2	4.5	20.7	62.3	2.07	7.22
P ₅	96.7	55.8	4.3	21.0	61.9	2.04	6.83
Mean	94.93	56.19	4.84	20.99	62.44	2.05	8.25
SE(m) _±	0.98	1.00	0.21	0.20	0.57	0.02	0.94
CD 5%	NS	NS	NS	NS	NS	NS	NS
CD 1%	NS	NS	NS	NS	NS	NS	NS
CV	3.01	6.69	8.98	3.26	2.68	3.40	16.01
<u>Phul Patas 72</u>							
P ₁	104.3	102.5	3.5	23.0	50.8	1.86	5.80
P ₂	103.1	107.4	4.3	21.8	54.4	2.24	8.04
P ₃	105.5	94.9	4.3	22.4	56.1	2.10	6.37
P ₄	106.5	98.1	3.5	21.5	54.2	1.99	5.62
P ₅	106.2	95.5	3.4	23.0	51.3	1.85	4.78
Mean	105.13	99.69	6.35	22.34	53.37	2.01	6.12
SE(m) _±	0.49	2.71	0.33	0.41	1.28	0.06	0.37
CD 5%	NS	NS	NS	NS	NS	NS	NS
CD 1%	NS	NS	NS	NS	NS	NS	NS
CV	1.53	6.81	10.91	8.39	9.77	10.50	18.01

NS - Non significant.

Table 6 : Mean values of different progenies for various characters in parents of the cross Himalaya-1 x China 988.

Varieties	Days to heading	Plant height (cm)	No. of tillers/ plant	Panicle length (cm)	Fertility (%)	100-grain weight (g)	Yield per plant (g)
<u>Himalaya-1</u>							
P ₁	95.1	56.5	5.0	20.9	57.2	2.04	7.54
P ₂	97.2	55.3	4.5	21.1	58.3	2.02	7.19
P ₃	94.0	56.4	5.1	21.3	54.2	2.04	7.78
P ₄	99.3	58.8	5.0	21.3	60.3	2.04	7.91
P ₅	98.7	57.5	4.6	20.3	52.1	2.03	6.52
Mean	96.87	56.90	4.51	20.96	56.41	2.03	7.39
S.E(m) _±	1.02	0.86	0.17	0.19	1.02	0.01	0.22
CD 5%	NS	NS	NS	NS	NS	NS	NS
CD 1%	NS	NS	NS	NS	NS	NS	NS
CV	2.48	5.56	11.0	3.47	5.84	2.05	11.29
<u>China 988</u>							
P ₁	97.8	96.2	6.7	21.1	50.0	2.51	8.80
P ₂	101.2	93.3	6.3	21.3	52.1	2.49	9.03
P ₃	102.5	91.7	5.4	20.7	98.1	2.46	7.98
P ₄	98.9	94.0	7.4	20.8	53.2	2.48	9.85
P ₅	101.5	92.0	5.9	21.3	49.9	2.47	7.70
Mean	100.39	93.44	3.80	21.04	50.65	2.48	8.67
S.E(m) _±	0.83	0.75	0.17	0.18	1.09	0.03	0.35
CD 5%	NS	NS	NS	NS	NS	NS	NS
CD 1%	NS	NS	NS	NS	NS	NS	NS
CV	1.73	2.12	14.49	2.78	6.06	1.29	11.90

NS - Non-significant.

Table 7 : Mean values of different progenies for various characters in F_3 of the cross Himalaya-1 x Phul Patas 72.

Progenies	Characters						
	Days to heading	Plant height	No. of tillers per plant	Panicle length	Fertility percentage	100-grain weight	Yield per plant
1.	2.	3.	4.	5.	6.	7.	8.
P ₁	93.3	89.4	5.3	19.8	50.4	2.31	6.16
P ₂	96.7	84.3	7.55	20.8	149.5	2.59	7.65
P ₃	102.4	65.9	4.0	21.3	58.5	2.22	7.50
P ₄	90.5	83.2	5.2	20.3	61.3	2.27	6.66
P ₅	93.9	81.6	5.2	21.4	58.6	2.06	8.06
P ₆	96.1	71.3	5.7	21.6	62.2	2.31	8.59
P ₇	100.5	62.2	5.2	20.4	43.1	2.12	5.04
P ₈	97.0	70.1	4.1	20.0	51.1	2.28	5.45
P ₉	94.8	74.5	5.7	21.0	55.8	2.31	9.87
P ₁₀	92.2	85.9	4.1	21.5	52.2	2.29	6.27
P ₁₁	101.2	81.8	4.6	22.0	44.1	2.49	5.86
P ₁₂	100.4	83.3	4.3	21.2	31.8	2.02	5.14
P ₁₃	96.8	96.6	6.0	23.7	49.1	2.40	6.29
P ₁₄	95.4	86.1	5.1	21.4	57.9	2.23	8.43
P ₁₅	95.5	92.5	4.2	22.0	56.4	2.52	5.68
P ₁₆	94.0	85.5	5.3	21.4	47.5	2.17	7.64
P ₁₇	89.5	96.4	3.9	21.8	53.6	2.32	4.73
P ₁₈	101.2	74.1	3.3	20.6	36.7	2.00	5.11
P ₁₉	92.0	93.8	4.3	22.7	41.6	2.61	5.10
P ₂₀	93.7	93.5	6.4	21.5	44.6	2.21	5.22

contd.....

Table 7 contd

1.	2.	3.	4.	5.	6.	7.	8.
P ₂₁	95.3	90.4	5.6	21.7	53.8	2.18	8.55
P ₂₂	94.9	80.3	5.2	21.3	44.4	2.16	5.50
P ₂₃	101.8	83.4	4.3	20.0	50.7	2.06	6.21
P ₂₄	101.7	74.9	5.1	20.9	49.0	1.97	4.25
P ₂₅	99.3	84.6	5.1	20.6	51.2	2.02	8.08
P ₂₆	90.4	84.8	3.9	20.7	44.0	2.15	5.52
P ₂₇	101.7	85.7	4.5	22.0	54.5	2.15	5.66
P ₂₈	99.6	72.6	6.7	21.4	56.2	1.90	7.79
P ₂₉	87.2	88.7	5.7	21.4	49.8	2.40	3.87
P ₃₀	100.6	87.9	4.3	21.3	48.5	2.42	5.87
P ₃₁	95.6	96.2	4.7	21.7	54.4	2.45	6.19
P ₃₂	88.3	89.3	8.4	22.8	43.0	2.26	6.89
P ₃₃	95.5	89.0	4.1	20.7	43.4	2.41	5.68
P ₃₄	107.8	69.5	4.0	22.5	45.4	2.31	5.01
P ₃₅	109.0	70.3	4.3	21.4	60.7	2.12	6.48
P ₃₆	100.5	73.0	5.2	21.1	54.1	2.28	3.47
P ₃₇	93.5	103.1	3.9	22.3	62.6	2.61	7.24
P ₃₈	92.0	91.9	5.1	21.6	62.6	2.20	8.68
P ₃₉	103.3	67.7	5.8	22.4	40.3	1.75	9.17
P ₄₀	107.0	72.0	4.6	22.4	40.3	2.01	4.55
Mean	97.08	82.68	4.99	21.37	50.32	2.25	6.43
S.E(m) _±	0.59	1.26	0.11	0.12	0.80	0.24	0.16
CD 5%	6.95	17.53	1.49	1.73	10.09	0.29	3.068
CD 1%	9.14	23.03	1.96	2.27	13.26	0.38	4.033
CV	4.48	13.25	18.7	5.05	12.52	8.03	19.6
Range	87.2-109.0	62.2-103.1	3.3-8.4	19.8-23.7	31.8-62.6	1.75-2.70	3.47-9.87

Table 8 : Mean values of different progenies for various characters in F₂M₂ of the cross Himalaya-1 x Phul Patas 72

Progenies	Characters						
	Days to heading	Plant height	No. of tillers per plant	Panicle length	Fertility percentage	100-grain weight	Yield per plant
1.	2.	3.	4.	5.	6.	7.	8.
P ₁	95.7	91.93	6.7	21.3	37.5	2.28	5.50
P ₂	97.2	72.5	5.0	20.6	50.0	2.36	6.51
P ₃	107.1	75.1	4.3	21.9	37.0	1.80	5.11
P ₄	98.9	67.0	6.8	20.9	48.0	2.18	6.52
P ₅	96.9	86.4	5.9	21.2	47.0	2.28	6.67
P ₆	102.4	84.2	5.9	21.3	44.3	2.08	8.20
P ₇	101.2	95.1	4.9	21.9	53.6	1.96	5.92
P ₈	97.7	67.6	6.4	19.9	54.3	2.39	5.75
P ₉	97.0	77.3	4.5	20.6	49.6	2.51	4.28
P ₁₀	101.1	86.6	5.7	20.3	41.5	2.36	5.42
P ₁₁	101.8	74.5	5.0	21.0	43.3	1.73	5.21
P ₁₂	89.9	67.1	7.1	22.1	62.7	2.06	10.39
P ₁₃	92.4	56.9	8.1	19.5	52.2	2.92	7.76
P ₁₄	99.9	59.2	5.5	10.4	37.4	2.16	5.04
P ₁₅	98.5	81.6	4.2	21.3	47.5	2.01	5.06
P ₁₆	94.9	75.7	4.7	19.8	33.2	2.13	5.53
P ₁₇	90.9	78.1	5.3	21.3	46.2	2.29	4.65
P ₁₈	100.9	92.3	4.7	21.0	48.8	1.86	7.18
P ₁₉	93.7	87.7	4.9	23.2	55.8	2.30	7.52
P ₂₀	90.1	94.9	5.5	21.6	53.3	2.31	7.01
P ₂₁	97.1	82.2	5.2	22.7	48.6	2.09	6.89
P ₂₂	91.4	81.2	7.5	21.5	51.3	2.38	9.44
P ₂₃	95.9	99.7	5.2	22.3	54.1	2.37	6.49

contd.....

Table 8 contd.....

1.	2.	3.	4.	5.	6.	7.	8.
P ₂₄	95.7	71.4	6.3	20.6	51.1	2.05	7.45
P ₂₅	101.0	75.5	5.2	21.3	38.9	2.00	5.15
P ₂₆	95.9	90.3	5.5	22.6	44.7	2.26	6.61
P ₂₇	96.3	79.5	7.1	22.0	47.1	2.49	5.97
P ₂₈	101.4	70.3	4.9	21.7	50.2	2.46	4.59
P ₂₉	95.1	73.4	5.8	20.5	56.6	2.31	7.97
P ₃₀	103.6	66.6	5.8	21.6	53.5	1.75	7.47
P ₃₁	109.2	86.9	4.5	20.7	46.2	2.31	5.44
P ₃₂	93.9	68.0	5.2	21.0	47.8	2.42	5.61
P ₃₃	91.8	86.1	6.7	21.1	51.5	2.25	5.75
P ₃₄	94.1	88.7	4.9	21.4	45.4	2.26	5.81
P ₃₅	100.8	86.0	4.0	20.7	44.1	2.41	5.09
P ₃₆	91.1	90.0	7.2	20.8	43.9	2.44	5.42
P ₃₇	94.0	59.5	5.5	21.1	47.0	2.19	5.15
P ₃₈	97.4	101.9	4.6	23.0	49.0	2.26	4.70
P ₃₉	98.3	74.6	4.3	21.0	49.2	2.18	6.15
P ₄₀	92.54	92.3	5.8	21.2	43.7	2.56	5.71
Mean	97.12	77.89	5.61	21.24	47.67	2.24	6.21
S.E(m) _±	0.52	1.21	0.12	0.11	0.84	0.03	0.15
CD 5%	6.74	13.38	1.65	1.79	12.85	0.32	1.85
CD 1%	8.90	15.59	2.17	2.35	16.89	0.42	2.43
CV	4.36	10.47	18.44	5.25	16.84	8.91	18.65
Range	89.9-109.2	56.9-101.9	4.0-8.0	19.5-23.2	33.2-62.7	1.73-2.92	4.28-10.39

Table 9 : Mean values of different progenies for various characters in F₃ of the cross Himalaya-1 x China 988

Progenies	Characters						
	Days to heading	Plant height	No. of tillers per plant	Panicle length	Fertility percentage	100-grain weight	Yield per plant
1.	2.	3.	4.	5.	6.	7.	8.
P ₁	97.8	51.6	5.2	21.5	46.7	2.45	5.50
P ₂	92.5	77.2	6.0	19.8	55.6	2.34	7.22
P ₃	96.7	66.2	6.7	19.7	46.7	2.44	4.66
P ₄	93.9	77.9	6.3	22.0	51.0	2.31	6.09
P ₅	95.7	84.4	6.3	20.8	58.2	2.32	8.51
P ₆	96.3	80.4	7.7	20.8	59.0	2.37	7.71
P ₇	94.5	82.5	7.9	20.1	57.6	2.54	3.36
P ₈	91.0	79.7	7.1	21.2	50.5	2.88	4.48
P ₉	94.0	73.1	4.6	20.4	54.9	2.30	6.10
P ₁₀	94.1	57.8	6.9	20.9	49.4	2.42	8.40
P ₁₁	99.2	80.1	6.2	21.3	47.9	2.25	6.51
P ₁₂	100.7	65.6	7.1	21.4	51.7	2.31	8.09
P ₁₃	97.9	53.2	6.6	19.5	47.5	2.48	5.80
P ₁₄	93.4	75.5	5.4	20.9	54.9	2.62	4.98
P ₁₅	93.6	82.1	6.7	21.6	43.7	2.42	8.33
P ₁₆	100.4	69.2	8.5	20.2	48.3	2.35	3.73
P ₁₇	98.9	72.1	6.1	20.5	55.8	2.53	4.97
P ₁₈	90.8	71.9	5.0	20.1	54.9	2.24	6.09
P ₁₉	94.0	80.0	7.1	21.7	53.2	2.69	8.62
P ₂₀	86.3	72.3	6.7	21.2	62.7	2.44	7.80
P ₂₁	91.9	85.2	6.8	19.9	53.3	2.70	6.25
P ₂₂	95.1	91.1	7.7	21.1	56.1	2.56	9.50
P ₂₃	98.7	81.4	6.2	20.7	57.9	2.39	8.38

contd.....

Table 9 contd#

1.	2.	3.	4.	5.	6.	7.	8.
P ₂₄	94.2	53.9	5.7	19.8	53.2	2.77	6.16
P ₂₅	90.5	92.3	6.7	20.9	52.5	2.35	8.89
P ₂₆	96.1	75.5	5.8	20.6	51.0.	2.49	5.86
P ₂₇	92.8	81.9	7.2	21.1	48.9	2.45	5.40
P ₂₈	95.9	92.7	7.1	21.8	57.2	2.45	8.44
P ₂₉	88.3	80.3	5.1	20.4	50.3	2.66	5.51
P ₃₀	94.9	74.3	7.7	22.7	50.4	2.27	6.48
P ₃₁	101.1	79.9	7.7	21.6	51.1	2.54	6.67
P ₃₂	90.1	89.0	7.2	21.4	48.1	2.44	9.06
P ₃₃	99.7	85.9	6.7	21.3	50.6	2.24	8.26
P ₃₄	94.5	83.7	5.5	21.9	58.2	3.06	6.65
P ₃₅	98.9	89.6	7.4	21.8	47.9	2.52	12.68
P ₃₆	94.3	88.4	6.5	19.3	42.2	2.64	7.60
P ₃₇	86.8	84.4	7.2	21.2	53.6	2.35	8.07
P ₃₈	101.3	84.2	6.5	21.2	51.7	2.32	11.39
P ₃₉	101.4	82.8	7.8	21.0	47.6	2.37	6.88
P ₄₀	101.1	89.6	6.7	21.0	52.1	2.36	5.15
Mean	95.24	78.14	6.64	20.91	52.10	2.46	7.22
S.E. (m) _±	0.60	1.19	0.13	0.17	0.77	0.02	0.18
CD 5%	7.93	11.17	1.92	1.65	13.14	0.28	1.141
CD 1%	10.42	14.68	2.52	2.16	17.27	0.37	1.86
CV	5.20	8.93	18.44	4.92	15.76	7.18	12.22
Range	86.3-101.4	51.6-92.7	4.6-8.5	19.3-22.7	42.2-62.7	2.24-3.06	4.48-12.68

Table 10: Mean values of different progenies for variances characters in F₃M₂ of the cross Himalaya-1 x China 988

Progenies	Characters						
	Days to Plant heading height	Plant height	No. of tillers per plant	Panicle length	Fertility percentage	100-grain weight	Yield per plant
1.	2.	3.	4.	5.	6.	7.	8.
P ₁	85.7	61.3	4.8	20.7	34.3	2.41	5.52
P ₂	87.9	84.6	5.9	20.4	51.7	2.74	6.65
P ₃	92.1	81.4	7.8	21.3	46.2	2.62	6.07
P ₄	92.1	85.2	4.9	21.0	52.2	2.60	4.68
P ₅	85.8	80.7	6.7	20.7	54.5	2.46	7.68
P ₆	84.8	58.3	6.3	20.6	45.1	2.09	4.58
P ₇	90.6	53.7	7.5	20.2	49.5	2.46	6.67
P ₈	94.2	82.4	6.5	20.9	59.8	2.31	6.98
P ₉	93.3	64.8	6.2	21.2	52.8	2.15	6.11
P ₁₀	97.3	72.7	6.1	21.0	47.6	2.85	6.45
P ₁₁	97.9	58.9	7.3	20.1	47.2	2.47	5.26
P ₁₂	82.1	90.0	6.5	21.9	58.8	2.29	9.80
P ₁₃	92.4	86.1	6.3	21.4	56.4	2.34	8.19
P ₁₄	87.8	84.5	6.3	20.7	43.8	2.61	5.61
P ₁₅	95.7	85.5	6.6	22.1	56.9	2.23	8.61
P ₁₆	84.7	56.3	5.2	20.0	66.2	2.32	4.69
P ₁₇	98.2	51.0	4.4	19.3	53.9	2.22	2.87
P ₁₈	96.5	70.7	6.7	21.9	48.1	2.32	9.99
P ₁₉	97.3	80.2	5.1	22.3	54.2	2.41	5.71
P ₂₀	94.6	86.9	6.9	21.3	44.0	2.39	5.87
P ₂₁	93.4	89.9	7.2	21.3	49.4	2.41	6.36
P ₂₂	89.7	51.2	5.8	19.7	52.3	2.35	4.06
P ₂₃	101.4	53.5	5.1	19.7	55.7	2.23	4.50

contd.....

Table 10 contd

1.	2.	3.	4.	5.	6.	7.	8.
P ₂₄	95.5	81.4	6.6	20.1	47.4	2.25	4.63
P ₂₅	87.7	91.0	6.3	21.7	52.7	2.51	5.46
P ₂₆	89.7	68.5	6.3	20.4	45.9	2.32	5.02
P ₂₇	96.5	84.9	5.2	22.0	57.5	2.69	5.79
P ₂₈	96.1	77.2	6.0	22.6	51.7	2.16	8.08
P ₂₉	101.3	53.7	6.5	21.1	44.9	2.00	4.81
P ₃₀	99.1	62.1	6.1	20.4	53.4	2.53	6.30
P ₃₁	94.4	66.3	5.6	21.9	59.1	2.34	7.33
P ₃₂	90.7	84.5	6.2	22.6	55.0	2.53	6.46
P ₃₃	89.2	84.9	5.6	20.4	51.6	2.35	6.37
P ₃₄	91.1	62.1	5.4	22.0	51.6	2.47	5.38
P ₃₅	95.8	85.2	5.6	20.9	53.5	2.49	7.80
P ₃₆	100.9	76.0	3.2	22.3	45.0	2.45	3.55
P ₃₇	101.8	88.3	5.6	22.2	56.2	2.48	7.97
P ₃₈	94.3	67.0	4.8	21.6	57.4	2.31	5.23
P ₃₉	87.9	86.7	6.3	18.9	48.2	2.53	7.31
P ₄₀	88.9	76.1	5.4	20.6	52.0	2.32	4.78
Mean	92.91	74.14	5.98	21.02	50.32	2.40	6.11
S.E. (m) \pm	0.60	1.28	0.12	0.11	0.72	0.02	0.16
CD 5%	7.44	9.80	1.62	1.42	11.96	0.32	1.34
CD 1%	9.78	12.88	2.13	1.87	15.72	0.42	1.76
CV	5.00	8.26	16.9	4.22	14.39	8.24	13.72
Range	82.1-101.8	51.0-91.0	3.2-7.8	18.9-22.6	34.3-66.2	2.00-2.85	2.87-9.99

(5.83%) as compared to F_3 population in which case these values were 2.91%, 23.88%, 2.79% and 5.96% respectively.

Plant height: In F_3M_2 population of the cross Himalaya-1 x Phul Patas 72, a higher GCV (12.72%), PCV (16.48%), estimates of heritability (59.65%) and GA (16.17%) were observed as compared to the F_3 population in which case these value were 9.09%, 16.07%, 32.05% and 8.77% respectively.

In the cross Himalaya-1 x China 988, the estimates of all genetic parameters viz., genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance were more in F_3M_2 population with respective values of 16.64%, 18.50%, 80.21% and 22.76% as compared to F_3 population in which case the values were 12.58%, 15.43%, 16.47% and 16.51% respectively.

Number of tillers per plant: The estimates for GCV (11.39%) PCV (25.51%) heritability (46.46%) and GA (1.22%) in F_3 population of the cross Himalaya-1 x Phul Patas 72 were higher than the F_3M_2 population where these values were 15.46%, 24.05%, 41.30% and 1.15% respectively.

Whereas, in the cross Himalaya-1 x China 988, the reverse was the case in which the estimates of GCV (11.26%), PCV(20.37%), heritability (30.57%) and GA (0.77%) in F_3M_2 were higher than that of F_3 population with respective values of 8.36%, 19.89%, 17.65% and 0.48%.

However, in general the estimates of heritability and genetic advance were very low in different populations of both the crosses, thereby indicating a little scope of improvement of this character through selection in these populations.

Panicle length: In the cross Himalaya-1 x Phul Patas 72, the F_3 population had a higher GCV (2.54%) as well as the estimates of heritability (24.69%) and expected GA (0.56%) than the F_3M_2 population where the values were 2.42%, 17.54% and 0.44% respectively. However, F_3M_2 had a higher PCV (5.79%) than the F_3 (5.11%).

In the cross Himalaya-1 x China 988, the estimates of all genetic parameters viz. GCV, PCV, heritability and GA were more in F_3M_2 populations with respective values of 3.52%, 5.50%, 41.02% and 0.98% as compared to the F_3 population in which case the values were 2.36%, 5.46%, 18.78% and 0.44% respectively. There is also a very little scope for improvement of this character through selection in these populations.

Fertility percentage: The F_3 population of the cross Himalaya-1 x Phul Patas 72 had a higher GCV (12.01%), estimates of heritability (47.92%) and GA (8.62%) but a lower PCV (17.35%) as compared to the F_3M_2 population in which case these values were 7.82%, 17.73%, 3.23% and 18.57% respectively.

No significant differences were observed in both F_3 and F_3M_2 populations of the cross Himalaya-1 x China 988 for this character.

100-grain weight: The estimates of GCV, PCV, heritability and GA in F_3M_2 population of the cross Himalaya-1 x Phul Patas 72 with respective values of 9.08%, 12.73%, 50.84% and 0.32% were higher than the F_3 population where these values were 7.81%, 11.19%, 48.66% and 0.25%.

The F_3 population of the cross Himalaya-1 x China 988 showed a higher GCV (5.57%), estimates of heritability (37.57%) and genetic advance (0.17%) than the F_3M_2 population with respective values of 5.53%, 31.05% and 0.15%. Whereas, the F_3M_2 showed a higher PCV (9.92%) compared to the F_3 population (9.09%).

In general the different genetic parameters were low in both the populations of the two crosses indicating thereby little scope for improvement through selection.

Yield per plant: In the cross Himalaya-1 x Phul Patas 72, the GCV (19.77%), PCV (28.29%) and the estimates of GA (1.83%) were higher in the F_3 population as compared to that of F_3M_2 population where these values were 18.43%, 26.22% and 1.66% respectively. However, the estimate of heritability (49.42%) was higher in the F_3M_2 than in the F_3 (48.85%) population.

The F_3M_2 population of the cross Himalaya-1 x China 988 had a higher GCV (24.79%) and PCV (28.33%) as compared to that of F_3 population in which case the values were 24.46% and 27.35% respectively. However, higher estimates of heritability (80.03%) and GA (3.26%) were observed in F_3 as compared to F_3M_2 population where these values were 76.54% and 2.73% respectively.

Table 11 : Mean performance and genetic parameters for Days to heading in Parents, F_3 and F_3M_2 generations.

Varieties/ Treatments	Mean \pm SE	GCV (%)	PCV (%)	H_{bs} (%)	GA (%)
Himalaya-1	94.93 \pm 0.98	NS	NS	NS	NS
Phul Patas 72	105.93 \pm 0.49	NS	NS	NS	NS
F_3 (Himalaya-1 x Phul Patas 72)	97.08 \pm 0.60	4.70	6.49	52.45	6.81
F_3M_2 (Himalaya-1 x Phul Patas 72)	97.13 \pm 0.53	4.63	6.82	46.17	6.03
Himalaya-1	96.87 \pm 1.02	NS	NS	NS	NS
China 988	100.39 \pm 0.83	NS	NS	NS	NS
F_3 (Himalaya-1 x China 988)	95.24 \pm 0.60	2.91	5.96	23.88	2.79
F_3M_2 (Himalaya-1 x China 988)	92.91 \pm 0.61	3.87	5.83	44.16	5.15

NS - Non-significant.

Table 12 : Mean performance and genetic parameters for plant height in Parents, F_3 and F_3M_2 generations

Varieties/ Treatments	Mean \pm SE	GCV (%)	PCV (%)	H _{bs}	GA
Himalaya-1	56.19 \pm 1.01	NS	NS	NS	NS
Phul Patas 72	99.69 \pm 2.71	NS	NS	NS	NS
F_3 (Himalaya-1 x Phul Patas 72)	82.68 \pm 1.26	9.09	16.07	32.05	8.77
F_3M_2 (Himalaya-1 x Phul Patas 72)	78.89 \pm 1.21	12.72	16.48	59.65	16.17
Himalaya-1	56.90 \pm 0.86	NS	NS	NS	NS
China 988	93.44 \pm 0.76	NS	NS	NS	NS
F_3 (Himalaya-1 x China 988)	78.14 \pm 1.19	12.58	15.43	66.47	16.51
F_3M_2 (Himalaya-1 x China 988)	74.14 \pm 1.28	16.64	18.57	80.21	22.76

Table 13 : Mean performance and genetic parameters for number of tillers per plant in parents, F_3 and F_3M_2 generations

Varieties/ Treatments	Mean \pm SE	GCV (%)	PCV (%)	H _{bs}	GA
Himalaya-1	4.51 \pm 0.17	NS	NS	NS	NS
Phul Patas 72	3.80 \pm 0.18	NS	NS	NS	NS
F_3 (Himalaya-1 x Phul Patas 72)	4.99 \pm 0.12	17.39	25.51	46.46	1.22
F_3M_2 (Himalaya-1 x Phul Patas 72)	5.61 \pm 0.12	15.46	24.05	41.30	1.15
Himalaya-1	4.84 \pm 0.21	NS	NS	NS	NS
China 988	6.35 \pm 0.33	NS	NS	NS	NS
F_3 (Himalaya-1 x China 988)	6.64 \pm 0.13	8.36	19.89	17.65	0.48
F_3M_2 (Himalaya-1 x China 988)	5.98 \pm 0.12	11.26	20.37	30.57	0.77

NS - Non-significant.

Table 14 : Mean performance and genetic parameters for Panicle length in parents, F_3 and $F_{3/2}$ generations

Varieties/ Treatments	Mean \pm SE	GCV (%)	PCV (%)	H _{bs}	GA
Himalaya-1	20.99 \pm 0.20	NS	NS	NS	NS
Phul Patas 72	22.34 \pm 0.41	NS	NS	NS	NS
F_3 (Himalaya-1 x Phul Patas 72)	21.37 \pm 0.12	2.54	5.11	24.69	0.56
$F_{3/2}$ (Himalaya-1 x Phul Patas 72)	21.24 \pm 0.11	2.42	5.79	17.54	0.44
Himalaya-1	20.96 \pm 0.19	NS	NS	NS	NS
China 988	21.04 \pm 0.18	NS	NS	NS	NS
F_3 (Himalaya-1 x China 988)	20.91 \pm 0.11	2.36	5.46	18.78	0.44
$F_{3/2}$ (Himalaya-1 x China 988)	21.02 \pm 0.11	3.52	5.50	41.02	0.98

Table 15 : Mean performance and genetic parameters for fertility percentage in parents, F_3 and $F_{3/2}$ generations

Varieties/ Treatments	Mean \pm SE	GCV (%)	PCV (%)	H _{bs}	GA
Himalaya-1	62.44 \pm 0.57	NS	NS	NS	NS
Phul Patas 72	53.37 \pm 1.25	NS	NS	NS	NS
F_3 (Himalaya-1 x Phul Patas 72)	50.32 \pm 0.81	12.01	17.35	47.92	8.62
$F_{3/2}$ (Himalaya-1 x Phul Patas 72)	47.67 \pm 0.85	7.82	18.57	17.73	3.23
Himalaya-1	56.41 \pm 1.02	NS	NS	NS	NS
China-988	50.65 \pm 1.09	NS	NS	NS	NS
F_3 (Himalaya-1 x China 988)	52.10 \pm 0.77	NS	NS	NS	NS
$F_{3/2}$ (Himalaya-1 x China 988)	51.95 \pm 0.72	NS	NS	NS	NS

NS - Non-significant.

Table 16 : Mean performance and genetic parameters for 100-grain weight in parents, F_3 and F_3M_2 generations

Varieties/ Treatments	Mean \pm SE	GCV(%)	PCV(%)	H_{bs}	GA
Himalaya-1	2.05 \pm 0.02	NS	NS	NS	NS
Phul Patas 72	2.02 \pm 0.06	NS	NS	NS	NS
F_2 (Himalaya-1 x Phul Patas 72)	2.25 \pm 0.02	7.81	11.19	48.66	0.25
F_2M_1 (Himalaya-1 x Phul Patas 72)	2.23 \pm 0.03	9.08	12.73	50.84	0.32
Himalaya-1	2.03 \pm 0.01	NS	NS	NS	NS
China 988	2.48 \pm 0.04	NS	NS	NS	NS
F_3 (Himalaya-1 x China 988)	2.46 \pm 0.02	5.57	9.09	37.57	0.17
F_3M_2 (Himalaya-1 x China 988)	2.40 \pm 0.22	5.53	9.92	31.05	0.15

Table 17 : Mean performance and genetic parameters for yield per plant in parents, F_3 and F_3M_2 generations

Varieties/ Treatments	Mean \pm SE	GCV(%)	PCV(%)	H_{bs}	GA
Himalaya-1	8.25 \pm 0.43	NS	NS	NS	NS
Phul Patas 72	6.12 \pm 0.37	NS	NS	NS	NS
F_3 (Himalaya-1 x Phul Patas 72)	6.43 \pm 0.17	19.47	28.29	48.85	1.83
F_3M_3 (Himalaya-1 x Phul Patas 72)	6.21 \pm 0.15	18.43	26.22	49.42	1.66
Himalaya-1	7.39 \pm 0.22	NS	NS	NS	NS
China 988	8.67 \pm 0.35	NS	NS	NS	NS
F_3 (Himalaya-1 x China 988)	7.22 \pm 0.18	24.46	27.35	80.03	3.26
F_3M_2 (Himalaya-1 x China 988)	6.11 \pm 0.16	24.79	28.23	76.54	2.73

NS - Non- significant.

Pooled analysis of variance

The results of pooled analysis of variance for various characters studied in two crosses are presented in Table 18.

In the cross Himalaya-1 x Phul Patas 72, the pooled analysis of variance for treatments showed significant differences for all the characters studied except panicle length. The differences between Himalaya-1 and Phul Patas 72 were found to be significant for all the characters except 100-grain weight, however, the differences between F_3 and F_3M_2 were non-significant for all the characters. Significant differences between F_3 , F_3M_2 verses parents were observed for days to heading, number of tillers per plant, fertility percentage, 100-grain weight and yield per plant.

In the cross Himalaya-1 x China 988, the pooled analysis of variance for treatments showed significant differences for days to heading, plant height, 100-grain weight and yield per plant only. The differences between Himalaya-1 and China 988 were significant for plant height, 100-grain weight and yield per plant. Non-significant differences between F_3 and F_3M_2 were observed for all characters studied except yield per plant. The differences between F_3 , F_3M_2 verses parents were significant for days to heading, 100-grain weight and yield per plant only.

The mean values for parents, F_3 and F_3M_2 for different characters are presented in the Tables 19 - 20 separately for the two crosses.

Table 18 : Pooled analysis of variance for different characters in Parents, F_3 and $F_{3/2}$ generations

Source of variation	d.f.	Mean squares						
		Days to heading	Plant height	No. of tillers/plant	Panicle length (cm)	Fertility (%)	100-grain weight	Yield per plant
<u>Himalaya-1 x Phul Patas 72</u>								
Treatment	3	60.62**	961.21**	1.76**	0.97	123.95**	0.04**	3.04*
Himalaya-1 Vs PP 72	1	156.06**	2838.38**	0.75*	-	123.31**	0.00	6.80**
F_3 Vs $F_{3/2}$	1	0.00	11.65	0.58	-	10.56	0.00	0.06
F_3 , $F_{3/2}$ Vs Parents	1	25.78*	33.60	3.94**	-	237.99**	0.13**	2.26*
Error	6	2.43	25.76	0.12	0.21	1.96	0.00	0.36
<u>Himalaya-1 x China 988</u>								
Treatment	3	29.66*	676.54**	1.87	0.01	13.38	0.13**	3.30**
Himalaya-1 Vs China 988	1	18.59	2002.76**	-	-	-	0.30	2.48*
F_3 Vs $F_{3/2}$	1	8.14	24.04	-	-	-	0.00	1.85*
F_3 , $F_{3/2}$ Vs Parents	1	62.24*	2.83	-	-	-	0.08**	5.56**
Error	6	6.20	7.21	0.60	0.10	13.58	0.00	0.24

* - Significant at 5% level

** - Significant at 1% level

Days to heading

In the cross Himalaya-1 x Phul Patas 72, the two parents were significantly different as regards the days to heading. The mean number of days to heading in $F_{3/2}$ population were almost same as F_3 population and the differences were non-significant. The mean number of days to heading in F_3 and $F_{3/2}$ were significantly less as compared to Phul Patas 72, whereas, no

significant differences were observed when compared with Himalaya-1.

In the cross Himalaya-1 x China 988, the two parents were statistically at par with each other in days to heading. The $F_{3/2}M_2$ took less number of days to heading as compared to the F_3 , however, the differences were non-significant. The mean number of days to heading in F_3 and $F_{3/2}M_2$ were significantly less as compared to China 988, whereas, no significant differences were observed when compared with Himalaya-1.

Plant height:

In the cross Himalaya-1 x Phul Patas 72, the mean plant height of the parents were significantly different from each other. The mean plant height of F_3 population, was more than that of $F_{3/2}M_2$ population, but the difference was not significant. The F_3 's and $F_{3/2}M_2$'s were significantly shorter than the tall parent, viz., Phul Patas 72 but, significantly taller than the short parent, viz., Himalaya-1.

In the cross Himalaya-1 x China 988, the results were similar as observed in the cross Himalaya-1 x Phul Patas 72.

Number of tillers per plant:

In the cross Himalaya-1 x Phul Patas 72, the two parents were significantly different from each other as regards the tiller numbers per plant. The mean number of tillers per plant in $F_{3/2}M_2$ were same as that of the F_3 . Both F_3 and $F_{3/2}M_2$ had significantly less number of tillers as compared to the parent Phul Patas 72. Only $F_{3/2}M_2$ had significantly higher number of tillers when compared to Himalaya-1.

In the cross Himalaya-1 x China 988, non-significant differences were observed among various treatments for number of tillers per plant.

Panicle length:

In both the crosses i.e. Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988, the differences among the various treatments were non-significant for panicle length.

Fertility percentage

The parents involved in the cross Himalaya-1 x Phul Patas 72 were significantly different from each other as regard fertility percentage. The mean fertility percentage in F_3M_2 was significantly less when compared to F_3 . In both F_3 and F_3M_2 , fertility percentage decreased significantly as compared to the parents.

The differences among treatments were non-significant in the cross Himalaya-1 x China 988 for fertility percentage.

100-grain weight:

In the cross Himalaya-1 x Phul Patas 72, the two parents were statistically at par with each other as regards 100-grain weight. The difference between F_3 and F_3M_2 for 100-grain weight was also non-significant. However, both F_3 and F_3M_2 were having significantly more 100-grain weight as compared to the parents, viz., Himalaya-1 and Phul Patas 72.

In the cross Himalaya-1 x China 988, the parents involved were significantly different from each other, however, the F_3 and F_3M_2 were statistically at par with each other. The mean 100-grain weight of both F_3 and F_3M_2 was significantly more as compared to Himalaya-1, however, there was no significant difference when compared with China 988.

Yield per plant

In the cross Himalaya-1 x Phul Patas 72, the two parents differed significantly from each other in yield per plant. No significant differences

were observed in the mean when F_3 and F_3M_2 were compared for yield per plant. The mean yield per plant of F_3 and F_3M_2 were significantly less as compared to the higher yielding parent i.e. Himalaya-1, however, no significant differences were observed when compared to Phul Patas 72.

The parents involved in the cross Himalaya-1 x China 988 were significantly different from each other as regards yield per plant. The mean yield per plant of F_3M_2 decreased significantly as compared to the F_3 . The F_3M_2 had significantly less yield as compared to the two parents, however, only F_3 had significantly less yield as compared to China 988.

Table 19 : Mean performance for different characters in Parents, F_3 and $F_{3/2}$ of the cross Himalaya-1 x Phul Patas 72

Varieties/ Treatments	Days to heading	Plant height (cm)	No. of tillers per plant	Panicle length (cm)	Fertility (%)	100- grain weight(g)	Yield/ plant (g)
Himalaya-1	94.93±0.98	56.19±1.00	484±0.21	20.99±0.20	62.41±0.57	2.05±0.02	8.25±0.41
Phul Patas 72	105.13±0.49	99.69±2.71	6.5±0.32	22.34±0.41	53.37±1.28	2.01±0.06	6.12±0.37
F_3 (Himalaya-1 x Phul Patas 72)	97.08±0.59	82.68±1.26	4.99±0.11	21.37±0.12	50.32±0.81*	2.25±0.02	6.43±0.1
$F_{3/2}$ (Himalaya-1 x Phul Patas 72)	97.12±0.60	77.89±1.21	5.61±0.12	21.24±0.11	47.67±0.84*	2.24±0.03	6.12±0.15
SE(m)±	±0.90	±2.93	±0.20	±0.27	±0.08	±0.02	±0.35
CD 5%	2.73	8.89	0.63	NS	2.46	0.07	1.05
CD 1%	3.79	12.32	0.84	NS	3.40	0.09	1.45
CV	1.58	6.37	7.29	2.14	2.62	1.76	8.87

NS - Not significant.

Table 20 : Mean performance for different characters in Parents, F_3 and $F_{3/2}$ of the cross Himalaya-1 x China 988.

Varieties/ Treatments	Days to heading	Plant Height (cm)	No. of tillers per plant	Panicle length (cm)	Fertility (%)	100- grain weight(g)	Yield per plant (g)
Himalaya-1	96.87±1.02	56.90±0.86	4.51±0.17	20.96±0.19	56.41±1.02	2.03±0.01	7.39±0.22
China 988	100.39±0.83	93.44±0.76	3.80±0.18	21.04±0.18	50.65±1.09	2.48±0.03	8.67±0.35
F_3 (Himalaya-1 x China 988)	95.24±0.60	78.14±1.19	6.64±0.13	20.19±0.11	52.10±0.77	2.69±0.02	7.22±0.18
$F_{3/2}$ (Himalaya-1 x China 988)	92.91±0.61	74.14±1.28	5.98±0.11	21.02±0.11	51.95±0.72	2.40±0.02	6.11±0.16
SE(m)	±1.46	±1.55	±0.45	±0.19	±2.12	±0.02	±0.28
CD 5%	4.36	4.70	NS	NS	NS	0.08	0.86
CD 1%	6.95	6.52	NS	NS	NS	0.10	1.20
CV	2.62	3.55	13.01	1.54	6.92	1.84	6.70

NS - Not Significant.

DISCUSSION

DISCUSSION

The major problem in breeding autogamous species is creation of useful and usable variation either through hybridization or mutagenesis. Mutation breeding offers an alternative to hybridization since quantitative variation generated by two methods is equally heritable (Gregory, 1956; Gregory, 1961). In mutation induction programmes, the choice of genotype to be treated is very important since different genotypes differ in their response to mutagenic agents and although mutations increase the variance, in the absence of selection or correlated response, they shift the population mean away from its previous breeding history (Brock, 1965). It has, therefore, been proposed that mutagenesis should be applied to supplement the variation generated following hybridization (Gregory, 1961). Due to the heterozygous nature of hybrid seed exposed to mutagenesis, release of variability commences in the first generation following treatments. The treatment of heterozygous and heterogeneous F_2 material allows mutational events to occur at both heterozygous and homozygous loci. Variation in the treated hybrid may be caused in one or set of characters by point mutations, by enhancement of recombination rate and by chromosomal aberrations so as to release the latent variability in the blocks of linked genes and hence offer the same advantages as generally expected from intermating in the early segregating generations.

Gaul (1965), discussing the usefulness of micro-mutations in plant breeding, opines that they might occur most frequently and on account of their being less deleterious, might not so often result in reduced vitality.

Work done on induced mutations in polygenic characters in various crop plants has been reviewed extensively by Scossiroli (1965). It is evident from this review as well as subsequently published works that studies on micro-mutations had largely been fundamental in nature. This was inspite of the classical work of Gregory (1968) on groundnut for the development of high yielding improved mutant varieties with micro-mutational approach.

Among the various physical mutagens, gamma rays have been widely employed for the induction of genetic variability. Sharma (1985) in a review on induced mutagenesis in rice reported that LD₅₀ r-rays ranged from 25 kR for China 988 to 40 kR for Jhona-351.

Therefore, the present investigation was undertaken to study the effects of gamma radiation (25 kR) on various metric characters in F_2 ^{generation} ($F_2 M_1$) and the following segregating generations ($F_3 M_2$) in two crosses of rice, viz., Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 to assess the magnitude of induced polygenic variability for yield and some quantitative characters and to study the spectrum and frequency of macromutations induced. The results of the investigation have been discussed as follows generationwise.

1. Induction of polygenic variability in $F_2 M_1$ generation

Plant height decreased significantly following 25 kR gamma irradiation of F_2 seeds as compared to the F_2 generations following hybridization in both the crosses. The observed decrease in plant height might either be due to physiological damage or chromosomal aberrations. Reduction in plant height after irradiation of F_2 seeds has also been reported by Saini and Sharma (1970) and Virk et al. (1978) in rice.

The number of tiller per plant remained unaffected in cross Himalaya-1 x China 988 after irradiation (F_2M_1) when compared with unirradiated F_2 . These observations are in agreement with Virk et al. (1978) who have also reported non-significant decrease of tiller number in irradiated segregating generation as compared to unirradiated. Whereas, in cross Himalaya-1 x Phul Patas 72, a significant increase in tiller number was observed following gamma-irradiation of F_2 seeds when compared with untreated F_2 . No information is available in the literature regarding increase in tiller number after irradiation of F_2 seeds as compared to F_2 .

Regarding panicle length, irradiation of F_2 seeds did not effect the same significantly in cross Himalaya-1 x Phul Patas 72, however a significant decrease in panicle length following gamma-irradiation of F_2 seeds of the cross Himalaya-1 x China 988 was observed as compared to the unirradiated F_2 's.

Fertility percentage decreased drastically in the F_2M_1 of both the crosses as compared to the F_2 . The decrease in fertility percentage in the irradiated F_2 may be due to chromosomal aberration as reported by Yeh and Henderson (1963) in pure breeding varieties of rice. Similar results have been reported in the M_1 generations in rice after neutron and gamma irradiation by Miah et al. (1970). The decrease in fertility percentage in the M_1 generation following gamma-irradiation has also been reported by Dogar (1981) and Bijral (1982) in different rice varieties.

100-grain weight was not affected by gamma-irradiation of F_2 seeds in the cross Himalaya-1 x Phul Patas 72, whereas, significant decrease in weight of irradiated F_2 was observed in the cross Himalaya-1 x China 988

when compared with the respective F_2 's. No information seems to be available in literature regarding the effect of irradiation of F_2 seeds in rice for 100-grain weight. However, it is apparent from these results that irradiation has differential effect on 100-grain weight depending upon the genetic constitution of background genotype.

The grain yield per plant decreased following gamma-irradiation of F_2 seeds in both the crosses as compared to the F_2 segregating generation. The reduction in yield after irradiation may be due to the cumulative detrimental effect on all the yield contributing characters, especially reduced panicle length and reduced fertility. Similar results of reduction in yield in M_1 generation after gamma-irradiation have been reported by various workers, viz., Bhatia (1973), Mehra (1975), Dogar (1981) and Bijral (1982) in pure varieties of rice.

In terms of variance, it has been observed that in F_2M_1 generation (after irradiation of F_2 seeds), the variance increased significantly for fertility percentage and 100-grain weight in both the crosses, however, it decreased significantly for yield per plant in comparison to F_2 generation. For other characters, viz., plant height, number of tillers per plant and panicle length the variance was almost the same in the F_2 and irradiated F_2 generations. Gregory (1956) in peanuts reported that in terms of standard deviation there was more variation generated in both irradiated parents and irradiated hybrids than in unirradiated hybrids. In general, it has been observed that plants in M_1 generation are chimeric in nature and the immediate change in plant character is not of a permanent nature. Changed genetic composition and the physiological disturbances comprise the phenotypic expression of M_1 plants. The affect of physiological disturbances is

eliminated almost completely in the subsequent generations. However, the manifestation of mutated character is modified by background genotypes, but even then the extent of change in the genetic composition can efficiently be estimated in the M_2 and subsequent generations.

Spectrum and frequency of induced chlorophyll mutations in $F_2 M_2$ generation

Regarding the spectrum of chlorophyll mutations, induced by gamma rays treatments in the present study, albinas had the highest frequency in both the crosses followed by xantha, striata, xantha-alba and viridis. Out of the total chlorophyll mutations, 63.71 per cent and 31.03 per cent of albinas were observed in the cross Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 respectively. Differences in spectra of chlorophyll mutations induced by physical and chemical mutagens in rice have been reported by Konak et al. (1961) Swaminathan et al. (1982), Basu and Basu (1969), Sharma (1970), Miah and Awan (1971), Kaushik (1974), Gupta (1976), Seetharam et al. (1978), Nallathambi (1982), Sharma (1985) and many others. They have also reported the higher proportion of albina after irradiation as compared to the other chlorophyll mutations. The viridis was the rarest of all chlorophyll mutations. Similar observations have been made by Basu (1969) in rice. The chlorophyll mutations have also been reported to arise spontaneously in rice (Imai, 1955; Ramiah and Rao, 1953). However no spontaneous chlorophyll mutations were observed in the present study.

In the cross Himalaya-1 x Phul Patas 72, the overall frequency of chlorophyll mutations in the irradiated $F_2 M_2$ population based on M_1 plant progeny basis was 27.83% and was higher than that calculated on the basis of M_2 seedlings (3.09%). Similarly, in the cross Himalaya-1 x China 988,

the overall frequency calculated on M_1 plant progeny basis (30.61%) was higher than that calculated on M_2 seedlings basis (1.26%). This suggests that all the tillers of a plant did not contain mutations, and only a few seedlings from different tillers contained mutations. Similar results were obtained by Dogar (1981) in M_2 and Gupta (1976) and Sharma (1977) in M_3 . The frequency of chlorophyll mutations based on M_1 plant progeny was higher in cross Himalaya-1 x China 988 as compared to cross Himalaya-1 x Phul Patas 72 whereas, on M_2 seedlings basis it was higher in the cross Himalaya-1 x Phul Patas 72. This also suggests that the manifestation of mutated characters were modified by background genotypes.

Albina was the most frequently occurred chlorophyll mutations in both the crosses (1.97% in cross Himalaya-1 x Phul Patas 72 and 0.39% in cross Himalaya-1 x China 988) followed by Xantha (0.32% in cross Himalaya-1 x Phul Patas 72 and 0.28% in the cross Himalaya-1 x China 988), striata (0.37% in cross Himalaya-1 x Phul Patas 72 and 0.30% in cross Himalaya-1 x China 988), xantha-alba (0.30% in cross Himalaya-1 x Phul Patas 72 and 0.20 in cross Himalaya-1 x China 988) and viridis (0.14% in cross Himalaya-1 x Phul Patas 72 and 0.09% in cross Himalaya-1 x China 988). The frequency of various chlorophyll mutations in the above order has also been reported by Mellathambi (1982) in rice. The observed differences in the frequency of albina mutations in the two crosses may be due to the differential response of different genotypes to mutagenic agents. However no desirable phenotypic mutants were available in the material.

Induction of polygenic variability in F_3M_2 generation

In view of the economic importance of quantitative traits, the variability induced by gamma rays in M_2 generation (F_3M_2) for various characters studied are discussed below.

Significant differences have been observed within F_3 and F_3M_2 progenies of the two crosses, viz. Himalaya-1 x PhulPatas 72 and Himalaya-1 x China 988 for all the characters i.e. days to heading, plant height, number of tillers per plant, panicle length, fertility percentage, 100-grain weight and yield per plant except for fertility percentage in both F_3 and F_3M_2 of the cross Himalaya-1 x China 988.

The mean values for days to heading in F_3M_2 in the two crosses, viz., Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 remained unaffected following gamma-irradiation of F_2 seeds as compared to the F_3 's of the two crosses respectively, thereby, suggesting that the mutations with plus and minus effects may have occurred equally frequently in both the directions and thus the mean values remained same in F_3M_2 and F_3 populations. These results are in conformity with the findings of Saini and Sharma (1970) who have reported that the mean values for days to heading in irradiated hybrid and unirradiated hybrid segregating generations in rice were similar. Similar results have also been reported by Oka *et al.* (1958) and Bijral (1982) in M_2 generation of pure breeding varieties treated with gamma rays. The variance was higher in the F_3M_2 as compared to F_3 population of the cross Himalaya-1 x China 988 and the case was reverse in the cross Himalaya-1 x Phul Patas 72. However, the differences in variance between F_3 and F_3M_2 of both the crosses were non-significant. Increase in variability for days to heading following mutagenic treatment of hybrid

seed in rice has also been reported by Saini and Sharma (1970). Moderate estimates of heritabilities in F_3 and F_3M_2 (52.45% and 46.17%) of the cross Himalaya-1 x Phul Patas 72 and only in F_3M_2 (44.16%) of the cross Himalaya-1 x China 988 alongwith genetic advance as 6.81, 6.03 and 5.10 per cent respectively indicated the scope of improvement in the desired direction through selection.

The mean values of the irradiated populations (F_3M_2 's) in the two crosses with respect to plant height was almost the same as that of F_3 populations, thereby suggesting the possibility that the mutations with plus and minus effects occurred equally frequently in both the directions. These findings are in agreement with those of Saini and Sharma (1970) and Virk *et al.* (1978). In both the crosses, *viz.* Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988, the variances were higher in the irradiated segregating generation (F_3M_2) as compared to the unirradiated segregating generation (F_3). However the increase in variances in F_3M_2 over F_3 in the two crosses were not significant. Increase in variance was also reported by Miah and Yamaguchi (1964) and Saini and Sharma (1970). Moderate estimates of heritability in F_3M_2 (59.65%) of the cross Himalaya-1 x Phul Patas 72 and in both F_3 and F_3M_2 (66.47% and 80.21%) of the cross Himalaya-1 x China 988 alongwith genetic advance as 16.17, 16.51 and 22.76 per cent respectively suggest that selection can be effective in these populations.

The mean values for number of tillers per plant remained unaffected in the gamma rays treated populations (F_3M_2) of the two crosses, *viz.*, Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 as compared to the respective F_3 segregating populations. The observed non-significant differences

in the mean values of irradiated segregating and unirradiated segregating generation suggests that mutations with plus and minus effects have occurred equally frequently in both the directions. Similar results were also reported by Saini and Sharma (1970) and Virk *et al.* (1978). Variances in the F_3M_2 populations were higher in both the crosses as compared to their respective F_3 populations, however, the differences were non-significant. The estimates of heritability and genetic advance were low in both F_3 and F_3M_2 generations of the two crosses, indicating thereby very little scope of improvement through selection for number of tillers per plant.

The average panicle length remained unaffected in F_3M_2 generations of both the crosses as compared to their respective F_3 's. No information is available regarding the effect on panicle length after irradiation of hybrid seeds in rice. Similarly, the variances in F_3M_2 's and F_3 's were same in both the crosses. The estimates of heritability and expected genetic advance in both F_3 and F_3M_2 populations were low in the two crosses indicating little scope of improvement through selection for this character in these populations.

The fertility percentage decreased significantly in the F_3M_2 population as compared to F_3 in the cross Himalaya-1 x Phul Patas 72 indicating possible occurrence of polygenic mutations in the minus direction, however, no differences were observed between F_3 and F_3M_2 of the cross Himalaya-1 x China 988. The variance was also higher in F_3M_2 population of the cross Himalaya-1 x Phul Patas 72 as compared to F_3 but, the differences were non-significant. The moderate estimates of heritability (47.92%) and genetic advance (8.62%) were observed in the F_3 population of the cross

Himalaya-1 x Phul Patas 72. Whereas, in the F_{3M_2} population the values of heritability (17.73%) and genetic advance (3.23%) were low, indicating little scope for improvement through selection.

The average 100-grain weight did not change significantly in the F_{3M_2} populations in the two crosses as compared to the respective F_3 's. These findings are in agreement with those of Sato (1966), Mehra (1975) and Bijral (1982) in pure breeding rice varieties. In the cross Himalaya-1 x Phul Patas 72, the variance in the irradiated population was higher than that of unirradiated, whereas, in the cross Himalaya-1 x China 988, the reverse was the case, however, the differences were non-significant in both the cases. Although in the cross Himalaya-1 x Phul Patas 72, the estimates of heritability were moderate in both F_3 and F_{3M_2} populations yet the values of genetic advance were low. However, in the cross Himalaya-1 x China 988, the estimates of both heritability as well as genetic advance were low in both F_3 and F_{3M_2} . This indicates very little scope for improvement through selection of 100-grain weight in all these populations.

In the cross Himalaya-1 x Phul Patas 72, the mean yield per plant in the F_{3M_2} population remained unchanged as compared to the F_3 population. Similar results have been reported by Saini and Sharma (1970), Virk *et al.* (1978). They reported similar mean values for yield in the conventional segregating population and in the population produced after irradiation of hybrid seed in rice. On the other hand, the mean value for yield per plant in the cross Himalaya-1 x China 988 in F_{3M_2} was significantly less as compared to F_3 yield. Sakai and Suzuki (1964) observed a significant shift for plant height, plant weight and grain yield in rice variety Norin-8 when

treated with gamma rays (20 kR). The shift in the mean might have been resulted from induced polygenic mutations with unequal effects (Bateman, 1959). A decrease in variance in the F_3M_2 was observed when compared with that of the F_3 in both the crosses for yield per plant, however, the decrease was significant only in the cross Himalaya-1 x China 988. Virk et al. (1978) observed no increase in variation following irradiation of segregating generation for yield in rice. They reported that the observed genetic variances in the irradiated hybrid in general are lower than expected because of the absence of any increase in F_3 variance following irradiation. The estimates of various genetic parameters, viz. heritability and genetic advance are moderate to high only in the cross Himalaya-1 x China 988 in both F_3 and F_3M_2 populations, thereby indicating better scope of selection for improvement of yield in this case as compared to the cross Himalaya-1 x Phul Patas 72 where these estimates are very low.

Some of the progenies like number 9 in F_3 and number 12 in F_3M_2 of the cross Himalaya-1 x Phul Patas 72 had higher yields per plant in comparison to the highest yielding progeny of standard variety, Himalaya-1. Similarly in the cross Himalaya-1 x China 988, progeny numbers 35 and 39 in F_3 and number 18 in F_3M_2 had higher yields per plant as compared to the highest yielding progeny of the recommended variety. These progenies were also superior for one or more yield components like number of tillers per plant, panicle length and 100-grain weight. Therefore, selection of above progenies from the different populations and further advancing and evaluating them for yield and other component traits may lead to development of high yielding genotypes in rice.

Concluding remarks

Results of the present investigation revealed that in the cross Himalaya-1 x Phul Patas 72, the means in irradiated F_2 population (F_2M_1) when

compared with unirradiated F_2 showed significant decrease for panicle length, fertility percentage and yield per plant; increase for number of tillers per plant, whereas remained unaffected for plant height and 100-grain weight. In the cross Himalaya-1 x China 988, when irradiated F_2 population (F_2M_1) was compared with unirradiated F_2 , significant decrease in plant height, panicle length, fertility percentage, 100 grain weight and yield per plant was observed in the irradiated F_2 . The means however remained unaffected for number of tillers per plant.

In both the crosses, the variance for yield per plant decreased significantly whereas, for fertility percentage and 100-grain weight the variance increased significantly following gamma-irradiation of F_2 seeds (F_2M_1) seeds as compared to the unirradiated F_2 . However, for plant height, number of tillers per plant and panicle length, no significant increase or decrease in variances were observed between F_2 and F_2M_1 generations.

Regarding the spectrum and frequency of chlorophyll mutation, it has been observed that in both the crosses, albinas had the highest frequency followed by Xantha, striata, xantha-alba and viridis. It has also been observed that in both the crosses, the overall frequency based on M_1 plant progeny was higher than that calculated on the basis of M_2 seedlings. In the F_3M_2 generation the mean values for different characters in general, decreased as compared to F_3 in both the crosses. In the F_3M_2 of the cross Himalaya-1 x Phul Patas 72, the mean values for plant height, panicle length, fertility percentage, 100-grain weight and yield per plant decreased as compared to F_3 but was significant only for fertility percentage. For characters, viz. days to heading and number of

tillers per plant the deviations were towards plus direction but were non-significant. In the cross Himalaya-1 x China 988, the mean values in $F_{3/2}M_2$ shifted towards negative as compared to F_3 for various characters, viz., days to heading, plant height, number of tillers per plant, fertility percentage, 100-grain weight and yield per plant, being significant only for yield per plant. However, for panicle length the mean shifted towards positive direction but was non-significant.

Regarding the relative variances for various characters in F_3 and $F_{3/2}M_2$ of the cross Himalaya-1 x Phul Patas 72, it has been observed that in $F_{3/2}M_2$ the variance decreased for days to heading, plant height, number of tillers per plant, panicle length, fertility percentage and yield per plant and increased only for 100-grain weight. However, the increase and decrease in variances were non-significant. In the cross Himalaya-1 x China 988, the variances increased for days to heading, plant height, number of tillers per plant, panicle length, fertility percentage and 100-grain weight in $F_{3/2}M_2$ as compared to F_3 , but the increase was non-significant, whereas for yield per plant the variance decreased significantly.

In general, there is no evidence that the variation in the hybrid increase following irradiation for most of the characters. The effect of irradiation on the segregating population in producing heritable mutations, therefore, seems to be balancing out with no net gain or loss to the total phenotypic variability as observed in the unirradiated segregating populations. The observed genetic variances in the irradiated hybrid, in general, are lower than expected, which may be because of the absence of any increase in F_3 variance following irradiation (Virk et al. 1978).

A few progenies, viz., number 9 in F_3 and number 12 in F_3M_2 of the cross Himalaya-1 x Phul Patas 72, and progeny numbers 35 and 39 in F_3 and number 18 in F_3M_2 ^{of the cross Himalaya-1 x China 988} had higher yields per plant as compared to the highest yielding progeny of the recommended variety. These progenies were also superior for one or more of yield components. Therefore these progenies may be selected for further testing and evaluation for yield and other component traits alongwith the recommended varieties for developing high yielding genotypes in rice.

SUMMARY

SUMMARY

The present investigation was undertaken to study the nature of variation induced by gamma rays in the segregating generation of two crosses of rice and was carried out during the Kharif seasons of 1983 and 1984. Dry F_2 seeds, stabilized at 13% moisture, of two crosses of rice, viz. Himalaya-1 x Phul Patas 72 and Himalaya-1 x China 988 were irradiated with 25 kR gamma rays. The experimental material for the trial during kharif 1983 comprised F_2 , F_2M_1 of the two crosses alongwith their parents. During Kharif 1984, the experimental material comprised of F_3 , F_3M_2 and the parents of the above crosses.

The objectives of the present investigation were as follows:

1. To assess the magnitude of induced variability for yield and some quantitative traits.
2. To study the spectrum and frequency of macro-mutation induced by gamma rays
3. To explore the possibilities of isolating desirable phenotypic mutants.

Results of the present investigation revealed that in the cross Himalaya-1 x Phul Patas 72, the mean values in the irradiated F_2 population (F_2M_1) for some characters, viz. panicle length, fertility percentage and yield per plant decreased and for number of tillers per plant increased significantly, as compared to unirradiated F_2 . However, for plant height and 100-grain weight, no differences were observed in the two populations. In the cross Himalaya-1 x China 988, when irradiated F_2 (F_2M_1) ^{population} was compared with unirradiated F_2 , significant decrease in plant height, panicle length, fertility percentage, 100-grain weight and yield per plant was observed in the irradiated F_2 . The means however, remained unaffected for number of tillers per plant.

In both the crosses, the variance for yield per plant decreased significantly, whereas for fertility percentage and 100-grain weight the variance increased significantly following gamma-irradiation of F_2 seeds as compared to the unirradiated F_2 . However, for plant height, number of tillers per plant and panicle length, no significant increase or decrease in variances were observed between F_2 and F_2M_1 generations.

Regarding the spectrum of chlorophyll mutations in the seedlings of F_3M_2 generation it was observed that chlorophyll mutations comprised mostly of albina i.e. 67.31% in the cross Himalaya-1 x Phul Patas 72 and 31.03% in the cross Himalaya-1 x China 988 of the total chlorophyll mutations, followed by xantha, striata, xantha-alba and viridis. In the cross Himalaya-1 x Phul Patas 72, the overall frequency of chlorophyll mutations in the irradiated F_3 population (F_3M_2) based on M_1 plant progeny was higher (27.83%) than that calculated on the basis of M_2 seedlings (3.09%). Similarly, in the cross Himalaya-1 x China 988, the overall frequency calculated on M_1 plant progeny basis was higher (30.61%) than that calculated on M_2 seedling basis (1.26%). This suggests that mutations did not occur in all the tillers of a plant and actually only a few seedlings from different tillers were mutated. No desirable phenotypic mutants were available in the present study.

In the F_3M_2 generation, the mean values for different characters, in general, decreased as compared to F_3 in both the crosses. In the F_3M_2 of the cross Himalaya-1 x Phul Patas 72, the mean values for plant height, panicle length, fertility percentage, 100-grain weight and yield per plant decreased as compared to F_3 but was significant only for

fertility percentage. For other characters, viz. days to heading and number of tillers per plant the deviations were towards plus direction but were non-significant. In the cross Himalaya-1 x China 988, the mean values in F_3M_2 shifted towards negative as compared to F_3 for characters, viz. days to heading, plant height, number of tillers per plant, fertility percentage, 100-grain weight and yield per plant, being significantly only for yield per plant. However for panicle length the mean shifted towards positive direction but was non-significant.

Regarding the relative variances for various characters in F_3 and F_3M_2 of the cross Himalaya-1 x Phul Patas 72, it has been observed that in F_3M_2 the variance decreased for days to heading, plant height, number of tillers per plant, panicle length, fertility percentage and yield per plant and increased only for 100-grain weight. However, the increase and decrease in variances were non-significant. In the cross Himalaya-1 x China 988, it has been observed that the variances increased for days to heading, plant height, number of tillers per plant, panicle length, fertility percentage and 100-grain weight in F_3M_2 as compared to F_3 , but the increase was non-significant whereas, for yield per plant the variance decreased significantly.

In general, there is no evidence that the variation in the hybrid increases following irradiation for most of the characters. The effect of irradiation on the segregating population in producing heritable mutations, therefore, seems to be balancing out with no net gain or loss to the total phenotypic variability observed in the unirradiated F_3 generations.

A few progenies like number 9 in F_3 and number 12 in F_3M_2 of the cross Himalaya-1 x Phul Patas 72; and progeny numbers 35 and 39 in F_3 and

number 18 in $F_{3/2}M_2$ of the cross Himalaya-1 x China 988, had higher yields per plant as compared to the highest yielding progeny of the recommended check variety. These progenies were also superior for one or more yield components, viz number of tillers per plant, panicle length and 100-grain weight. Further testing and evaluation of these progenies may lead to development of high yielding genotypes in rice.

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* Original not seen.