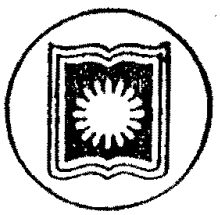
1994

Post-irradiation ageing effect on chromosomal structural changes and yield in wheat

Chowdhury, Mrs.Debashri

University of Rajshahi

POST-IRRADIATION AGEING EFFECT ON CHROMOSOMAL STRUCTURAL CHANGES AND YIELD IN WHEAT



M. PHIL. THESIS.

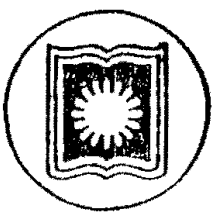
BY

Mrs. Debashri Chowdhury
B. Sc. (Hons.), M. Sc.

OCTOBER, 1994

CYTOGENETICS LABORATORY
DEPARTMENT OF BOTANY
UNIVERSITY OF RAJSHAHI
RAJSHAHI, BANGLADESH.

POST-IRRADIATION AGEING EFFECT ON CHROMOSOMAL STRUCTURAL CHANGES AND YIELD IN WHEAT



A THESIS

SUBMITTED TO THE UNIVERSITY OF RAJSHAHI IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PHILOSOPHY.

M. PHIL. THESIS.

BY

Mrs. Debashri Chowdhury
B. Sc. (Hons.), M. Sc.

OCTOBER, 1994

CYTOGENETICS LABORATORY
DEPARTMENT OF BOTANY
UNIVERSITY OF RAJSHAHI
RAJSHAHI, BANGLADESH.

Dr. Golam Kabir.
B.Sc. (Hons), M.Sc., Ph.D.
Associate Professor.

Phone : 6041—9/421
Department of Botany
RAJSHAHI UNIVERSITY
Rajshahi.

CERTIFICATE

I have pleasure in certifying the thesis entitled "Post-irradiation ageing effect on chromosomal structural changes and yield in wheat" submitted by Mrs. Debashri Chowdhury to the Rajshahi University for the degree of Master of Philosophy in Botany.

I hereby certify that (i) the candidate has fulfilled residential requirement, (ii) the works embodied in the thesis were carried out by the candidate, and (iii) to the best of my knowledge the data are genunine and original. No part of the work has been submitted in substance for any degree.

G Kabir 27.10.94
Supervisor

A C K N O W L E D G E M E N T

The authoress finds a great pleasure in expressing her heartfelt gratitude and indebtedness to Dr. Golam Kabir, Associate Professor, Deptt. of Botany, Rajshahi University for his day to day guidance, advice, kind assistance and valuable help in the preparation of the thesis.

Grateful thanks are due to the Chairman, Deptt. of Botany, Rajshahi University for giving facilities and to Prof. O.I. Joarder and Prof. A. Ahmed for giving permission to use their apparatuses.

The authoress is greatly indebted to her husband, Prof. N.K. Paul, Department of Botany, Rajshahi University for his help at different stages of this work and constant inspiration.

The authoress is thankful to all the research colleagues of Cytogenetics Laboratory for their help and assistance during the course of this study.

Sincere thanks are extended to the Officer-in-Charge, BARI, Regional Station, Shyampur for kindly supplying the seed samples and to the Director, Atomic Energy Establishment, Savar, Dhaka, for irradiating the seeds.

Thanks are also due to Mr. Md. Helal Uddin for neatly typing the thesis.

The authoress.

C O N T E N T S

	Page No.
ACKNOWLEDGEMENT	I
LIST OF FIGURES AND PLATES.	II
LIST OF TABLES.	IV
LIST OF APPENDICES.	VIII
INTRODUCTION.	1
REVIEW OF LITERATURE	6
MATERIALS AND METHODS	24
RESULTS	31
MITOTIC STUDY	31
MEIOTIC STUDY	51
YIELD AND YIELD COMPONENTS STUDY	123
DISCUSSION	135
SUMMARY	147
REFERENCES	151
APPENDICES	160

.....

LIST OF FIGURES AND PLATES

Figures No.		Page No.
Figure 1.	Relationship between gamma rays doses and interphase chromosome volume of root tip cells of Sonalika and Cocoit (Expt.1). ...	34
Figure 2.	Relationship between gamma rays doses and % of dividing and abnormal cells of root tip of Sonalika and Cocoit (Expt.1)	36
Figure 3.	Relationship between gamma rays doses and % of dividing and abnormal PMCs of Sonalika and Cocoit (Expt.1).	54
Figure 4.	Relationship between gamma rays doses and % of pollen sterility and pollen grain volume of Sonalika and Cocoit (Expt.1).	56
Figure 5.	Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika induced by gamma rays (Expt.1).	107
Figure 6.	Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Cocoit induced by gamma rays (Expt.1).	108
Figure 7.	Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika induced by temperature and duration of temperature (Expt.2). ...	111
Figure 8.	Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Cocoit induced by temperature and duration of temperature (Expt.2). ...	112

P.T.O.

Figures No. Page No.

Figure 9. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3). 121

Figure 10. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Cocoit induced by gamma rays, temperature and duration of temperature (Expt.3). 122

Figure 11. Effect of gamma rays on grain yield of Sonalika and Cocoit (Expt.3). 125

Plates No.

Plate 1. Photomicrographs showing mitotic abnormalities in root tip cells of tetraploid and hexaploid wheat treated by gamma rays and temperature. 38

Plate 2. Photomicrographs showing meiotic abnormalities in pollen mother cells of tetraploid and hexaploid wheat treated by gamma rays and temperature. 51b

Plate 3. Photomicrographs showing pollen grain abnormalities in tetraploid and hexaploid wheat treated by gamma rays and temperature. ... 106

.....

LIST OF TABLES

Tables No.		Page No.
Table 1.	Interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat induced by gamma rays (Expt.1).	32
Table 2.	Effect of gamma rays on interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat (Expt.3).	33
Table 3.	Interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat induced by temperature and duration of temperature (Expt.2).	39
Table 4.	Effect of temperature and duration of temperature on interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat (Expt.3).	40
Table 5.	Interacting effect of temperature and duration of temperature on interphase chromosome volume and percentages of dividing and abnormal cells in root tips of hexaploid and tetraploid wheat (Expt.2).	41
Table 6.	Interphase chromosome volume, and percentages of dividing and abnormal cells in root tips of Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3). ...	43

P.T.O.

Tables No.		Page No.
Table 7.	Interphase chromosome volume and percentages of dividing and abnormal cells in root tips of Cocoit induced by gamma ryas, temperature and duration of temperature (Expt.3).... ...	46
Table 8.	Percentages of dividing PMCs, abnormal PMCs , pollen sterility and pollen grain volume in hexaploid and tetraploid wheat induced by gamma rays (Expt.1).	52
Table 9.	Effect of gamma rays on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat (Expt.3).	53
Table 10.	Percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat induced by temperature and duration of temperature (Expt.2).	59
Table 11.	Effect of temperature and duration of temperature on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume of hexaploid and tetraploid wheat (Expt.2).	60
Table 12.	Percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat induced by temperature and duration of temperature (Expt.3).	61
Table 13.	Interacting effect of gamma rays, temperature and duration of temperature on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in Sonalika (Expt.3)....	65

P.T.O.

Tables No.		Page No.
Table 14.	Interacting effect of gamma rays, temperature and duration of temperature on percentage of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in Cocoit.	68
Table 15.	Chromosome association and chiasma frequency at diakinesis/metaphase I of Sonalika induced by gamma rays (Expt.1).	75
Table 16.	Chromosome association and chiasma frequency at diakinesis/metaphase I of Cocoit induced by gamma rays (Expt.1).	77
Table 17.	Chromosome association and chiasma frequency at diakinesis/metaphase I of Sonalika induced by temperature and duration of temperature (Expt.2).	79
Table 18.	Chromosome association and chiasma frequency at diakinesis/metaphase I of Cocoit induced by temperature and duration of temperature (Expt.2).	81
Table 19.	Chromosome association and chiasma frequency at diakinesis/metaphase I of Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3).	83
Table 20.	Chromosome association and chiasma frequency at diakinesis/metaphase I of Cocoit induced by gamma rays, temperature and duration of temperature (Expt.3).	93
Table 21.	Percentages of pollen grain abnormalities in Sonalika and Cocoit induced by gamma rays (Expt.1).	104

P.T.O.

Tables No.		Page No.
Table 22.	Percentages of pollen grain abnormalities in Sonalika and Cocoit induced by temperature and duration of temperature (Expt.2). ...	110
Table 23.	Percentage of pollen grain abnormalities in Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3).	114
Table 24.	Percentages of pollen grain abnormalities in Cocoit induced by gamma rays, temperature and duration of temperature (Expt.3).	117
Table 25.	Effect of gamma rays on grain yield and its components of hexaploid and tetraploid wheat (Expt.3).	124
Table 26.	Effect of temperature and duration of temperature on grain yield and its components of hexaploid and tetraploid wheat (Expt.3). ...	127
Table 27.	Interacting effect of gamma rays, temperature and duration of temperature on grain yield and its components of Sonalika (Expt.3). ...	128
Table 28.	Interacting effect of gamma rays, temperature and duration of temperature on grain yield and its components of Cocoit (Expt.3).	131

.....

LIST OF APPENDICES

Appendix No.		Page No.
Appendix 1.	Mitotic index and percentages of different abnormalities in root tip cells of Sonalika and Cocoit induced by gamma rays (Expt.1). ...	160
Appendix 2.	Mitotic index and percentages of different abnormalities in root tip cells of Sonalika and Cocoit induced by temperature and duration of temperature (Expt.2).	161
Appendix 3.	Interacting effect of gamma rays, temperature and duration of temperature on mitotic index and percentages of different abnormalities in root tip cells of Sonalika(Expt.3)...	162
Appendix 4.	Interacting effect of gamma rays, temperature and duration of temperature on mitotic index and percentages of different abnormalities in root tip cells of Cocoit(Expt.3). ...	165
Appendix 5.	Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Sonalika and Cocoit induced by gamma rays (Expt.1).	168
Appendix 6.	Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Sonalika and Cocoit treated by temperature and duration of temperature (Expt.2).	169
Appendix 7.	Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3).	170

P.T.O.

Appendix No. Page No.

Appendix 8. Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Cocoit induced by gamma rays, temperature and duration of temperature (Expt.3). 173

.....

INTRODUCTION

INTRODUCTION

From his early outstanding work on the genetic analysis of mutations induced by X-rays, Stadler (1932, 1954) stated that all the so-called point mutations were actually minute chromosomal aberrations. Sparrow et al. (1961) also have reached a similar conclusion from their analysis of X-or gamma-ray induced plants of various species. Variation in the sensitivity of plants to radiation has been extensively investigated by Sparrow and his colleagues (Sparrow et al., 1961 ; Sparrow and Woodwell, 1962 ; Van't Hof and Sparrow, 1963 ; Sparrow et al., 1963 ; Sparrow, 1965 ; Sparrow and Sparrow, 1965 ; Sparrow et al., 1965) and broad relationships have been established between the extent of injury and mean chromosome volume at interphase. While this information provides an important general guide to the expected sensitivity of crops,considerably fuller information is necessary to predict the outcome of exposure (Sparrow et al., 1965).

It has long been known that the ageing of seeds increases the frequency of spontaneous chromosomal aberrations and mutations. Navashin (1933) found spontaneous chromosomal aberrations in only 0.1 percent seedlings of Crepis tectorum grown from fresh seed, but found that 80 percent of the seedlings from 5-6 year old seed had chromosomal aberrations. At about the same time Peto (1933) found similar ageing effects in maize. He found no chromosome aberrations in seedlings from 6 month old seeds, but in seedling from 6 year old seeds he found that 25 percent of them

possessed chromosome aberrations. Peto (1933) also found that fresh barley seeds, subjected to high temperatures with high humidity, produced seedlings with a high frequency of chromosomal aberrations, apparently due to the artificial ageing effect of high temperature and humidity.

More recently, it has been shown that ageing of seeds not only increases frequency of spontaneous chromosome aberrations, but also increases the sensitivity of the chromosomes to the effect of X-rays. Nilan and Gunthard (1956) found that the frequency of spontaneous chromosomal aberrations in root tip cells of wheat increased with the age of the seed - from 0.02% in 1 year old seed to 0.43% in 17 year old seed. It was found that X-ray induced aberrations averaged about 4.0% in the 1 and 3 year old seed and about 5.5% in the 13 and 17 year old seed. Thus, the ageing of the seed for 12 to 14 years increased their sensitivity to X-rays, as measured by induced chromosomal aberrations by about 40%.

A considerable number of workers have reported increased chromosomal aberrations in seeds of a wide range of species : e.g. in Allium cepa (Nichols, 1941 ; Sax and Sax, 1963), in peas (D'Amato, 1951), and in common and durum wheat, barley, rye and peas (Gunthardt et al., 1953).

However, it gradually became apparent that chronological age of the seed is not only the factor involved in the production

of chromosome aberrations. It is evidenced that factors such as temperature and moisture during storage are important, appears not only from cytological work on Crepis (Navashin and Gerassimove, 1936a,b) but also from investigations on pollen abortion in Datura (Cartledge et al., 1936). The importance of temperature during storage is also highlighted by many investigators. It is shown that heat treatments induce chromosome breakage. Peto (1933) reported that treatment of barley seeds at 95°C for 25 minutes or at 40°C at high humidity for 30 days resulted chromosomal abnormalities. A series of papers by Navashin and Shkvarnikov (Navashin and Shkvarnikov, 1933 a,b; Shkvarnikov and Navashin, 1934, 1935 ; Shkvarnikov, 1936, 1939) on wheat and Crepis showed that treatment of fresh seeds with temperatures of 50-60°C for 20 days had a comparable effect on the production of chromosome aberrations with that of ageing at room temperature for 6-7 years. However, compared to the above mentioned works Smith (1943, 1946) reported that exposing seeds of cereals to temperatures of 50-70°C for 5-15 days or 80°C for 45-80 min. had little effect upon the frequency of chromosomal aberrations. In addition to temperature and humidity, oxygen can contribute to the induction of chromosomal aberration (Moutschen - Dahmen et al., 1959). The production of chromosome damage during the ageing of seeds probably depends on the integration with time of the collective effects of these three factors. Roberts and Abdalla (1967) reported that these

are the major factors which control the viability period of seeds. Consequently, it might be surmised that there is some sort of connection between the accumulation of chromosome damage and loss of viability.

Emery et al. (1970) are of the opinion that irradiation breeding may be a possible alternative and supplement to hybridization as a source of creating genetic variability and the proper utilization of the same. However, in order to carry out mutation breeding experiment in any biological material, the knowledge of its radiosensitivity is of primary importance. Little work has been done on this aspect in wheat. Less information is also available regarding the relationship between artificial ageing of seeds to cytogenetic effects of wheat.

There are several reports which indicate that grain yield and some of its components of wheat are affected by gamma rays (Matsumura, 1961 ; Davies, 1968 ; Killion and Constantion, 1971). Both plant height and grain yield were reduced with the increase of gamma radiation (Matsumura, 1961 ; Davies, 1968 ; Killion and Constantin, 1971), but some enhancement of tillering was caused by 500 rad of gamma rays delivered at the 2-leaf stage of wheat (Davies, 1968).

This study had the following objectives :

(i) to study the relationship between exposure of seeds to gamma-radiation and the subsequent cytological changes as well as

grain yield,

(ii) to study cytological effects and grain yield variation resulting from artificial ageing of seeds induced by high temperature, and finally

(iii) to study the effects of interaction between artificial ageing and gamma - radiation on cytological characters and grain yield of tetraploid and hexaploid wheat.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Ionizing radiations can bring about changes in genetic architecture of plants. A great amount of work on radiation genetics has been done by many workers covering a wide range of plants from both wild and cultivated species of different ploidy levels. Information on the effect of artificial ageing, induced by high temperature, on the chromosomal anomalies and grain yield of wheat is scanty. The literature regarding the effect of ionizing radiation and artificial ageing on chromosomal aberrations and grain yield of wheat and some other related crops are reviewed here.

Smith (1946) studied the effects of heat and X-ray on dormant seeds of cereals with special reference to polyploidy. Diploids were as tolerant of high temperature as polyploids, whether the duration of treatment was a few hours or several days. Polyploids showed greater tolerance to X-ray radiation. The stocks tested included diploid, tetraploid and hexaploid wheat and oats, diploid and autotetraploid barley, maize and rye; Aegilops uniaristata and amphidiploid of A. uniaristata. Seeds of diploid wheat given heat treatments after irradiation were injured slightly more than those given irradiation only. On the centrary, seeds given heat treatments before irradiation were injured less than those given irradiation only.

Konzak and Singleton (1952) observed that the hexaploids of Avena and Triticum showed the greatest resistance to a given

dose of x-rays. But the tetraploids were more resistant than the hexaploids to thermal meutrons.

Gunthardt et al. (1953) observed that chromosomal aberrations and genetic mutations arose from storing seeds of several economic crop species. Decreased viability and increased cytogenetic changes were parallel effects of ageing. Both chromosomal aberrations and genetic mutations had arisen in the seeds and that the frequencies of these cytogenetic changes increased with age. The types of chromosomal aberrations appeared to be identical to those arising from ionizing radiations.

Caldecott et al. (1954) compared the effects of irradiating dormant seeds of barley with x-rays and thermal neutrons as measured by survival and the frequency of chromosomal aberrations and mutations. Over the range of doses used, seeds subjected to thermal neutron irradiation were much more uniformly affected by the irradiation than the seeds subjected to X-radiation. The frequencies of chromosomal bridges in root tip cells and interchanges in pollen mother cells obtained with the highest non-lethal dose of thermal neutrons was about 2-5 times the value obtained with 20,000 r of X-rays. In the same way, the highest mutation frequency obtained with thermal neutron treatments, which did not cause a high degree of sterility was about 2 times that obtained with 20,000 r of X-rays.

Nilan (1956) proposed that, generally seeds of polyploid species of a genus were able to tolerate higher doses of x-rays than the seeds of diploid species. He showed that radio-sensitivity of an individual depended upon various factors like, genotype, age of tissue, moisture content in tissue at the time of irradiation, stage of cell division, temperature of tissue, O_2 content of tissue etc.

Ouang and Chang (1958) counted less number of tillers when rice was treated with x-rays. In some cases, more tillers were also observed. Some induced strains were found to head earliar and other later than the parental varieties. The frequency and degree of sterility was related to the dose of X-rays applied. Induced strains were shorter in plant height.

Mackey (1959) worked on the effects of X-rays on survival of 2x, 4x and 6x wheat and observed that diploid was more sensitive to a given dose of radiation than the polyploids.

Vijayalakshmi and Rao (1960) worked on different species of Saccharum exposing them to various doses of gamma - irradiation from 60_{Co}. They reported that seedling height decreased at the initial stage but recovered to a great extent at a later stage.

Matsumura (1961) soaked seeds of Triticum monococcum flavescens in 32P and 131I solutions for 2 days before sowing, to

compare the radiation effects of beta-rays with those of gamma-rays. Radioactive solutions of pH 6-7 contained 0.05-0.8 mc/g 32P and 0.2-0.8 mc/g ^{131}I. For comparison, seeds soaked in water for 2 days were exposed to gamma-radiation with ^{60}Co at the dosages 2.5, 5, 10 and 20 kr. The growth of seedlings, height of mature plants, single-spike fertility, and chromosome aberrations of treated plants in X_1 and chlorophyll mutations in X_2 were compared. The higher the dosage of beta and gamma-rays, the more delayed were emergence and growth of seedlings and the lower were survival rate, height of mature plants, and fertility. The relation between the inhibition of seedlings growth and dosage of beta- and gamma-radiations coincided roughly with that between the decrease of survival rate or fertility and dosage.

Natarajan and Maric (1961) using dry barley seeds and heterozygous maize seeds, demonstrated that there was a time-intensity effect on biological response to electro-magnetic radiations, such as X- and gamma-rays. Lower intensity was found to be more effective than high intensity. This response was in contradiction to results from other organisms studied previously, viz., viruses, bacteria, Drosophilla, Tradescantia, Antirrhinum, etc., where the response was either dose rate independent or the higher intensity was more effective than lower intensity. This time-intensity factor did not operate in "wet" seeds (10 percent and greater moisture content) to any appreciable degree. The time-intensity factor in dry seeds has been shown to be an expression of storage effect.

accumulated during the period of irradiation and thus depended on the moisture content and the dose rate. It was suggested that in critical radiation studies with dry seeds, in addition to factors such as moisture content, storage time and method of hydration, consideration should also be given to both the exposure time and the intensity of the radiation.

Sax and Sax (1961) reported that the ageing of onion seeds for one year more than doubled the frequency of spontaneous chromosome aberrations in the first division of the root tip cells. The older seeds also showed about 50 percent greater sensitivity to gamma-radiation as measured by the increased frequency of induced chromosome aberrations.

Jagathesan and Sastry (1963) studied the effects of 48 kr, 60 kr and presoaking for 8 hours in water + 48 kr of X-rays on some varieties of Gossypium harbaceum (diploid), G. hirsutum (tetraploid) and G. barbadense (tetraploid). They found that varieties of diploid species were less tolerant to radiations than those of tetraploids.

Matsumura and Fujii (1963) worked on the effects of acute and chronic gamma-rays on 2x, 4x and 6x wheat and observed that polyploids were more radio-resistant than the diploids.

Matsumura et al. (1963) studied the relative biological effectiveness (R BE) of thermal neutrons relative to gamma-rays

for seedling height depression, chromosome aberrations and chlorophyll mutations in Einkorn wheat. The net effects of the heavy particles were estimated and compared with the gamma-ray effects for seeds under the same soaking conditions as for neutron treatments. The RBE values obtained for chromosome aberrations in pollen mother cells and for chlorophyll mutations were 23 ± 10 and 29 ± 10, respectively. Most of the present results were explicable on the assumption that chromosome breakage in wheat requires many ionizations to occur within a chromosome and that the majority of radiation induced chlorophyll mutations resulted not from point mutations but from chromosome breakage events.

Sax and Sax (1963) reported that both chronological and physiological ageing of onion seeds increased the frequency of both spontaneous and X-arys induced chromosome aberrations. Both types of ageing resulted in increased sensitivity of X-rays. In general, the factors which reduced radiation damage in seeds also promoted longer life.

Donini et al. (1964) subjected the plants of different varieties of durum and bread wheats to several dose rates of chronic gamma irradiation for the whole of their life cycle or allowed to recover after 38 or 56 days of irradiation. In plants subjected to daily exposures of 148 and 72 r with or without a recovery period, the following growth reactions were observed : (1) increase in the mean number of culms per plant and (2)

increase in the mean weight per mature plant. In both durum and bread wheats the strongest tillering reaction was typical of the late varieties. Analysis of the number of spikes per plant showed that three out of the ten varieties tested formed spikes in greater number than the controls at 148 r/day chronic exposure ; an increase in mean number of spikes per plant was observed in most of the varieties at 52 and 72 r/day. Spikelet fertility and germinability of seeds produced by irradiated plants showed that the group of bread wheat varieties, as a whole, was more radiation resistant than the group of durum wheat varieties.

Biebl and Mostafu (1965) studied the relation between water content of wheat and barley seeds and their radiosensitivity. Seeds were allowed to attain different water contents by soaking or keeping in desiccators of known vapuur pressures. Seeds were then exposed to 20 kr of either X-or gamma-rays. Seedlings were grown in filter paper rolls for ten days and the reduction in height (expressed as percentage of control) was used as a criterion for assessing immediate damage of radiation. An optimum water content, at which the radiosensitivity of seeds reached its minimum, was found to be around 11.2 and 12.9% for barley and wheat, respectively. While in case of soaked seeds the radiosensitivity increased below and above the optimum water content, desiccator seeds on the other hand showed a sensitivity increase below, but not above the optimum. This increase in sensitivity above the optimum water content in case of soaked seeds might be due to

changes in metabolic activity accompanying the rapid changes in water content during soaking.

Kapoor et al. (1965) studied several varieties and species of wheat and barley grown under chronic gamma - irradiation, during 1961 - 64, at the Gamma Garden of the Indian Agricultural Research Institute, New Delhi. The response of these varieties and species, with regard to the development of epidermal hairs on leaves was studied. Some non-hairy wheat varieties (N.P. 797, 798, 836) were found to develop profuse hairness, while others did not. The optimum dose for induction of maximum hair production was found to vary with varieties. Species which are normally hairy, were found to have reduced hairiness following irradiation.

Abdalla and Roberts (1968) studied the effects of temperature, seed moisture content, and oxygen level on the production of chromosome aberrations during seed storage. It has been found that an increase in any of these factors increased the rate of loss of seed viability and that any treatment which led to a loss of viability also led to an accumulation of aberrant cells in the embryo. Under most storage conditions irrespective of the combination of factors which led to loss of viability or the rate at which viabilty was lost, the relationship between percentage viability and mean frequency of aberrant cells in the surviving seed population was always the same. Under very severe storage conditions, which resulted in leaf viability

periods of about a week or less, however, the relationship was altered so that for any given percentage viability the mean frequency of aberrant cells in the surviving seeds was less than typical of more normal storage conditions. In all the treatments (except the most severe) the curve showing mean frequency of aberrant cells in surviving seeds against time eventually became asymptotic to a critical value peculiar to the species. It was suggested that these results were compatible with the hypothesis that under most storage conditions death of the embryo was the result of the accumulation of nuclear damage which has reflected in chromosome breakage.

Davies (1968) investigated the effects of acute doses of gamma/ irradiation on ranging from 250 to 2000 r delivered to wheat at various stages of growth. Before tiller initiation was complete, doses of 2000 r caused premature death, while 750 - 1250 r led to the number of tillers and ears being increased by factors of up to three. Some enhancement of tillering was also caused by 500r delivered at the 2-leaf stage. These effects were shown to depend on the doses received by the apical meristems ; increased tillering was always associated with some retardation in the development of the main axis. In contrast, when plants were irradiated after tillering was complete neither the number of tillers nor the number of ears was affected by doses up to 2000r. The weight of seeds per plant was unaffected by exposure to 500r. The

effects of 1000r were variable, but on average yield was reduced to about 60 percent of that in the control ; no consistent relationship was found between the effects of this dose and the age when plants were irradiated. In contrast, the effects of 2000r varied greatly during the growing season ; exposure, before tillering was complete, inhibited all ear development, at the time ear emergence yield was reduced to less than a quarter of that of the controls ; whereas when irradiation was deferred to the time of anthesis or later yield was much less affected. All treatments which reduced the yield of seed per plant also caused the weight per seed to be smaller.

Rahman and Mia (1970) studied the effects of 55, 70, 85 and 100 kr of gamma-rays on the seed of Corchorus capsularis var. D-154 and C. olitorius. The survival percentage was decreased with the increase in dose. MLD was found to be in between 85 and 100 kr for both the species. They reported that the pollen fertility was reduced in irradiated populations.

Abidi and Haq (1970) studied the effects of 75, 100, 125, 150 and 175 kr of gamma - rays on three varieties of Brassica campestris. They observed that the pollen fertility was reduced in comparison to their respective control. And they observed that radiation induced chromosomal aberration in the form of translocation.

Killion and Constantin (1971) studied the effect of acute gamma irradiation applied at different developmental stages of winter wheat on survival, height and grain yield. The interaction of exposure X exposure rate X developmental stage was found to be significant for survival and height at maturity and grain yield. Survival was reduced to essentially zero with 1.6 kr at 40r/minute, but unaffected at 5 r/minute, in those plants irradiated at 1-through 4-leaf stage, whereas survival of plants irradiated at winter-dormant through anthesis stage was unaffected by 1.5 kr at 20 r/minute the highest rate used. Height was reduced to a maximum of approximately 60 percent of control in plants at the 1-through 4-leaf stage exposed to 1.6 kr at a rate of 10 r/minute or more. The greatest reduction in grain yield occurred in those plants irradiated at the meiotic and gametogenic stages. At these development stages, grain yield was essentially zero with 1.5 kr at an exposure rate as low as 5 r/minute.

Rahman (1972) reported that with the increase in doses of gamma-rays there were gradual reduction in the germination percentage and seedling height in Allium sativum, Ipomoea batatas and Solanum melongena.

Shaikh (1972) studied the effects of 5, 10, 15, 20, 25, 30 and 50 kr of gamma-rays on Lathyrus species and Vicia ervilia and observed delayed flowering in the irradiated populations and there

was a gradual reduction in percentage of fertile pollen grains.

Shaikh and Godward (1972a) exposed mature, dry seeds of Lathyrus sativus and Vicia ervilia to 5, 10, 15, 20, 25, 30 and 50 kr of gamma-rays. They observed different types of chromosomal aberrations like bridges (single, double, triple and interlocked) at the mititic anaphase, fragments and laggards at mitotic anaphase, unequal metaphase chromosomes showing more variation in length than that was observed in normal karyotype micronuclei in the interphases, degenerated cells with very little chromatin material and less stainability and giant (only in Vicia ervilia) in the irradiated populations but not in control.

Shaikh and Godward (1972b) observed different types of meiotic abnormalities in gamma-irradiated (5, 10, 15, 20, 25, 30 and 50 kr) populations of Vicia ervilia and Lathyrus sativus. The meiotic abnormalities which they observed were of various types like heavy fragmentation of nucleolus at diakinesis, univalents at MI, quardrivalents at MI, multivalents at MI, bridges at AI, bridges with laggards at AI, and laggards at all.

Sinha and Godward (1972a) studied the radiosensitivity as reflected by germination percentages was unaffected at 4 and 8 kr (^{60}Co gamma-rays) in both varieties of L. culinaris. The percentage of survival at maturity remained unaffected at 4 and 8 kr in both the varieties, but in variety macrosperma it ranged from

82% at 12 kr to 30% at 32 kr. In variety microsperma it varied from 92% at 12 kr to 12% at 32 kr. There was an apparent stimulation in the growth of root and shoot at 4 and 8 kr in both varieties. At the doses of 12, 16 and 20 kr the retarding effect of radiation on piant attributes were recorded at doses of 4, 8, 12, 16 and 20 kr in 3 successive generations. The plant attributes taken into consideration were plant height, number of primary branches, number of flowers, number of pods and number of seeds set per plant. Genetic variability and sterility increased with dose in M_1 generation. The capacity to set seeds appeared to have decreased with the increase of dose in both varieties. In the M_2 and M_3 generations the plants showed a definite tendency to return to normality. It appeared that macrosperma is more radiosensitive than macrosperma at all the above doses.

Sinha and Godward (1972b) observed that in M_1, the pollen mother cells (PMC) showed abnormalities, which appeared to have increased with dose, and they persisted throughout the development of the shoot. In M_2 the PMC with aberrations were perpetuated through the male and female gametes of the M_1 generation. The types of aberrations recorded were translocations, bridges, micronuclei, pairing difficulties and pollen abnormalities. The low fertility following high doses in M_1 plants, may be attributed to the phenomenon of chromosomal aberrations and changes in the nature of gene, thereby creating pairing difficulties.

Gilyarovskaya (1973) studied the effects of different terms of the storage of barley seeds on the total amount and spectrum of chromosome aberrations induced by gamma-irradiation. At longer terms of storage, the seeds exposed to gamma-irradiation at a dose of 10 kr showed variations in the total mutation rate. Examination of the spectrum of chromosomal structural rearrangements showed that the storage affected not only the total amount of rearrangements, but their spectrum as well. The study confirmed the hypothesis that in the majority of cells overwhelming majority of rearrangements observed were of chromosomal type.

Roberts (1973) observed that seeds suffered damage to their nuclear material during storage. This was expressed as chromosome breakage, and the induction of recessive mutations which were manifested by increased pollen abortion in the plants produced from the stored seeds, and by segregation of mutant phenotypes in the subsquent generations. These studies have shown that (with the exception of very severe storage conditions which to mean viability periods of the order of a week or less) for any species there was a predictable relationship between percentage viability and the amount of chromosome damage in the surviving seeds. This was so irrespective of the combination of conditions which led to the loss of viability , or how rapidly the viability was lost. The possible reasons for the accumulation of nuclear damage are discussed and the practical implications of the accumulation of

mutations in stored seed were considered.

Sadykhov (1973) reported that the frequency and the spectrum of mutations shown to depend on the specificity of the mutagen, the concentration of the solution of the mutagen, the duration of the exposure, the genotype, the conditions of cultivation, before and after the treatment and on several other factors. Experimental studies on the sensitivity of wheat seeds of different age to chemical mutagens were undertaken. The initial experimental materials were 5 tetraploid and hexaploid wheat species. In a number of species, no seeds collected on the 10th 15th and even 20th day after flowering survived after the treatment with chemical mutagens were shown by these investigations to exhibit a high frequency and a considerably wide spectrum of mutations.

Underbrink et al. (1973) studied the effect of x-ray or gamma-rays and 0.43 - MeV neutrons on pollen abortion, as measured by cotton blue staining, in 15 members of 4 genera of the family Commelinaceae. The roles of interphase chromosome volume (ICV), nuclear volume (NV) and ploidy on the degree of pollen abortion induced by radiation were investigated. For each species, the maximum percentage of aborted grains was determined over a post- radiation period equivalent to an entire period of microsporogenesis. Dose-response curves were constructed for each species and these were found to vary in slope.

Ploidy was not found to influence the radiation response to an appreciable extent to be more radioresistant, but this response appeared to be a function of ICV and not the degree of ploidy. Correlations were sought between 50% pollen abortion and ICV or NV. No correlations were found using NV.

Bhadra and Mia (1975) studied the effects of gamma-rays on diploid and colchicine induced tetraploid Corcorus capsularis. They observed that colchicine induced tetraploid capsularis was more radiosensitive than the diploid. The survival percentage decreased with the increase in radiation dose. MLD was above 80 kr for 2x capsularis and 70 and 80 kr for C-4x capsularis.

Akbar et al. (1976) in their experiment on gamma-ray effect on Indica and Japonica varieties of rice observed that in both varieties seedling height and the survivality percentage decreased with the increase in dose of gamma rays. RD_{50} was almost double in Indica varieties than in Japonica.

Bhattacharyya (Ganguli) and Sen- Mandi (1985) studied the embryos of aged non-germinating wheat seeds, when placed on sucrose/glucose, germinated well and grew into normal plantlets, while on agar alone they remained ungerminated as in the intact seed. From the results of amylase assays in seeds of different ages it appeared that failure of amylolytic activity in aged seeds could be a cause of unavailability of utilizable substrate

to the embryonic axis of aged seeds. This would bring about a limitation in the capacity of germination and growth of the embryonic axis even before the embryo became non-viable.

Ganguli and Sen-Mandi (1990) reported that the growth performance of deteriorated wheat embryos in cultural conditions depended largely on the method of ageing treatment. Low viability embryos obtained by different ageing methods behaved widely differently when grown on sucrose media. The ability of badly deteriorated embryos, which did not germinate when attached to the endosperm, to utilise sucrose for rejuvenation was found to be much lower in naturally seed stocks than in artificially deteriorated ones. Studies on chromatin associated proteins in embryos showed a similar increase in acid soluble protein in both naturally aged and artificially aged embryos and acid insoluble (non-histone) proteins was particularly marked in the hot-water dip artificially aged embryos. They concluded that different conditions that cause deterioration of intact seeds may bring about completely different effects in cellular event of the embryonic axis.

Akhter et al. (1992) carried out an experiment to ascertain the effects of age on wheat and barley seeds . Germination percentage of different years old wheat and barley seeds were found to decrease gradually with an increase of the storage time. The germination percentages of wheat seeds were much lower than that of barley seeds. Mitotic index and chromosomal irregularities from root tip cells were also studied. Most of the

irregularities were characterized by precocious separation of chromosomes and inactivation of spindle mechanism, chromosome fragment, laggard, bridge condensed and sticky chromosome, ring chromosomes etc. In both the materials, the frequencies of dividing cells were found to decrease with the increase of the age of seeds. Frequency of abnormal cells were also found to increase with the increase of the age of seeds. The frequency of chromosomal aberrations with increased storage time was closely related to the loss of germinability.

MATERIALS AND METHODS

MATERIALS AND METHODS

For all the three experiments the materials used were Triticum aestivum L. cv. Sonalika and Triticum durum Dest. cv. Cocoit. Seeds of these two varieties were procured from BARI, Regional Station, Shyampur, Rajshahi.

Experiment 1. Effect of gamma radiation on some cytological characters of wheat.

Air - dried seeds of the two varieties were subjected to 5,10,15,20,25 and 30 kr of gamma rays from 650, 50,000 curie Co^{60} source of Institute of Food and Radiation Biology, Atomic Energy Research Establishment, Savar, Dhaka. During irradiation, the dose rate was 297 kr/hour.

(a) Collection and fixation of root tips :

Irradiated and control seeds of both the varieties were allowed to germinate on moist filter paper in petridishes in the laboratory at room temperature. When the roots grew upto 1 to 1.5 cm length, eight to ten root tips of each treatment were collected by a pair of fine forceps and fixed in 1:3 acetoalcohol (1 part glacial acetic acid and 3 parts absolute alcohol). After 48 hrs. of fixation, these root tips were washed with water for few minutes. Then these were transfered to 70% ethyl alcohol and stored in a refrigerator.

(b) Staining of root tips and preparation of slides :

To study mitotic behaviour and interphase chromosome volume in root tip cells, chromosomeswere stained following squash method of Haque et al. (1976) with certain modifications. The schedule was as follows :

(1) Preserved root tips were washed in distilled water for 7-8 minutes.

(2) The materials were hydrolysed with 50% HCl for about 30-35 minutes.

(3) Again the root tips were washed in distilled water for 5-6 minutes.

(4) The root tips were then mordanted in 2% aqueous solution of iron alum (ferric ammonium sulphate) for 9-10 minutes.

(5) The root tips were washed in distilled water for 7-8 minutes with frequent changes of distilled water in order to complete removal of the mordanting fluids from the tissues.

(6) The root tips were stained in 0.5% haematoxylin for 9-10 minutes.

(7) The root tips were washed in distilled water for 5 minutes with frequent changes of water.

The stained root tip was cut with a razor blade and was taken on a clean slide and a drop of 0.5% acetocarmine was added to it. Then a cover glass was placed on the material and squashed by a plastic tapper. Then the slide was warmed over an alcohol flame and a slight pressure was applied by finger tips over the

cover glass keeping the slide duly wrapped in blotting paper. Then the slides were observed under compound microscope.

Cytological screening was carried out at all the stages of meiosis. Data on chromosome association and chiasma frequency was recorded from diakinesis/first metaphase.

(i) Determination of interphase chromosome volume (ICV):

In order to calculate interphase chromosome volume from the root tip cells, nuclear volume was measured by oculometer and converted into micron by a stage micrometer. The nuclear volume (NV) was calculated using the formula for Spherical, $V = 4/3\pi r^3$ (Nayar et al., 1971). The mean nuclear volume divided by the somatic chromosome number gave the interphase chromosome volume.

(c) Collection and fixation of inflorescences :

Young inflorescences of field-grown plants were collected between 8-30 a.m. and 9-30 a.m., and immediately fixed in Carnoy's fixative (6 ethanol : 3 chloroform : 1 acetic acid). After 48 hours of fixation, the inflorescences were transferred to 70% ethyl alcohol and stored in a refrigerator for meiotic study.

(i) Staining of anthers and preparation of slides :

For the collection of data on meiotic behaviour and chiasma frequency, temporary slides were prepared by the acetocarmine smear technique. The schedule is as follows :

(1) Young anther was placed on a clean slide and a drop of 2% acetocarmine was added.

(2) The anther wall was then crushed by a curved dissecting needle and the anther wall was removed.

(3) The pollen mother cells were covered with a cover glass, warmed gently over an alcohol flame and a slight pressure was exerted by thump to spread out the chromosome.

(ii) Collection of data on pollen sterility :

A mature anther was taken on a clean slide with a drop of iodine in potassium iodide solution. The anther wall was then ruptured with a help of a curved dissecting needle and pressure was applied to squieeze out its pollen grains in the fluid. The anther wall was then removed and the entire fluid containing pollen grains was covered with a cover glass and observed under a compound microscope. A total number of fertile and sterile pollen grains was scored and the percentages were calculated as follows :

$$\text{Percentage of pollen sterility} = \frac{\text{Total number of sterile pollen grains}}{\text{Total number of fertile + Sterile pollen grains}} \times 100$$

(iii) Collection of data on pollen grain abnormality :

For studying pollen grain abnormality, the procedure of Jagathesan and Sreenivasan (1966) was modified to suite wheat pollen grains. The complete procedure used was as follows :

1. Ripe yellow anthers were collected before anthesis and were treated with 0.2% colchicine solution in a small vial at 25-27°C.

2. Anthers were washed in distilled water for 5 minutes, treated with 0.002 M hydroxyquinoline solution for 1 hour at 28°C and then they were washed in distilled water for 5 minutes.

3. Anthers were fixed for 24 hours in Ostergreen and Heneen's solution which was composed of methanol 60 ml, chloroform 30 ml, distilled water 8 ml, picric acid 1 g and mercuric chloride 1 g. At the end of fixation the materials were stored for a period of 4 weeks in 70% methanol in a refrigerator.

4. The anthers were hydrated in 50 and 35% methyl alcohol and then washed in distilled water for 5 minutes.

5. The anthers were hydrolysed in IN HCl for 20 minutes and then washed in water.

6. The anthers were stained in leuco-basic fuchsin (Schiff's reagent) for 45-60 minutes.

7. The anthers were smeared into a drop of 0.5% acetocarmine, gently heated, a cover glass was placed over the material and a gentle pressure was applied by finger tips keeping the slide duly wrapped in between folds of a filter paper.

Data for pollen grain abnormality along with normal pollen grain were recorded. Photomicrographs for different chromosomal

abnormalities, abnormal pollen grains and pollen sterility were taken from desired slides.

Experiment 2 : Effect of temperature on some cytological characters of wheat.

Seeds of two varieties of wheat were spread over petri dishes and kept at constant temperatures of 25, 30 and 35°C in hot air oven for 72, 144 and 288 hours. Control seeds were spread over petridishes and kept at room temperature (23-25°C) for the same period.

The procedures for germination and collection of cytological data were same as in experiment 1.

Experiment 3 : Effect of gamma radiation and constant temperature on some cytological characters and grain yield and its components of wheat.

(a) Collection of cytological data :

The methods followed for the collection of cytological data were same as it was described in experiment 1.

(b) Measurements of grain yields and its components :

Seeds of all the treatments along with control of the two cultivars were sown in the experimental field of Rajshahi University on 10 December, 1990.

The experimental design was a split plot design with three replications. Necessary cultural practices such as weeding,

spreading of soil and irrigation were done as and when necessary.

At the time of final harvest the following characters were measured : Number of tillers/plant, plant height, length of spike, no. of spikes/plant, no. of spiklets on main spike, no. of grains/ main spike, weight of grains on main spike and grain yield/plant.

Statistical analysis of data :

Analysis of variance was done, and regression and correlation coefficients between pair of characters were calculated. For analysis of variance angular transformation was done for the percentage values.

RESULTS

R E S U L T S

Results obtained in this study are presented under different heads and subheads as follows :

MITOTIC STUDY

Effect of Gamma Rays :

Interphase chromosome volume (ICV), percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid (Sonalika) and tetraploid (Cocoit) wheat induced by gamma rays (expt. 1 and 3) are given in Tables 1 and 2, respectively. ICV in root tip cells of both the hexaploid and tetraploid wheat increased with the increase of doses of gamma rays in both the experiments. This increase was much pronounced from 0 to 5 kr of gamma rays. Among the different doses of gamma rays, increase of ICV was less marked. Between the two varieties, Cocoit had greater ICV.

The relationship between gamma rays doses and ICV in root tip cells of Sonalika and Cocoit (expt.1) is shown in Figure 1. In both the varieties ICV increased with the increase of gamma rays dose. The correlation study revealed that the positive correlation between the gamma rays doses and ICV was significant for Sonalika. The regression study showed that the rate of increase of ICV was higher in Cocoit (2.631 um^3/kr) than Sonalika (1.707 um^3/kr).

In expt. 1, percentage of dividing cells in root tips of Sonalika and Cocoit increased upto 10 kr and then gradually

Table 1. Interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat induced by gamma rays (Expt. 1).

	Radiation dose (kr)							
	0	5	10	15	20	25	30	LSD 5%
	Sonalika (hexaploid)							
Interphase chromosome volume (um^3)	146	197	201	205	209	212	213	3.13
Percentage of dividing cells	29.7	31.2	31.3	31.1	30.8	28.6	27.8	0.64
Percentage of abnormal cells	3.4	8.9	9.6	9.6	10.2	11.1	11.4	1.14
	Cocoit (Tetraploid)							
Interphase chromosome volume (um^3)	212	296	304	312	319	291	333	4.27
Percentage of dividing cells	30.0	32.0	31.1	31.0	30.3	29.0	27.4	0.40
Percentage of abnormal cells	3.3	5.2	4.8	5.7	5.7	6.4	9.1	0.39

Table 2. Effect of gamma rays on interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat (Expt. 3).

	Radiation dose (kr)							
	0	5	10	15	20	25	30	LSD 5%
				Sonalika				
Interphase chromosome volume (um^3)	150	312	316	321	326	331	335	5.25
Percentage of dividing cells	29.6	27.2	26.2	26.5	25.8	26.0	26.5	1.62
Percentage of abnormal cells	3.3	14.2	14.6	15.0	15.0	15.3	15.6	2.54
				Cocoit				
Interphase chromosome volume (um^3)	213	524	469	540	565	556	564	8.31
Percentage of dividing cells	29.3	27.6	26.7	26.9	27.0	27.5	26.6	1.10
Percentage of abnormal cells	3.6	13.9	14.1	14.5	15.0	15.4	15.7	3.64

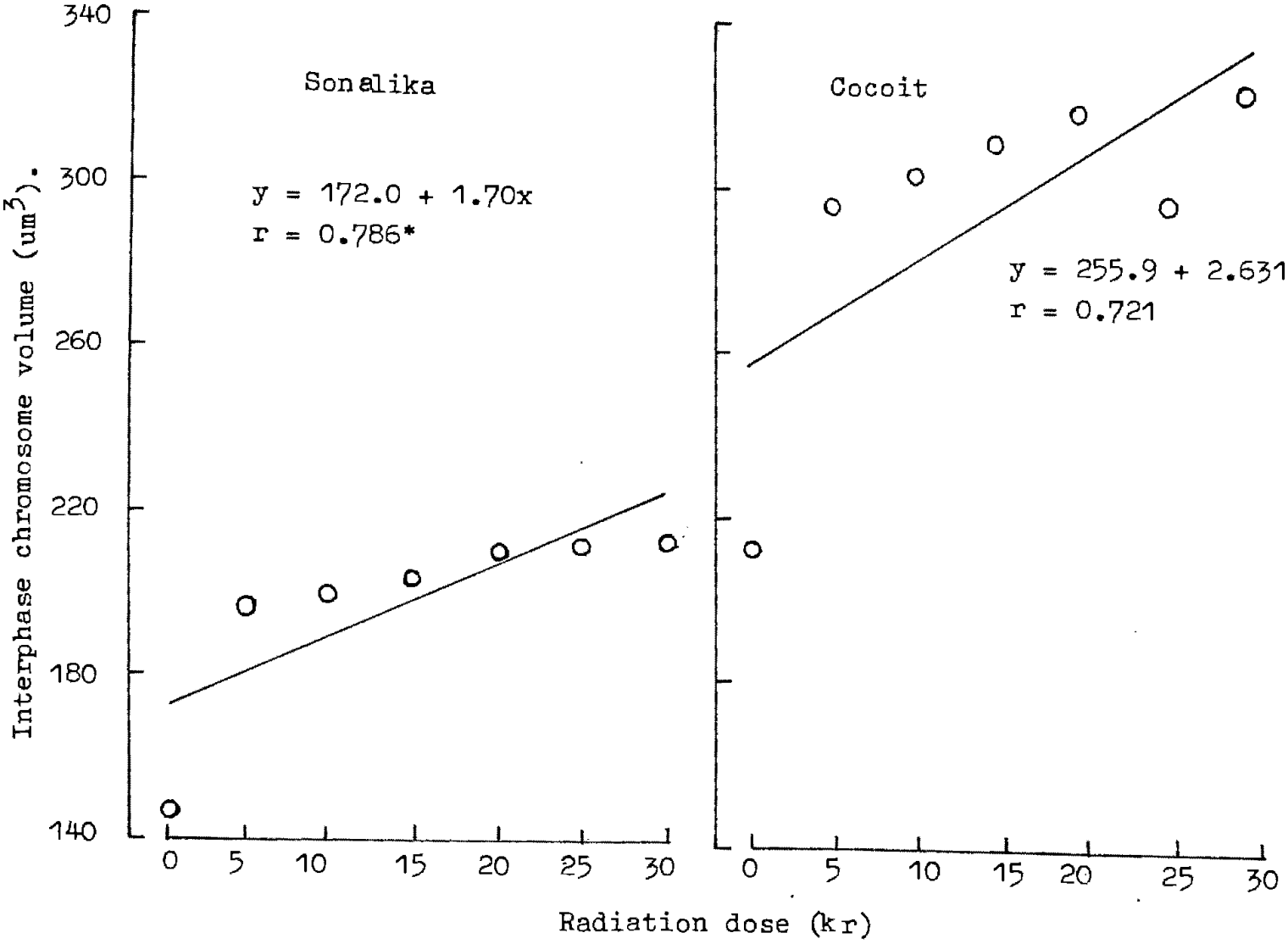


Figure 1. Relationship between gamma rays doses and interphase chromosome volume of root tip cells of Sonalika and Cocoit (Expt.1).

decreased (Table-1 and Figure-1). But in expt. 3, percentage of dividing cells in root tips of both the varieties gradually decreased with the increase of radiation dose. In both the varieties percentage of dividing cells was more or less similar. The correlation coefficient between gamma rays dose and percentage of dividing cells in root tip was negative but not significant in both the varieties. The rate of decrease of the percentage of dividing cells was higher in Cocoit (Figure-2).

Percentage of abnormal cells in root tips of both the varieties increased with the increase of radiation dose. Compared to 5 kr, percentage of abnormal cells in root tips of both the varieties was much lower in the control. The increase of percentage of abnormal cells from 5 to 30 kr was less marked. Sonalika had higher percentage of abnormal cells than that of Cocoit, especially in expt. 1. Correlation coefficient between gamma rays dose and percentage of abnormal cells was positive and significant (Figure-2). The rate of the increase of percentage of abnormal cells was higher in Sonalika (Figure-2).

Mitotic indices and percentages of different abnormalities in root tip cells of Sonalika and Cocoit induced by gamma rays of expt. 1 are given in Appendix-1.

Most of the abnormal cells were characterised by inhibited chromosomes (C-metaphase), disturbed anaphase, bridges, clumping, fragments, lagging chromosomes, rings and micronuclei

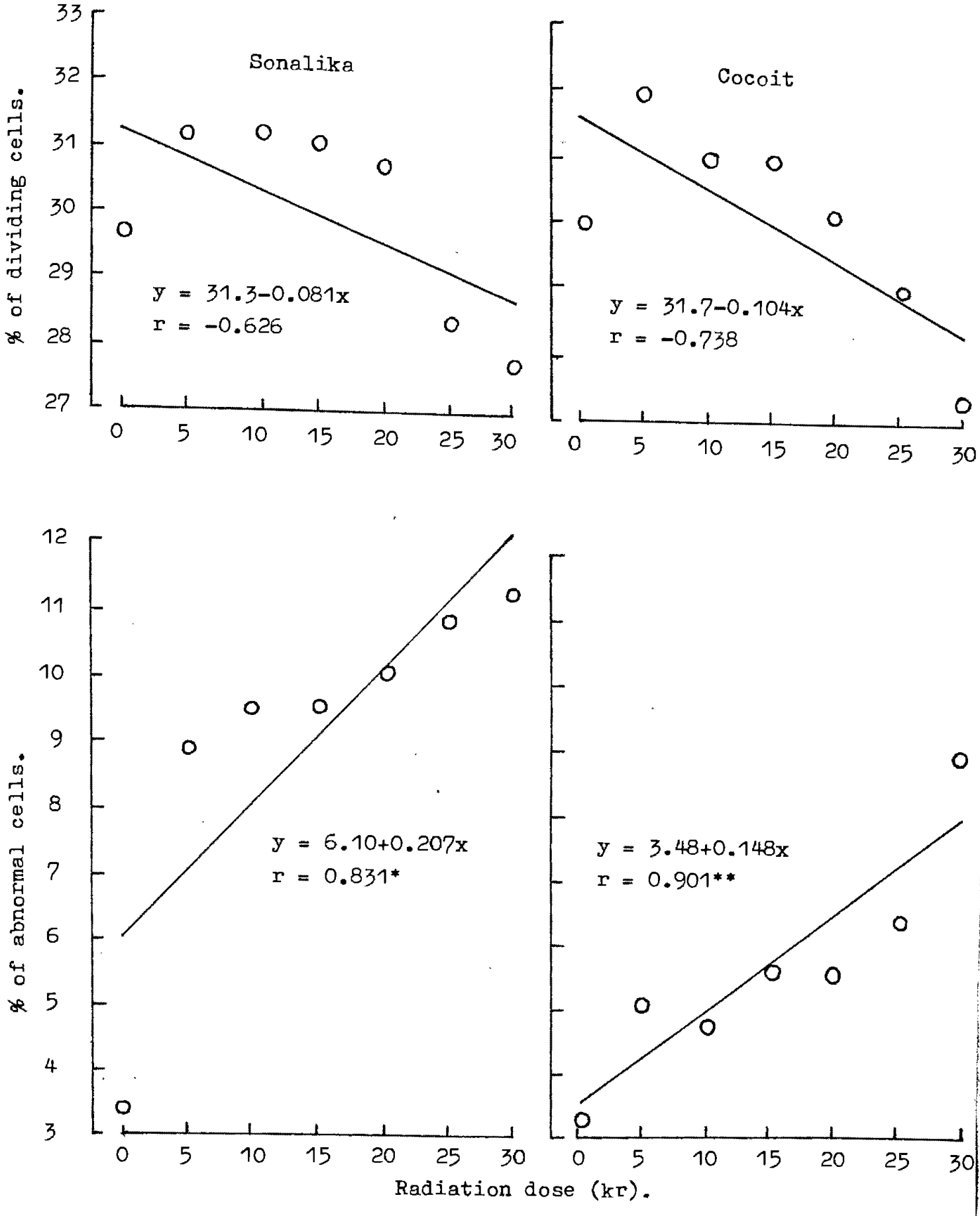


Figure 2. Relationship between gamma rays doses and % of dividing and abnormal cells of root tip of Sonalika and Cocoit (Expt.1).

(Plate-1). Different abnormalities (C-metaphases to micronuclei or ring) gradually increased with the increase of radiation doses. But the highest percent of fragments and laggards of Sonalika were observed at 5 kr.

Effect Of Temperature (^{o}C) And Duration (hrs.) Of Temperature :

The effect of temperature (^{o}C) and duration (hrs.) of temperature treatment on ICV, percentages of dividing and abnormal cells in root tip of Sonalika and Cocoit are given in Table-3 (expt.2) and Table-4 (expt.3). The effect of temperature and duration of temperature treatment on all the three characters was significant for both the varieties. Except for percentages of dividing cells and abnormal cells of Cocoit in expt.3, ICV and percentage of abnormal cells increased and percentage of dividing cells decreased with the increase of temperature and duration of temperature.

Interacting effects of temperature and duration of temperature on ICV and percentages of dividing and abnormal cells in the root tips of hexaploid and tetraploid wheat are presented in Table-5. In both Sonalika and Cocoit, the highest ICV and percentage of abnormal cells were found at 35^{o}C and 288 hours duration of temperature treatment and the lowest values were observed at 25^{o}C and 72 hours duration and at 35^{o}C and 288 hours duration of temperature treatment.

Plate 1. Photomicrographs showing mitotic abnormalities in root tip cells of tetraploid and hexaploid wheat treated by gamma rays and temperature.

A. Metaphase (Normal).

B. Metaphase with lagging chromosomes.

C. Metaphase with chromosome fragments.

D. Anaphase with chromosome fragments.

E. Anaphase (late) with laggards.

F. Anaphase (late) with chromatid bridge.

G. Anaphase (late) with chromatid bridge and fragment.

H. Telophase with broken chromatid bridge and micronuclei.

I. Telophase with chromatid bridge (Obscure).

PLATE - I

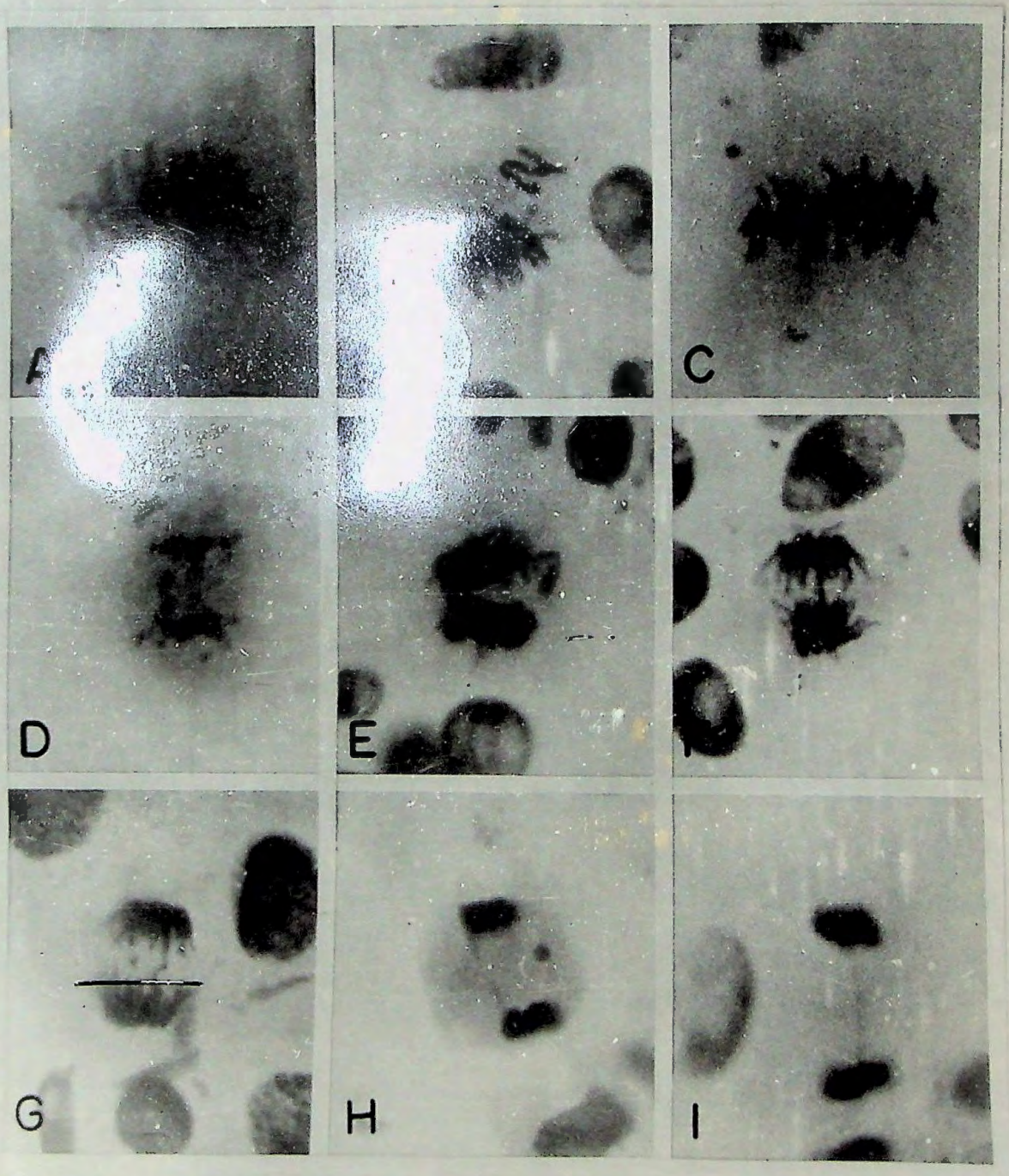


Table 3. Interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat induced by temperature and duration of temperature (expt. 2).

	Temperature(°C)				Duration (hour)			
	25	30	35	LSD 5%	72	144	288	LSD 5%
				Sonalika				
Interphase chromosome volume (um^3)	217	230	247	1.18	222	232	241	1.40
Percentage of dividing cells	29.0	24.0	19.7	0.66	27.3	24.3	21.0	0.19
Percentage of abnormal cells	13.0	16.3	19.3	0.47	12.7	16.0	20.0	0.44
				Cocoit				
Interphase chromosome volume(um^3)	221	235	248	1.05	228	235	242	1.23
Percentage of dividing cells	29.9	25.8	21.4	0.49	28.4	25.3	23.3	0.23
Percentage of abnormal cells	13.8	17.0	19.2	0.82	13.7	16.6	19.8	0.40

Table 4. Effect of temperature and duration of temperature of interphase chromosome volume, percentage of dividing cells and percentage of abnormal cells in root tips of hexaploid and tetraploid wheat (Expt. 3).

	Temperature (°C)				Duration (hour)			
	25	30	35	LSD 5%	72	144	288	LSD 5%
				Sonalika				
Interphase chromosome volume (um^3)	278	297	303	4.62	231	293	373	4.10
Percentage of dividing cells	28.4	26.9	26.4	1.41	28.8	26.5	25.2	1.57
Percentage of abnormal cells	12.1	13.4	14.3	1.14	9.8	13.2	16.9	1.28
				Cocoit				
Interphase chromosome volume (um^3)	452	500	548	4.30	371	482	647	6.30
Percentage of dividing cells	27.6	27.4	27.1	NS	29.8	27.3	25.0	1.85
Percentage of abnormal cells	12.0	13.3	14.2	NS	9.6	13.3	16.6	1.98

Table 5. Interacting effect of temperature and duration of temperature on interphase chromosome volume and percentages of dividing and abnormal cells in root tips of hexaploid and tetraploid wheat (Expt. 2).

Duration (hour)	Temperature (°C)	Interphase chromosome volume (um^3)	Percentage of dividing cells	Percentage of abnormal cells
		Sonalika		
	25	209	31	10
72	30	221	28	12
	35	237	23	16
	25	216	29	13
144	30	231	24	16
	35	249	20	19
	25	227	27	16
288	30	239	20	21
	35	257	16	23
LSD 5%		2.42	0.33	0.79
		Cocoit		
	25	216	32	10.9
72	30	227	28.9	14.0
	35	240	24.3	16.2
	25	220	30.4	13.4
144	30	236	24.9	17.1
	35	248	20.6	19.2
	25	227	27.3	17.1
288	30	243	23.5	19.9
	35	256	19.2	22.3
LSD 5%		2.13	0.40	0.69

Mitotic indices and percentages of different abnormalities in root tip cells of Sonalika and Cocoit induced by temperature (^{o}C) and duration (hrs) of temperature in expt. 2 are given in Appendix-2.

From inhibited chromosome to micronuclei all the abnormalities gradually increased with the increase of temperature and duration of temperature treatment. But in Sonalika for bridges and in Cocoit for fragments the abnormality percentages were not gradually increased but fluctuated.

Effect Of Gamma Rays, Temperature (^{o}C) And Duration (hrs) Of Temperature :

The interacting effects of gamma rays, temperature (^{o}C) and duration (hrs) of temperature on ICV and percentages of dividing and abnormal cells in root tips of Sonalika and Cocoit are given in Table 6 and 7, respectively. The results indicated that ICV of both the varieties increased with the increase of radiation dose, temperature and duration of temperature. The highest ICV was observed at 30 kr radiation, 35^{o}C temperature and 288 hours duration of temperature treatment. The results also indicated that the interactions between radiation dose and temperature (^{o}C) and between radiation dose and duration (hrs) of temperature were non-significant. Similar results were observed for percentage of abnormal cells. Variability was low for

Table 6. Interphae chromosome volume, and percentages of dividing and abnormal cells in root tips of Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3).

Temperature (°C)	Radiation dose (kr)	Interphase chromosome volume (um^3)	Percentage of dividing cells	Percentage of abnormal cells
		72 hours		
	0	150.6	29.9	3.3
	5	218.8	28.5	8.6
	10	221	27.8	9.0
25	15	225	30.5	10.1
	20	229.4	27.3	10.1
	25	233	28.2	10.1
	30	234.8	29.9	10.3
	0	150.6	30.1	3.3
	5	234.6	30.6	10.4
	10	236.6	29.6	11.3
30	15	243.2	29.3	11.5
	20	245.8	29.3	11.6
	25.	251.4	27.9	11.5
	30	250.2	29.2	11.7
	0	151.6	29.9	3.2
	5	251	28.7	11.3
	10	260	27.9	11.6
35	15	262	27.3	11.7
	20	268	28.0	11.5
	25	270.2	27.4	11.7
	30	275	28.0	12.0

Contd....

Table 6. Continued.

		144 hours		
	0	150.8	29.6	3.2
	5	278.4	27.9	11.9
	10	280	27.2	11.8
25	15	286	26.9	12.9
	20	289.2	24.3	12.8
	25	290.8	25.1	13.3
	30	296.4	26.4	13.9
	0	150.8	29.1	3.1
	5	299.6	26.9	14.1
	10	307.2	26.2	14.4
30	15	309.6	26.5	14.9
	20	317	24.8	15.4
	25	324	27.2	15.4
	30	329	25.6	16.3
	0	150.6	29.7	3.3
	5	336.2	25.8	16.0
	10	341	24.1	16.2
35	15	348.8	24.2	16.3
	20	351	26.2	16.6
	25	356.2	26.4	17.4
	30	365	26.0	17.4

Contd. .....

Table 6. Continued.

288 hours.

	0	150.6	29.5	3.5
	5	373	27.3	18.6
	10	377.2	26.3	19.1
25	15	379.8	25.1	18.2
	20	385.8	22.8	17.5
	25	391.8	25.0	18.4
	30	395	25.8	18.4
	0	150	29.3	3.2
	5	395.8	23.8	17.8
	10	402.4	23.6	18.2
30	15	408	24.9	19.3
	20	408.6	23.7	19.2
	25	413.6	22.6	19.2
	30	419.8	24.3	19.5
	0	151	29.4	3.3
	5	422.4	25.2	19.4
	10	426	23.5	19.5
35	15	434	23.4	20.0
	20	447	25.5	20.6
	25	447.8	24.1	20.7
	30	452.4	23.2	20.9

Table 7. Interphase chromosome volume and percentages of dividing and abnormal cells in root tips of Cocoit induced by gamma rays, temperature and duration of temperature (Expt. 3).

Temperature ($0^{o}C$)	Radiation dose (kr)	Interphase chromosome volume (um^3)	Percentage of dividing cells	Percentage of abnormal cells
		72 hours		
	0	212.4	29.9	3.8
	5	341.7	29.7	9.5
	10	353.1	29.3	10.0
25	15	358.1	29.4	9.0
	20	361.9	28.7	9.6
	25	372.2	30.7	10.3
	30	375.2	29.6	10.4
	0	213.2	29.8	3.7
	5	382.4	29.3	9.1
	10	387.4	29.8	9.1
30	15	398.4	29.2	10.0
	20	402.7	30.7	11.6
	25	407.6	32.0	11.9
	30	416.8	29.5	11.1
	0	212.6	29.9	3.8
	5	422.4	29.9	10.0
	10	425.6	28.5	9.9
35	15	430.4	29.2	10.9
	20	433.0	28.8	11.6
	25.	442.1	30.8	13.0
	30	445.8	30.2	13.3

Contd. ....

Table 7. Continued.

144 hours

	0	212	29.0	3.4
	5	465.6	28.1	11.7
	10	473.2	27.3	11.9
25	15	480.8	27.5	12.9
	20	486.4	26.7	12.9
	25	493.4	26.5	13.3
	30	503.8	26.5	14.1
	0	212.4	28.6	3.6
	5	508.4	27.6	14.1
	10	516.4	26.6	14.3
30	15	529	27.7	15.2
	20	534.6	28.0	15.7
	25	539.4	26.4	15.7
	30	545.6	27.1	16.4
	0	212.2	28.8	3.6
	5	555.8	27.3	16.0
	10	558.4	26.6	16.3
35	15	566.6	27.1	16.7
	20	573	26.8	16.6
	25	583.8	26.7	16.7
	30	590.4	25.8	17.3

Contd. .....

Table 7. Continued.

288 hours

	0	215.8	29.2	3.6
	5	599.8	25.3	16.6
	10	604.4	25.0	16.9
25	15	618.8	25.0	17.6
	20	653.8	25.3	17.8
	25	657.2	25.9	18.1
	30	670.6	24.2	18.3
	0	213	29.4	3.6
	5	684.8	25.2	18.3
	10	704.6	24.2	18.7
30	15	709.6	24.2	18.8
	20	724	23.5	18.9
	25	733.6	24.1	19.2
	30	751.8	23.4	19.5
	0	214	28.9	3.6
	5	763.2	25.8	19.5
	10	780.8	22.9	19.5
35	15	799.2	22.7	19.6
	20	815.8	24.1	20.2
	25	827.4	24.0	20.4
	30	858.2	23.4	20.5

percentage of dividing cells. With some fluctuations, percentage of dividing cells decreased with the increase of radiation dose. With a few exceptions, percentage of dividing cells in root tips decreased with the increase of both the temperature (^{o}C) and duration (hrs) of temperature treatment at the same dose of radiation.

Interacting effects of gamma rays, temperature (^{o}C) and duration (hrs) of temperature treatment on mitotic indices and percentages of different abnormalities in root tip cells of Sonalika in expt. 3 are given in Appendix-3.

Among the different types of abnormalities induced by 72 hours duration of temperature treatment the highest percentage (4.11%) was found for disturbed anaphase and it was at 35^{o}C temperature and 30 kr and the lowest abnormal percentage was 0.03% (ring) at 25^{o}C temperature in 15 kr at the same duration (72 hours). All the abnormalities increased with the increase of temperature and radiation dose.

In case of 144 hours duration of temperature treatment, the inhibited chromosomes had the highest frequency (5.09%) in 30 kr at 35^{o}C and the micronuclei had the lowest value (0.10%) at 25^{o}C in 10 kr of the same duration (144 hours). But clumping and laggards did not gradually increase, but fluctuated.

In case of 288 hours duration of temperature treatment, the highest percentage of abnormality was for C-metaphase and the lowest percentage was found for ring. The highest percentage of C-metaphase was 5.81 in 30 kr at 35°C and the lowest percentage was 0.10 in control at 30°C temperature at the same duration (288 hours).

Interacting effect of gamma rays, temperature (°C) and duration (hrs) of temperature treatment on mitotic indices and percentages of different abnormalities in root tip cells of Cocoit are presented in Appendix-4 (expt.3).

In case of 72 hours duration of temperature treatment the highest percentage of micronuclei was 4.12 in 30 kr at 35°C and the lowest percentage was 0.05 in 15 kr at 25°C. In case of clumping, the percentages were less than the other abnormalities.

In case of 144 hours duration, the inhibited chromosomes had the highest value (5.13%) in 30 kr at 35°C and the ring had the lowest value (0.08%) in 10 kr at 25°C. The percentage of ring chromosome was less.

In case of 288 hours duration, the percentages of abnormalities were more for disturbed anaphase and less for micronuclei. But in case of bridges, the percentages fluctuated. The highest percentage of abnormality was found for disturbed anaphase (5.62%)

in 30 kr at 35°C and the lowest percentage of abnormality for micronuclei was 0.19 in 5 kr at 25°C of same duration (288 hours).

MEIOTIC STUDY

Effect Of Gamma Rays :

Percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid (Sonalika) and tetraploid (Cocoit) wheat induced by gamma rays (expt. 1 and 3) are given in Tables 8 and 9, respectively. Percentages of dividing PMCs in both the varieties decreased with the increase of doses of gamma rays in both the experiments.

In expt.1 percentage of dividing PMCs in Sonalika and Cocoit decreased upto 5 kr and 10 kr , respectively and then gradually increased (Table 8 and Figure 3). But in expt. 3, percentage of dividing PMCs of both the varieties gradually decreased with the increase of radiation dose. The percentages of dividing PMCs were more or less same in both the varieties. The correlation coefficient between gamma rays dose and percentage of dividing PMCs was positive in Sonalika and negative in Cocoit, but was non-significant in both the cases.

Percentages of abnormal PMCs in both the varieties increased with the increase of radiation dose. Compared to 5 kr, percentages of abnormal PMCs in control of both the varieties were much lower. In both the experiments the increase of the percentage of

Plate 2. Photomicrographs showing meiotic abnormalities in pollen mother cells of tetraploid and hexaploid wheat treated by gamma rays and temperature.

A. Diakinesis (Normal).

B. Prometaphase I (Disorganized).

C. Metaphase I with lagging chromosome.

D. Clumped metaphase I chromosome.

E. Irregular disjunction of anaphase I chromosome.

F. Unequal distribution of anaphase I chromosomes.

G. Disorganized anaphase II chromosomes.

H. Telophase II with chromosome fragment.

I. Fertile and sterile pollen grains.

PLATE-2

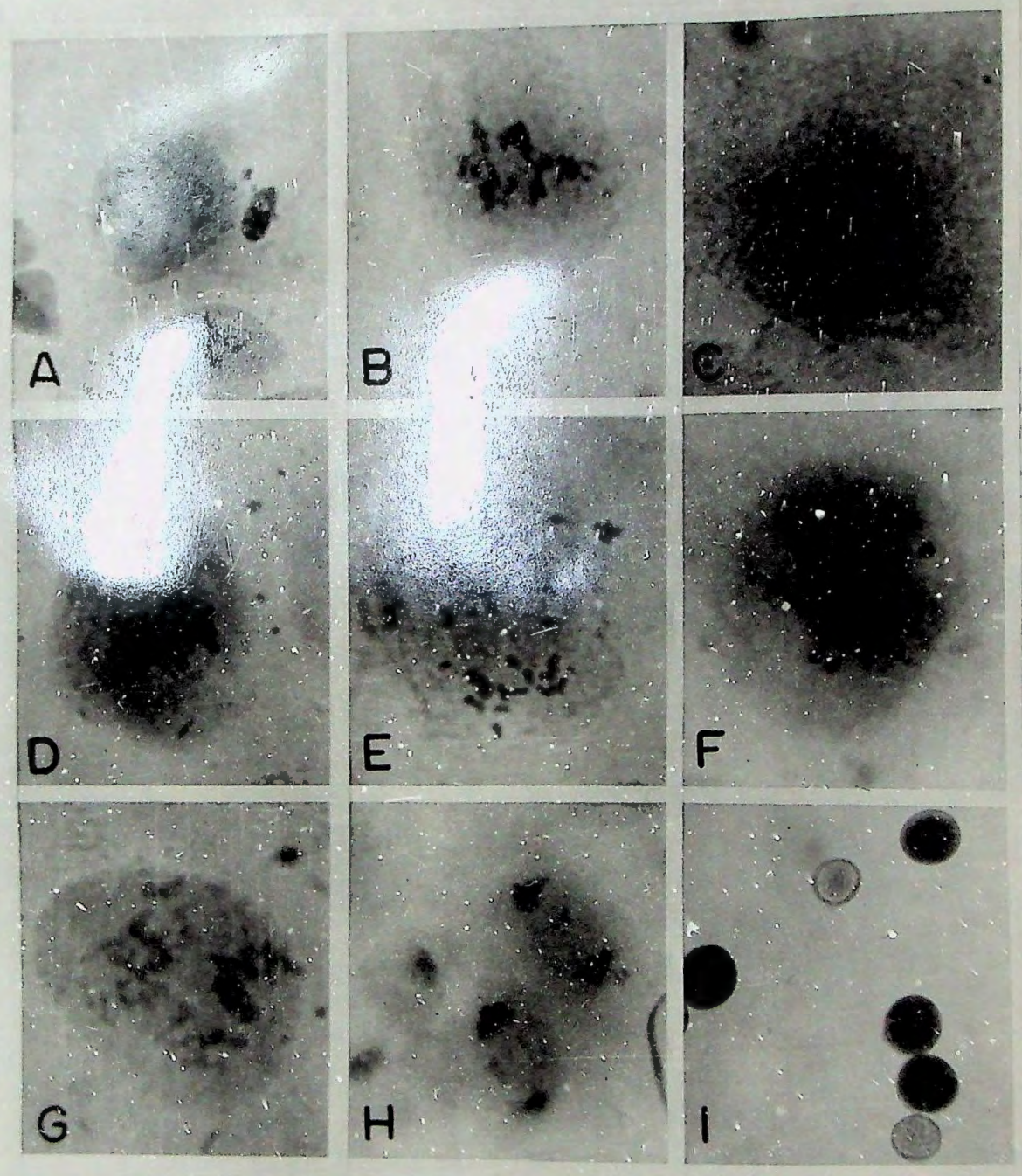


Table 8. Percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat induced by gamma rays (Expt. 1).

	Radiation dose (Kr)							
	0	5	10	15	20	25	30	LSD 5%
				Sonalika				
Percentage of dividing PMCs	29.3	27.2	28	28.1	29.4	29.4	29.4	0.64
Percentage of abnormal PMCs	3.3	7.4	8.1	9.7	9.4	11.0	12.0	1.37
Percentage of pollen sterility	9.0	11.4	12.0	12.3	14.0	14.0	15.0	1.13
Pollen grain volume ($mm^3 \times 10^{-4}$)	1.1	1.5	1.8	2.0	2.3	2.4	2.6	0.20
				Cocoit				
Percentage of dividing PMCs	31.0	29.3	28.0	29.4	30.0	29.2	29.3	0.36
Percentage of abnormal PMCs	4.0	5.0	6.0	7.0	8.0	8.2	9.4	0.62
Percentage of pollen sterility	9.4	10.4	11.2	13.0	13.3	14.0	15.0	0.96
Pollen grain volume ($mm^3 \times 10^{-4}$)	1.2	1.5	1.7	2.0	2.3	2.4	2.7	0.15

Table 9. Effect of gamma rays on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat (Expt. 3).

	Radiation dose (Kr)							
	0	5	10	15	20	25	30	LSD 5%
				Sonalika				
Percentage of dividing PMC	28.7	26.8	25.6	24.9	23.8	22.9	21.9	1.65
Percentage of abnormal PMC	3.8	17.5	17.6	17.9	17.8	18.4	18.7	2.12
Percentage of pollen sterility	8.6	18.3	18.6	19.0	19.4	19.7	20.0	1.98
Pollen grain volume ($mm^3 \times 10^{-4}$)	1.5	4.0	4.3	5.0	5.3	5.6	5.9	1.22
				Cocoit				
Percentage of dividing PMC	30.0	27.6	27.9	27.5	27.2	26.6	25.9	2.45
Percentage of abnormal PMC	3.7	17.3	17.6	18.4	18.6	18.0	18.5	4.31
Percentage of pollen sterility	8.9	18.3	18.6	18.7	19.0	19.5	19.7	2.24
Pollen grain volume ($mm^3 \times 10^{-4}$)	1.4	5.0	5.5	6.0	6.5	6.9	7.4	1.08

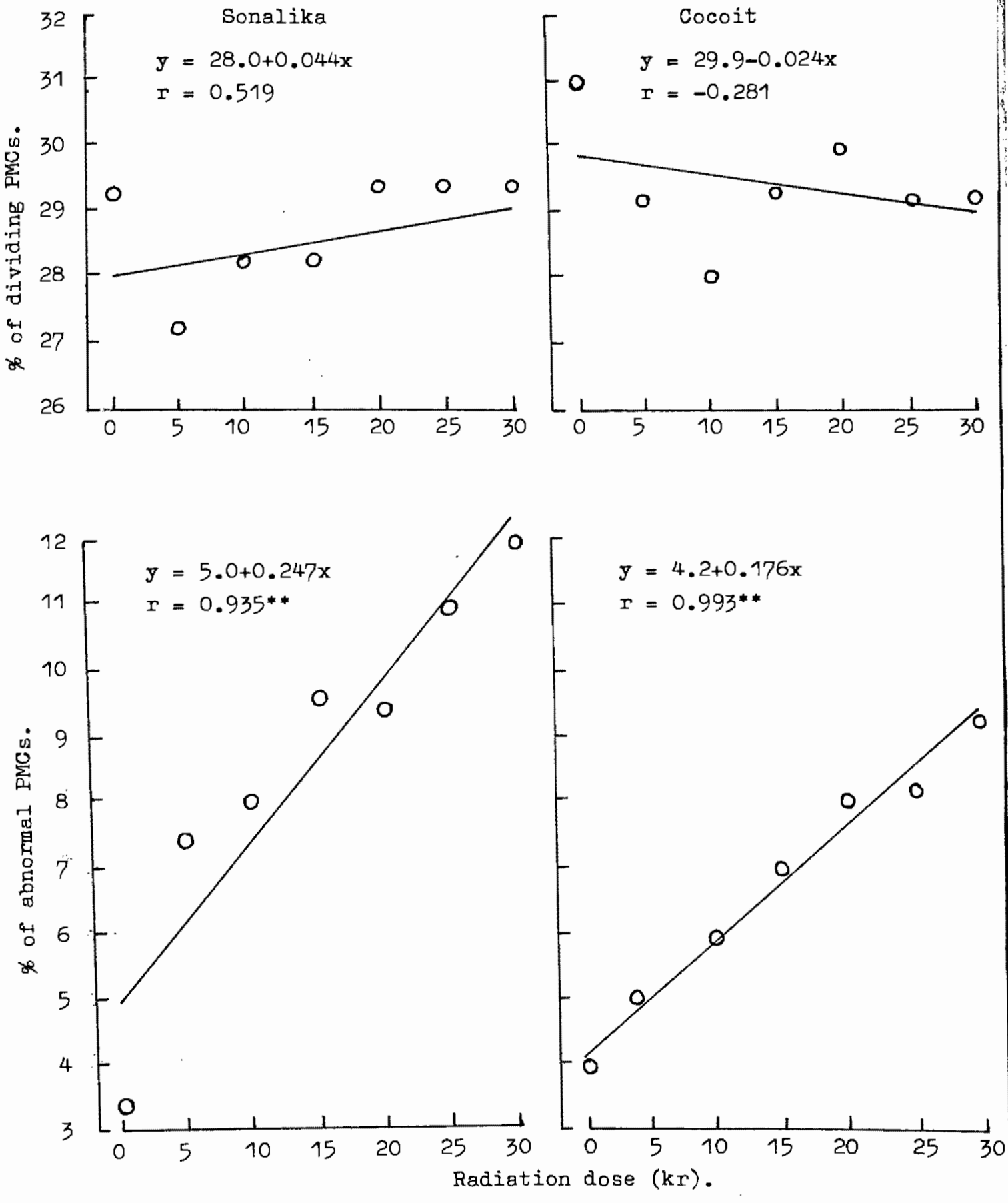


Figure 3. Relationship between gamma rays doses and % of dividing and abnormal PMCs of Sonalika and Cocoit (Expt.1).

abnormal PMCs from 5 to 30 kr was less marked in Sonalika and higher percentage of abnormal PMCs than that of Cocoit in expt.1, but more or less similar in expt.3. Correlation coefficient between gamma rays dose and percentage of abnormal PMCs was positive and significant (Figure 3). The rate of the increase of abnormal PMCs was higher in Sonalika (0.247/kr) than Cocoit (0.176/kr) (Figure 3).

Percentage of pollen sterility in both the hexaploid and tetraploid wheat increased with the increase of doses of gamma rays in both the experiments. This increase was much pronounced from 0 to 5 kr gamma rays in expt.3. Between the two varieties, percentages of sterile pollens were more or less similar.

The relationship between gamma rays dose and percentage of pollen sterility in Sonalika and Cocoit (expt.1) is shown in Figure 4. In both the varieties percentages of pollen sterility increased with the increase of radiation doses. The correlation study revealed that the positive correlation between the gamma rays dose and percentage of pollen sterility was significant for both the varieties. The rate of increase of the percentage of pollen sterility was higher in Cocoit (Figure 4).

Pollen grain volume in both the wheat varieties increased with the increase of doses of gamma rays (expt. 1 and 3). This increase was much pronounced from 0 to 5 kr gamma rays in expt.3.

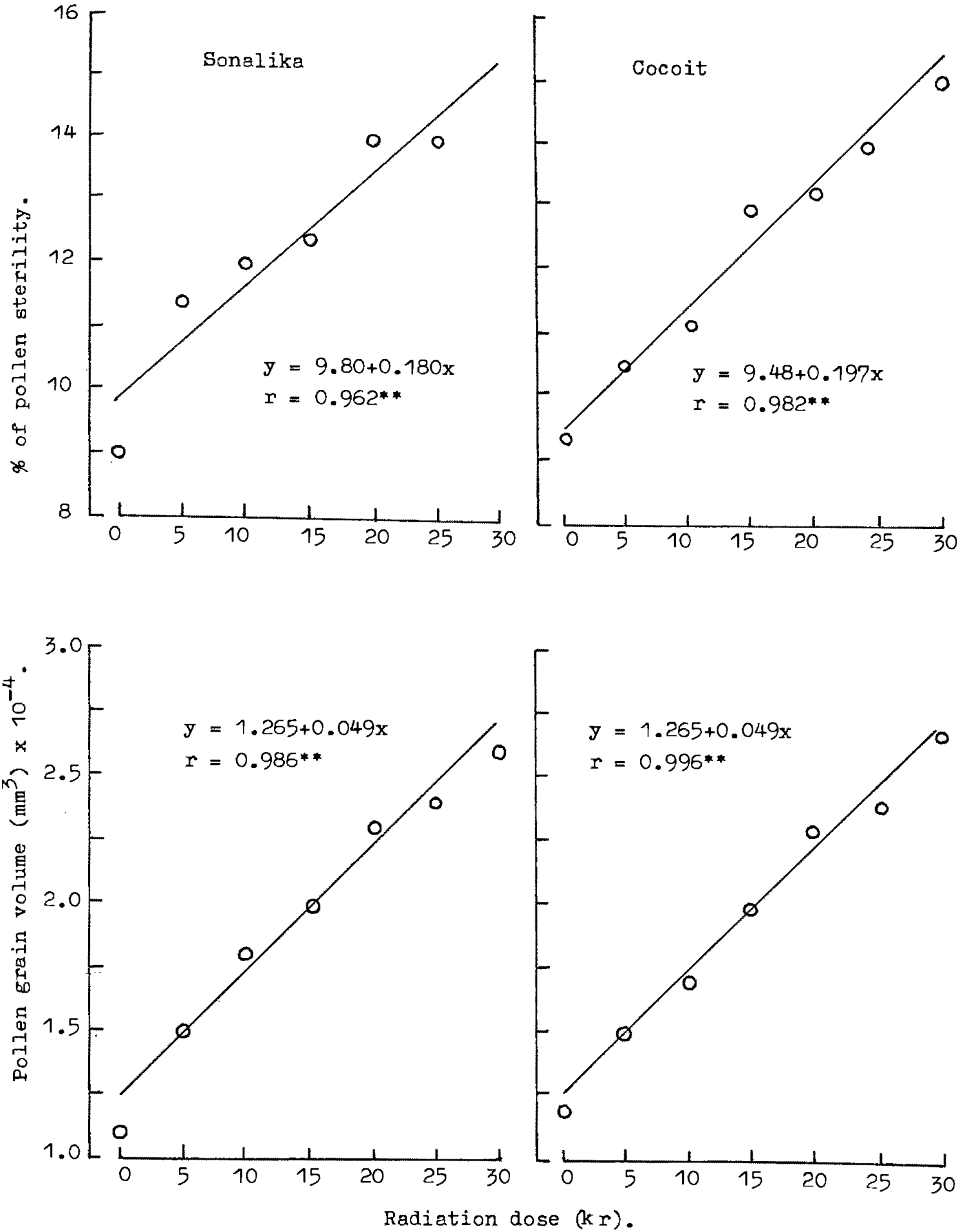


Figure 4. Relationship between gamma rays doses and % of pollen sterility and pollen grain volume of Sonalika and Cocoit (Expt.1).

Among the different doses of gamma rays, the increase of pollen grain volume was less marked. Between the two varieties Cocoit had greater pollen grain volume (expt.3).

The relationship between gamma rays doses and pollen grain volume of Sonalika and Cocoit (expt.1) is shown in Figure 4. In both the varieties pollen grain volume increased with the increase in dose. Correlation coefficient between gamma rays dose and pollen grain volume was positive and significant (Figure 4). The rate of increase of pollen grain volume was same in both the varieties (Figure 4).

Percentages of dividing PMCs , abnormal PMCs and different abnormalities in Sonalika and Cocoit induced by gamma rays (expt.1) are given in Appendix-5. The different abnormalities were fragments, lagging chromosomes and bridges. Percentages of these aberrations were recorded from 1st metaphase to 2nd telophase.

The highest percentage of abnormal cells was in 30 kr and it was 12.00%. Here the abnormality percentage was more at 1st metaphase, then anaphase and then at telophase. In case of metaphase I the abnormal percentage also gradually increased with the increase of radiation doses. In case of 1st metaphase, the highest percentage of abnormal cells for lagging chromosome was 4.40% in 30 kr. The percentage was lowest in control (1.10%). The abnormality percentage was also gradually increased at anaphase I. The highest value was 2.70% in 25 kr for bridge and the

lowest value was 0.02% in control. In case of telophase I, the highest percentage was 0.75 in 30 kr for fragment and the lowest was 0.03% in 10 kr for fragment and bridge. There was no abnormality at metaphase, anaphase and telophase of second dividion.

In case of Cocoit, the abnormality percentage was also gradually increased with the increase of radiation doses. The percentage was more at metaphase I. Here, the highest percentage was 3.60 in 25 kr for fragment and the lowest was 0.10% in 25 kr for lagging chromosome. In case of first anaphase, the highest abnormal percentage was 2.30 in 30 kr for bridge and the lowest was 0.04% in 15 kr for laggard. In case of telophase I, the percentage of abnormal cells heavily fluctuated. The highest value was 1.30% in 20 kr for fragment and the lowest was 0.03% in 10 and 25 kr for lagging chromosome. Here also, no abnormal cells were observed from metaphase II to telophase II.

Effect Of Temperature (^{o}C) And Duration (hrs) Of Temperature :

Percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat induced by temperature (^{o}C) and duration (hrs) of temperature are given in Table 10 (expt.2) and Table 12 (expt.3). The effect of temperature and duration of temperature on all the four characters were significant for both the varieties. But percentages of dividing PMCs in both the varieties were not significant and percentage of

Table 10. Percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat induced by temperature and duration of temperature (Expt. 2).

	Temperature (°C)				Duration (hour)			
	25	30	35	LSD 5%	72	144	288	LSD 5%
				Sonalika				
Percentage of dividing PMC	27.4	24.6	22.5	0.45	27.9	25.1	21.5	0.37
Percentage of abnormal PMC	10.4	14.5	18.2	0.52	11.7	14.4	17.1	0.72
Percentage of pollen sterility	13.7	16.0	21.1	0.60	12.8	17.1	20.9	0.40
Pollen grain volume ($mm^3 \times 10^{-4}$)	1.3	1.8	2.2	0.079	1.3	1.8	2.3	0.080
				Cocoit				
Percentage of dividing PMC	27.8	26.9	25.7	0.47	28.5	26.9	25.0	0.52
Percentage of abnormal PMC	12.2	14.0	15.2	0.76	12.2	13.6	15.7	0.57
Percentage of pollen sterility	13.7	15.5	17.9	0.45	13.1	15.9	18.1	0.37
Pollen grain volume ($mm^3 \times 10^{-4}$)	2.3	3.8	5.2	0.27	3.1	3.8	4.5	0.18

Table 11. Effect of temperature and duration of temperature on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume of hexaploid and tetraploid wheat (Expt. 2).

Duration (hour)	Temperature (°C)	Percentage of dividing PMC	Percentage of abnormal PMC	Percentage of pollen sterility	Pollen grain volume (mm^3 $x10^{-4}$)
			Sonalika		
	25	30.1	8.7	9.8	0.90
72	30	28.0	11.4	12.4	1.27
	35	25.7	14.9	16.3	1.63
	25	28.0	10.5	14.1	1.37
144	30	24.3	15.1	15.8	1.73
	35	22.9	17.7	21.3	2.27
	25	24.1	12.0	17.3	1.67
288	30	21.5	17.1	19.7	2.27
	35	18.9	22.1	25.7	2.83
LSD 5%		0.64	1.25	0.69	0.139
			Cocoit		
	25	29.9	10.7	9.9	1.53
72	30	28.4	11.9	13.2	3.07
	35	27.1	13.9	16.1	4.57
	25	27.3	12.4	14.4	2.27
144	30	27.3	13.7	15.3	3.87
	35	26.1	14.8	18.0	5.33
	25	26.2	13.6	16.8	3.067
288	30	25.0	16.5	17.9	4.50
	35	23.9	16.9	19.5	5.83
LSD 5%		0.91	0.99	0.64	0.31

Table 12. Percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat induced by temperature and duration of temperature (Expt. 3).

	Temperature (°C)				Duration (hour)			
	25	30	35	LSD 5%	72	144	288	LSD 5%
				Sonalika				
Percentage of dividing PMC	25.6	26.2	24.3	NS	24.9	22.5	27.4	1.85
Percentage of abnormal PMC	14.7	16.1	17.1	1.44	13.2	16.4	18.2	2.42
Percentage of pollen sterility	16.5	17.5	19.0	1.85	16.9	17.3	18.8	NS
Pollen grain volume ($mm^3 \times 10^{-4}$)	2.8	4.6	6.1	1.75	4.3	4.6	4.5	NS
				Cocoit				
Percentage of dividing PMC	27.5	27.9	27.1	NS	26.6	27.8	28.2	NS
Percentage of abnormal PMC	14.9	16.4	16.9	1.80	11.9	16.9	19.3	2.45
Percentage of pollen sterility	16.4	17.0	19.2	2.10	16.5	17.1	19.0	1.45
Pollen grain volume ($mm^3 \times 10^{-4}$)	3.3	5.6	7.6	1.72	6.2	4.8	5.5	1.75

pollen sterility and pollen grain volume of Sonalika was not significant in expt.3. Percentages of abnormal PMCs, percentages of pollen sterility and pollen grain volume increased and percentages of dividing PMCs decreased with the increase of temperature and duration of temperature. Percentage of dividing PMCs in Sonalika decreased up to 144 hours and again increased (Table 12) at 288 hours and in Cocoit increased with the increase of temperature and duration of temperature.

Interacting effects of temperature and duration of temperature on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in hexaploid and tetraploid wheat are presented in Table 11. In both Sonalika and Cocoit, the highest percentages of abnormal PMCs, pollen sterility and pollen grain volume were found at 35°C and 288 hours duration of temperature and the lowest values were observed at 25°C and 72 hours. In case of the percentage of dividing PMCs the highest value was observed at 25°C and 72 hours duration and the lowest value was observed at 35°C and 288 hours duration of temperature.

Percentages of dividing PMCs , abnormal PMCs and different abnormalities at different stages of Sonalika and Cocoit treated by temperature and duration of temperature (expt.2) are given in Appendix-6.

In case of metaphase I the percentage of abnormal cells was found to increase with the increase of the duration of temperature

treatment. The highest abnormal value was 7.06% at 35°C and 288 hours duration for fragment and the lowest value was 0.88% at 25°C and 144 hours duration for lagging chromosome. At anaphase I, the highest abnormal percentage was 4.06% at 35°C and 288 hours duration for bridge and the lowest value was 0.30% at 25°C and 72 hours duration for fragment. In case of telophase I the highest percentage was 2.63% at 35°C and 288 hours duration for bridge and the lowest percentage was 0.02 at 25°C temperature and 144 hours duration. There was no abnormal cells in the second division, except at telophase II for laggard at 35°C and 288 hours duration.

In case of Cocoit, at metaphase I the highest abnormal percentage was 3.96 at 35°C and 288 hours duration for lagging chromosome and the lowest was 1.43% at 25°C temperature and 72 hours duration. At anaphase I, the highest percentage was 3.82 at 30°C and 288 hours duration for bridge and the lowest value was 0.27% at 25°C temperature and 72 hours duration for fragment. At first telophase, the highest abnormal percentage was 3.37 at 30°C and 144 hours duration for bridge and the lowest value was 0.24% at 25°C temperature and 72 hours duration for fragment. There was no abnormal PMCs in the second division except at anaphase II.

Effect Of Gamma Rays, Temperature (°C) And Duration (hrs) Of Temperature :

The interacting effects of gamma rays, temperature (°C) and duration (hrs) of temperature on percentage of dividing PMCs,

abnormal PMCs, pollen sterility and pollen grain volume in Sonalika and Cocoit are given in Table 13 and 14, respectively.

The results indicated that percentage of abnormal PMCs in both the varieties increased with the increase of radiation dose, temperature (^{o}C) and duration (hrs) of temperature. The highest percentage of abnormal PMCs was observed at 30 kr radiation, 35^{o}C temperature and 288 hours of treatment duration. The result also indicated that the interactions between radiation dose and temperature (^{o}C) and between radiation dose and duration (hrs) of temperature were non-significant. Similar results were observed for percentage of pollen sterility and pollen grain volume. But in case of the percentage of dividing PMCs variability was low. With some fluctuations percentage of dividing PMCs decreased with the increase of radiation dose. With a few exceptions, the percentage of dividing PMCs decreased with the increase of both the temperature at the same dose of radiation.

Percentage of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Sonalika induced by gamma rays, temperature (^{o}C) and duration (hrs) of temperature (expt.3) are presented in Appendix-7.

In case of 72 hours duration, the highest percentage of abnormal value was 17.80 at 35^{o}C for 30 kr and the lowest value

Table 13. Interacting effect of gamma rays, temperature and duration of temperature on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen volume in Sonalika (Expt. 3).

Temperature (°C)	Radiation dose (kr)	Percentage of dividing PMC	Percentage of abnormal PMC	Percentage of pollen sterility	Pollen grain volume ($mm^3 \times 10^{-4}$)
			72 hours		
	0	29.5	3.7	8.8	1.28
	5	28.7	11.3	17.0	1.80
	10	26.3	11.2	17.5	2.26
25	15	25.8	11.6	16.4	2.66
	20	24.3	12.6	17.4	2.98
	25	23.1	13.6	17.6	3.34
	30	22.1	13.4	17.7	3.76
	0	29.1	4.0	9.0	1.28
	5	27.4	14.5	17.5	3.82
	10	25.8	14.3	18.2	4.26
30	15	24.7	14.3	18.6	4.7
	20	23.1	13.2	17.8	5.12
	25	22.3	16.7	18.5	5.48
	30	21.1	16.3	19.3	5.88
	0	28.7	3.8	8.2	1.26
	5	25.7	15.8	18.8	5.52
	10	25.2	16.5	18.8	6.24
35	15	24.9	16.8	19.5	6.72
	20	22.8	17.5	19.4	7.12
	25	21.4	17.4	19.9	7.56
	30	20.1	17.8	19.5	7.94

Contd. ....

Table 13. Continued.

144 hours

	0	29.2	3.8	8.7	1.24
	5	27.4	17.6	17.3	2.1
	10	25.3	16.7	16.5	2.48
25	15	24.7	18.1	17.7	2.92
	20	22.0	18.3	18.3	3.32
	25	20.3	17.4	18.3	3.78
	30	18.6	18.7	17.9	4.2
	0	27.7	3.5	8.4	1.24
	5	25.9	17.9	17.9	4.18
	10	24.4	18.5	18.4	4.56
30	15	22.2	19.2	18.6	5.00
	20	20.4	19.0	18.5	5.56
	25	19.7	18.8	18.6	5.84
	30	17.3	19.2	19.2	6.30
	0	26.5	3.9	8.6	1.26
	5	24.1	19.2	18.6	6.16
	10	21.9	19.5	19.2	6.58
35	15	20.4	18.4	20.3	7.00
	20	20.1	19.3	20.6	7.44
	25	18.5	18.9	20.7	7.96
	30	16.8	19.3	21.3	8.44

Contd. ....

Table 13. Continued.

288 hours

	0	28.9	3.5	8.7	1.46
	5	27.3	19.4	17.7	1.64
	10	27.1	19.6	17.9	1.86
25	15	27.4	19.7	18.4	2.24
	20	26.9	18.2	19.0	4.12
	25	27	19.7	18.9	6.60
	30	26.7	19.8	19.2	2.68
	0	28.9	4.1	9.0	2.32
	5	27.4	21.3	18.6	7.14
	10	26.9	20.3	19.4	3.14
30	15	26.6	20.5	19.7	5.02
	20	27.0	20.6	20.3	7.48
	25	27.0	21.3	21.0	3.44
	30	26.8	20.8	21.0	5.28
	0	29.4	3.8	8.4	2.10
	5	27.6	20.5	21.3	3.92
	10	27.4	21.4	21.4	5.76
35	15	27.4	22.1	21.9	8.70
	20	27.2	21.3	22.9	4.76
	25	27.0	22.1	24.0	6.78
	30	27.2	22.6	25.1	8.98

Table 14. Interacting effect of gamma rays, temperature and duration of temperature on percentages of dividing PMCs, abnormal PMCs, pollen sterility and pollen grain volume in Cocoit.

Temperature (°C)	Radiation dose(kr)	Percentage of dividing PMCs	Percentage of abnormal PMCs	Percentage of pollen sterility	Pollen grain volume ($mm^3 \times 10^{-4}$)
			72 hours		
	0	30.5	3.6	9.2	1.34
	5	30.0	11.2	16.5	2.02
	10	28.1	11.2	16.8	2.66
25	15	27.3	11.9	16.9	3.48
	20	26.4	12.2	15.4	4.20
	25	25.0	11.4	16.8	5.00
	30	23.4	13.1	16.8	5.40
	0	30.1	3.6	9.4	1.32
	5	29.7	13.2	17.3	5.76
	10	27.5	12.1	17.3	6.24
30	15	27.0	13.2	17.5	7.10
	20	26.1	14.4	17.6	7.50
	25	25.6	13.2	17.4	7.90
	30	22.7	14.1	18.2	8.60
	0	30.0	3.8	8.9	1.40
	5	27.9	15	18.3	9.20
	10	26.3	14.1	18.6	9.68
35	15	25.6	14.5	18.7	10.04
	20	24.3	15.9	19.8	10.50
	25	23.4	14.4	19.5	10.60
	30	21.0	14.4	19.0	11.10

Contd. .....

Table 14. Continued.

144 hours

	0	29.9	3.8	8.8	1.40
	5	25.5	15.2	17.5	2.20
	10	27.1	16.8	17.6	2.60
25	15	26.4	16.6	17.4	3.04
	20	26.9	17.3	18.2	3.42
	25	26.5	17.2	17.7	3.82
	30	27.0	18.1	17.7	4.16
	0	30.1	3.7	8.4	1.48
	5	26.6	18.4	17.5	4.48
	10	27.5	19.0	17.6	4.88
30	15	27.3	20.0	17.6	5.24
	20	26.5	19.3	17.6	5.66
	25	30.2	20.5	18.2	6.06
	30	29.3	19.7	18.3	6.42
	0	30.3	4.0	9.0	1.36
	5	27.8	19.6	18.5	6.54
	10	26.7	19.4	19.1	7.02
35	15	28.5	22.2	19.7	7.40
	20	28.4	21.5	20.4	7.82
	25	26.4	19.6	21.3	8.20
	30	28.7	22.4	21.9	8.64

Contd. .....

Table 14. Continued.

288 hours

	0	29.9	3.7	8.9	1.44
	5	26.6	19.5	18.4	2.72
	10	27.4	20.4	18.5	3.36
25	15	31.6	22.2	18.3	3.82
	20	29.1	22.0	18.5	4.38
	25	27.5	22.6	19.3	4.74
	30	26.0	21.9	19.6	5.10
	0	29.7	3.6	8.6	1.48
	5	27.2	22.8	19.1	4.86
	10	31.2	24.2	19.3	5.38
30	15	26.0	22.8	19.3	5.90
	20	29.5	24.0	19.5	6.40
	25	27.3	21.1	20.5	6.88
	30	27.8	21.0	20.3	7.38
	0	29.8	3.6	9.0	7.40
	5	26.8	21.1	21.6	7.10
	10	28.9	21.2	23.0	7.60
35	15	27.4	22.6	22.9	8.20
	20	27.7	21.2	24.4	8.50
	25	27.3	22.0	24.6	8.98
	30	26.8	21.9	25.2	9.52

was 3.70 at 25°C for control. At metaphase I, the abnormal values were gradually increased with the increase of radiation dose in all the temperatures (°C) and duration (hrs) of temperature. The highest value was 6.71% at 35°C in 20 kr for fragment and the lowest value was 0.10% at 25°C in control for lagging chromosome. At anaphase I, the highest abnormal value was 4.96% in 25 kr at 35°C for bridge and the lowest value was 0.07% at 25°C in control for lagging chromosome. For telophase I, the percentages of abnormal cells fluctuated. The highest abnormal percentage was 3.97 at 30°C in 25 kr for bridge and the lowest percentage was 0.03 at 30°C in control for fragment. There was no abnormal PMCs in second meiotic division.

In case of 144 hours duration, at metaphase I, the highest abnormal value was 5.01% at 35°C in 30 kr for fragment and the lowest value was 0.54% at 25°C in control for lagging chromosome. There was no abnormal PMCs at metaphase II.

In case of anaphase I also the abnormality percentages were gradually increased. The highest abnormal percentage was 3.07 at 30°C in 30 kr for bridge and the lowest value was 0.10% at 25°C in control for lagging chromosome. There was abnormality percentage at anaphase II at 30°C in 20 kr for bridge.

At telophase I, the percentages of abnormal cells were more or less increased with the increase of radiation dose at all the temperatures (°C) and duration (hrs) of temperature. The highest

value was 3.99 at 30°C in 15 kr for bridge and the lowest value was 0.04 at 35°C in control for fragment. At telophase II the abnormal cells were 0.57% at 30°C and 15 kr and 0.32% at 35°C and in 15 kr for bridge.

In case of 288 hours duration, at metaphase I the abnormal percentages were gradually increased. The highest percentage was 6.08 at 35°C in 30 kr for fragment and the lowest value was 0.60% at 25°C in control for lagging chromosome. There was no abnormal PMCs at metaphase II.

At anaphase I, the abnormal values were gradually increased but not systematically. The highest abnormal value was 3.98% at 30°C and in 15 kr for bridge ; the lowest abnormal value was 0.14% at 30°C in control for bridge. There was abnormal PMCs at anaphase II. It was 0.25% at 25°C in 25 kr and 0.23% at 30°C in 25 kr for lagging chromosome and 0.42% at 35°C in 25 kr for bridge.

At telophase I, abnormality percentage was gradually increased in case of bridge but fragment and laggard did not gradually increase. The highest abnormal percentage was 4.94 at 35°C in 30 kr for bridge and the lowest value was 0.01% at 25°C in control for fragment. There was no abnormality at telophase II.

Percentages of dividing PMCs, abnormal PMCs and different abnormalities of Cocoit induced by gamma rays, temperature (°C) and duration (hrs) of temperature (expt.3) are given in Appendix-8.

In case of 72 hours duration, at metaphase I, the abnormal cells were gradually increased with the increase of radiation doses and temperature. The abnormal cell was highest in 30 kr at 35°C for fragment and the lowest value was 0.70% in control at 25°C for lagging chromosome. At first anaphase, the highest value was 2.84% at 35°C in 15 kr for fragment and the lowest percentage was 0.32% at 25°C in control and 20 kr for bridge and lagging chromosome. At telophase I, the highest abnormality percentage was 3.29% at 35°C in 20 kr for bridge and the lowest value was 0.50% at 30 and 35°C in control for fragment and lagging chromosome. There were no abnormalities at metaphase, anaphase and telophase of second meiotic division.

In case of 144 hours treatment duration, similar results were obtained. In second meiotic division, the highest abnormality percentage was found at 35°C and 30 kr and the lowest value was in control. There was no abnormal cells at metaphase II, anaphase II and Telophase II except at 30°C and 30 kr for bridge at telophase II.

In case of 288 hours duration, the highest percentage of abnormal cells was found at 35°C in 25 kr for fragment and the lowest value was found in control at the same temperature for fragment at metaphase I. At anaphase, the highest value was 3.97% in 5 kr at 35°C and the lowest value was 0.49% in control for fragment. The percentages of abnormal cells were 0.56% , 0.94% and

0.63% for bridges at anaphase II at 25, 30 and 35°C temperature and 15, 20 and 15 kr. For first telophase the abnormality percentages were not gradually increased. The highest abnormal percentage was 3.98% at 30°C in 25 kr for fragment and the lowest abnormal percentage was 0.42% at 30°C in 30 kr for fragment. The abnormality percentages were 0.63% and 0/34% at telophase II for bridge in 30 and 15 kr and for 25 and 35°C, respectively.

Chromosome Association And Chiasma Frequency :

Effect Of Gamma Rays :

Chromosome association and chiasma frequency in two varieties of wheat were studied from the same preparation of pollen mother cells (PMCs) made for meiotic study. The pollen mother cells containing univalents, bivalents and quadrivalents were observed at diakinesis/prometaphase 1. The data of chromosome association and chiasma frequency of Sonalika induced by gamma rays (expt.1) are given in Table 15. Univalent was absent in the control. In 10 and 20 kr, the mean values for univalent were 1.18 and 1.14, respectively and were increased slowely for the other radiation doses. Of the two bivalents, ring was of more frequent than rod. In control, 5 kr and 10 kr mean ring bivalents were 16.02, 13.46 and 14.86 with a range of 12-21, 10-21 and 11-21, respectively. The highest mean rod bivalent was 9.12 for 25 kr with a range of 2-10 and the lowest mean rod bivalent was 4.96

Table 15. Chromosome association and chiasma frequency at diakinesis/metaphase 1 of Sonalika induced by gamma rays (Expt. 1).

Configaration and X-ma distribution		Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	0-3	2-8	1-4	1-8	1-4	1-4
	Mean	0	0.42	1.18	0.84	1.14	0.86	0.88
Bivalent Ring	Range	12-21	10-21	11-21	10-18	10-17	10-16	10-21
	Mean	16.02	13.46	14.86	12.64	12.34	12.22	12.98
Bivalent Rod	Range	5-9	2-10	4-9	2-9	4-9	2-10	2-10
	Mean	5.04	7.36	4.96	6.98	5.26	9.12	6.7
Trivalent	Range	0	1-3	2-3	1-5	1-5	3-5	1-3
	Mean	0	0.38	0.34	0.7	0.7	0.68	0.5
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	36.4 -42	38.8 -41.4	35.6 -41.2	36.2 -40.5	35 -40.5	36.8 -40.2	35 -40.6
	Mean	40.72 ±2.44	40.28 ±1.06	38.96 ±2.09	38.76 ±1.1	37.94 ±2.0	38.04 ±1.44	38.32 ±2.12
X-ma/II	Range	1.73-2	1.85 -1.97	2.54 -2.94	1.72 -1.94	1.67 -1.93	1.75 -1.91	1.67 -1.93
	Mean	1.94 ±0.12	1.92 ±0.05	2.78 ±0.15	1.84 ±0.10	1.81 ±0.10	1.81 ±0.07	1.83 ±0.10

with a range of 4–9 for 10 kr. Trivalent was absent in the control. Here the mean values were gradually increased but fluctuated in the different radiation doses. The mean was highest in both 15 and 20 kr (0.7). Quadrivalent was not observed in the control as well as in any of the radiation doses. Mean chiasma frequency per PMC varied little among the different treatments. However, chiasma frequency induced by all the radiation doses was less than the control. Mean chiasma frequency per bivalent was highest in 10 kr (2.78 $\pm$ 0.15) with a range of 2.54–2.94 and the lowest mean was 0.05 in 5 kr with a range of 1.85–1.97. With the exception of 10 kr, all the remaining radiation doses showed lower chiasma frequency per bivalent.

Chromosome association and chiasma frequency at diakinesis/prometaphase 1 of Cocoit induced by gamma rays (expt.1) are presented in Table 16. Univalent was absent in the control to 10 kr and then gradually increased. The highest mean value was 0.08 with a range of 0–1 for 25 and 30 kr. Of the two bivalents, ring was more than the rod. Mean ring bivalent was highest in the control with a range of 10–14 and the variation among the radiation doses was less. On the other hand, the lowest rod bivalent was observed in the control and there was conspicuous variation in the radiation doses. Univalent was absent in the control, 5 and 10 kr, and trivalent, with slight fluctuation, increased with the increase of radiation dose. Quadrivalents were absent in all the treatments.

Table 16. Chromosome association and chiasma frequency at diakinesis/metaphase I of Cocoit induced by gamma rays (Expt. I).

Configaration and X-ma distribution		Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	0	0	0-1	0-1	0-1	0-1
	Mean	0	0	0	0.06	0.04	0.08	0.08
Bivalent Ring	Range	10-14	8-14	7-14	8-14	8-14	8-14	8-14
	Mean	12.92	11.64	11.24	11.72	11.80	11.26	11.82
Bivalent Rod	Range	2-4	1-5	2-7	2-6	1-6	1-6	1-6
	Mean	1.08	1.88	2.34	2.20	2.32	1.9	1.54
Trivalent	Range	0	0	0	0-1	0-1	0-1	0-1
	Mean	0	0	0	0.04	0.04	0.08	0.06
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	28-32	28-28	28-28	27.6-28	26.8-28.0	26.8-28	27-28
	Mean	28.8±1.79	28.0±0	18.0±0	23.87 ±8.86	27.60± 0.49	27.60± 0.49	27.6± 0.37
X-ma/II	Range	2-2.29	2-2	2-2	1.97-2.0	1.91-2	1.91-2	1.93-2
	Mean	2.06± 0.13	2.0±0	2.0±0	1.99± 0.016	1.97± 0.037	1.98± 0.037	1.98± 0.029

Mean chiasma frequency per PMC was highest in the control (28.8 ± 1.79) with a range of 28-32 and lowest in 15 kr (23.84 ± 8.86) with a range of 27.6-28. For the remaining radiation doses the variation was less. Although the highest mean chiasma frequency per bivalent was in the control, the effect of gamma radiation was almost absent.

Between the two varieties, univalent, bivalent and trivalent were more in Sonalika than in Cocoit. Chiasma frequency per PMC was also high in Sonalika, but chiasma frequency per bivalent was similar in the two varieties.

Effect Of Temperature (^{o}C) And Duration Of Temperature Treatment :

Chromosome association and chiasma frequency at diakinesis/prometaphase 1 of Sonalika induced by temperature and duration of temperature (expt.2) are given in Table 17.

In case of univalent for 72 hours duration mean was increased with a increase of temperature. At 35^{o}C mean was highest (1.13) with a range of 1-8. In 144 hours and 288 hours treatment means were highest at 25^{o}C (1.1, 1.14) with a range of 1-4 and 2-8.

In case of bivalents, rings were more than rods. Ring and rod were found to increase gradually in 72 hours duration. In 144 hours duration, mean was highest at 35^{o}C for both the ring and

Table 17. Chromosome association and chiasma frequency at diakinesis/metaphase 1 of Sonalika induced by temperature and duration of temperature (Expt. 2).

Configaration and X-ma distribution		Duration (hour)								
		72			144			288		
		Temperature(°C)								
		25	30	35	25	30	35	25	30	35
Univa-lent	Range	1-3	1-4	1-8	1-4	3-8	3-8	2-8	1-8	1-8
	Mean	0.3	0.89	1.13	1.1	0.76	0.89	1.14	0.99	0.99
Biva-Ring lent	Range	10-21	10-21	11-21	10-21	9-21	9-21	11-21	10-19	10-19
	Mean	13.72	13.79	14.23	13.93	13.48	14.61	14.14	13.98	13.98
Rod	Range	4-10	2-10	4-9	3-9	3-12	4-9	3-9	2-10	2-10
	Mean	6.64	7.68	8.71	7.64	6.94	8.11	6.69	6.78	6.78
Triva-lent	Range	1-3	1-5	1-5	1-3	0-3	1-5	2-3	2-3	2-3
	Mean	0.12	1.61	0.8	0.13	0.12	0.63	0.48	0.54	0.54
Quadri-valent	Range	0	0	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0	0	0
X-ma/PMC	Range	38.2-47.9	38.9-45.3	36.9-41.2	37.9-40.9	38.2-40.9	36.7-40.8	37.1-41.1	36.8-42.1	36.8-42.1
	Mean	41.64±4.06	39.78±3.98	40.69±4.01	40.61±3.08	40.5±1.68	38.71±1.2	39.07±3.98	39.69±1.31	39.69±1.31
X-ma/II	Range	1.82-2.28	1.85-2.16	1.76-1.96	1.80-1.95	1.82-2.04	1.75-1.94	1.77-1.96	1.75-2	1.75-2
	Mean	1.98±0.20	1.83±0.18	1.91±0.19	1.88±0.17	1.93±0.08	1.83±0.11	1.90±0.18	1.82±0.12	1.82±0.12

rod ; but for 288 hours ring was highest at 25°C (14.14) and rod was at 30 and 35°C (6.78) with a range of 11-21 and 2-10.

Trivalent had the highest mean of 1.61 with a range of 1-5 at 30°C in 72 hours and lowest value was observed at 25 and 30°C in 72 hours and 144 hours (1.2) with a range of 1-3 and 0-3. Quadrivalent was absent.

The mean chiasma frequency per PMC varied little among the different treatments. Chiasma frequency was less than the control for all the temperatures (°C) and durations of temperature treatment.

Mean chiasma frequency per bivalent was highest in the control (1.98 ± 0.20) with a range of 1.82-2.28 and the lowest value was 1.82 ± 0.12 in 288 hours at 30 kr and 30°C. All the remaining temperatures (°C) and durations of temperature treatment had lower chiasma frequency per bivalent.

Chromosome association and chiasma frequency in Cocoit induced by temperature (°C) and duration of temperature treatment (expt.2) are presented in Table 18.

In case of univalent, mean value was gradually increased with fluctuations. Mean was highest (0.28) at 30°C in 288 hours with a range of 1-6 and lowest was 0.1 at 25°C in 72 hours with a range of 1-2.

Table 18. Chromosome association and chiasma frequency at diakinesis/metaphase 1 of Cocoit induced by temperature and duration of temperature (Expt. 2).

Configaration and X-ma distribution		Duration (hour)								
		72			144			288		
		Temperature (°C)								
		25	30	35	25	30	35	25	30	35
Univalent	Range	1-2	1-3	1-6	1-6	1-6	1-2	1-6	1-6	1-6
	Mean	0.1	0.16	0.22	0.22	0.24	0.12	0.20	0.28	0.26
Bivalent Ring	Range	9-14	9-14	8-14	10-14	9-14	9-14	8-14	10-14	6-14
	Mean	12.44	12.58	12.06	12.44	12.44	12.06	12.34	12.16	12.12
Bivalent Rod	Range	1-5	1-5	1-6	1-6	1-5	1-5	1-6	1-4	1-4
	Mean	1.46	1.46	1.74	1.24	1.62	1.82	1.74	1.54	1.38
Trivalent	Range	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.08	0.1
Quadrivalent	Range	0	0	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0	0	0
X-ma/PMC	Range	27.5-27.8	27-28	27-28	27.4-28	27.4-28	27.4-28	27.2-29.4	27.2-27.8	26.8-30.6
	Mean	27.64±0.089	27.56±0.38	27.60±0.424	27.68±0.303	27.64±0.36	28.23±0.94	28.24±0.93	27.92±0.73	28.04±1.50
X-ma/II	Range	1.97-1.99	1.93-2	1.93-2	1.96-2	1.94-2	1.96-1.99	1.94-2.1	1.94-1.99	1.91-2.19
	Mean	1.97±0.028	1.97±0.027	1.97±0.029	1.98±0.02	1.97±0.026	1.95±0.072	2.02±0.07	1.11±0.05	2.00±0.11

For ring and rod bivalents mean was decreased in 288 hours an duration with/increase of temperature. For the ring the highest value was 12.58 at 30°C in 72 hours with a range of 9-14. For rod the highest value was 1.82 at 35°C in 144 hours duration with a range of 1-5.

For trivalent mean was more or less same. The highest mean was 0.08 at 30°C in 288 hours. Quadrivalent was absent.

Mean chiasma frequency per PMC and per bivalent varied little among the different temperatures (°C) and durations of temperature treatment. The highest values were 28.24 ± 0.93 and 2.02 ± 0.07 with a range of 27.2 - 29.4 and 1.94-2.1 at 25°C in 288 hours for the mean chiasma frequency per PMC and per bivalent, respectively.

Effect Of Gamma Rays, Temperature (°C) And Duration Of Temperature Treatment :

Chromosome association and chiasma frequency at diakinesis/prometaphase 1 of Sonalika induced by gamma rays, temperature (°C) and duration of temperature treatment (expt.3) are given in Table-19.

Univalent and trivalent were absent in the control. Quadrivalent was also absent in the all the treatments except in 288 hours at 30°C for 5, 10 and 20 kr and at 35°C for 15,25 and 30 kr.

Table 19. Chromosome association and chiasma frequency at diakinesis/metaphase 1 of Sonalika induced by gamma rays, temperature and duration of temperature (Expt. 3).

Configaration and X-ma distribution		Duration (hour) 72 Temperature (°C) 25 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-8	1-6	1-3	2-4	1-6	2-4
	Mean	0	1.30	0.80	0.61	0.60	1.12	0.60
Univalent Ring	Range	12-21	10-21	10-21	11-21	10-21	11-21	10-21
	Mean	16.04	13.14	14.16	13.96	12.80	13.98	13.0
Univalent Rod	Range	5-7	2-10	1-10	2-10	3-10	3-10	3-10
	Mean	5.06	6.28	7.11	6.92	6.82	6.78	7.22
Trivalent	Range	0	1-5	1-6	1-5	1-3	1-5	1-3
	Mean	0	0.62	0.78	0.98	0.42	0.97	0.3
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	36.61-42.04	35.4-39.8	33.5-41.3	35.6-42	26.4-42	37.8-42.1	36.2-41.6
	Mean	40.70± 2.36	37.96± 1.76	39.2± 3.98	38.3± 4.29	37.28± 6.26	39.76± 3.69	38.84± 2.05
X-ma/II	Range	1.74-2	1.69-1.90	1.6-1.97	1.7-2	1.26-2	1.8-2	1.72-1.98
	Mean	1.92± 0.14	1.81± 0.08	1.91± 0.08	1.83± 0.69	1.96± 0.53	1.89± 0.12	1.85± 0.10

Contd. ...

Table 19. Continued.

Configaration and X-ma distribution		Duration (hours) 144 Temperature (°C) 25 Radiation dose (kr) 0	5	10	15	20	25	30
Univalent	Range	0	3-4	1-4	3-4	2-4	3-4	2-4
	Mean	0	0.63	0.66	0.79	0.46	0.62	0.78
Bivalent Ring	Range	12-21	10-21	10-21	11-21	10-21	10-21	10-21
	Mean	16.02	13.46	13.08	13.86	13.60	12.96	12.93
Bivalent Rod	Range	5-9	4-10	2-10	2-11	3-9	4-10	3-9
	Mean	5.07	7.23	6.98	7.13	6.66	6.96	6.71
Trivalent	Range	0	1-3	1-5	1-3	1-3	1-3	1-3
	Mean	0	0.39	0.34	0.41	0.24	0.38	0.28
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	36.6-44	39.2-41.6	39-41.8	37.4-41.8	37.4-41.4	37.4-40.8	37.8-41.6
	Mean	41.7 ± 2.46	40.44± 1.02	40.32± 1.01	41.34± 1.01	39.64± 1.44	39.72± 1.38	39.61± 1.29
X-ma/II	Range	1.76-2.0	1.87-1.98	1.86-1.99	1.78-1.99	1.78-1.95	1.78-1.94	1.8-1.98
	Mean	1.94± 0.12	1.92± 0.05	1.92± 0.05	1.89± 0.05	1.88± 0.06	1.89± 0.06	1.78± 0.07

Contd. .....

Table 19. Continued

Configaration and X-ma distribution		Duration (hours) 288 Temperature (°C) 25 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univa-lent	Range	0	3-4	2-4	2-8	2-4	2-4	3-8
	Mean	0	0.62	0.78	0.84	0.62	0.70	0.71
Biva-lent Ring	Range	12-21	11-21	10-21	9-19	10-21	10-21	11-21
	Mean	17.01	13.44	14.41	13.14	13.46	12.96	13.42
Rod	Range	5-8	3-10	4-10	3-9	4-10	4-10	3-10
	Mean	6.0	6.76	6.98	5.89	6.54	7.62	5.63
Triva-lent	Range	0	1-3	0-3	1-3	1-3	0-3	1-5
	Mean	0	0.26	0.29	0.25	0.44	0.24	0.62
Quadri-valent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	36.4-42	39.4-42.8	37.8-43.4	39.3-41.4	39.2-40.8	39-44.2	37.2-42.1
	Mean	40.74±2.48	40.88±1.33	40.81±3.14	39.78±1.39	40±0.62	40.88±1.97	39.58±1.27
X-ma/II	Range	1.72-2.02	1.88-2.04	1.80-2.07	1.87-1.97	1.87-1.94	1.86-2.10	1.77-2
	Mean	1.92±0.14	1.95±0.06	1.83±0.21	1.76±0.20	1.90±0.03	1.94±0.10	1.68±0.07

Contd. .....

Table 19. Continued.

Configaration and X-ma distribution		Duration (hours) 72 Temperature (°C) 30 Radiation dose (kr) 0	5	10	15	20	25	30
Univa-lent	Range	0	2-8	2-8	3-8	2-3	1-8	2-8
	Mean	0	0.91	0.84	0.68	0.52	1.78	0.88
Ring Biva-lent	Range	12-21	11-21	10-21	10-21	10-21	11-21	10-21
	Mean	17.06	12.98	14.46	13.62	13.76	14.18	13.48
Rod	Range	5-9	3-10	3-9	2-9	2-11	1-10	2-11
	Mean	4.09	4.98	5.68	5.68	6.44	4.14	6.42
Triva-lent	Range	0	1-5	1-3	1-3	0-3	1-3	3-4
	Mean	0	0.51	0.22	0.61	0.36	0.72	0.44
Quadri-valent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	34.9-40.8	35.9-40.2	35.4-41.2	33.6-40.2	37.8-50.4	36.8-41.2	38.8-41.6
	Mean	40.70±2.36	38.79±2.17	39.48±2.33	37.05±2.98	41.84±4.91	38.62±2.03	39.52±1.17
X-ma/II	Range	1.72-2	1.71-1.91	1.69-1.96	1.60-1.91	1.80-2.40	1.75-1.96	1.85-1.98
	Mean	1.96±0.14	1.81±0.10	1.88±0.11	1.78±0.16	1.99±0.23	1.68±0.10	1.88±0.05

Contd. ;....

Table 19. Continued.

Configaration and X-ma distribution		Duration (hours) 144 Temperature (°C) 30 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	3-8	2-8	1-8	2-8	2-4	1-7
	Mean	0	0.64	0.98	1.86	0.94	0.46	1.66
Bivalent Ring	Range	12-21	11-21	9-19	10-21	10-21	10-19	9-21
	Mean	16.02	13.44	13.46	14.22	13.42	13.12	12.93
Rod	Range	5-9	2-11	3-10	2-10	2-9	2-10	3-9
	Mean	5.06	6.88	6.92	6.14	4.98	7.1	3.98
Trivalent	Range	0	1-3	1-5	1-5	1-3	1-3	1-5
	Mean	0	0.26	0.38	0.16	0.36	0.26	0.42
Quadri-valent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	36.2-42.02	39.8-41.4	35.8-41.6	37.8-40.4	38-42.4	39-41.8	38.4-42.6
	Mean	38.72±2.34	40.6±0.76	38.22±2.11	39.64±1.08	40.12±1.01	40.4±1.33	39.8±1.18
X-ma/II	Range	1.74-2	1.90-1.97	1.70-1.98	1.80-1.92	1.81-2.02	1.86-1.99	1.83-2.03
	Mean	1.94±0.14	1.93±0.04	1.80±0.10	1.89±0.05	1.89±0.04	1.92±0.06	1.82±0.05

Table. 19. Continued.

Configaration and X-ma distribution		Duration (hours) 288 Temperature (°C) 30 Radiation dose (kr) 0	5	10	15	20	25	30
Univalent	Range	0	1-7	1-4	1-8	1-8	3-9	1-9
	Mean	0	1.16	0.72	0.98	1.32	1.21	1.1
Bivalent Ring	Range	12-21	9-16	10-19	10-21	10-21	11-21	10-21
	Mean	16.08	12.04	12.44	13.69	14.48	13.82	13.98
Bivalent Rod	Range	5-9	1-10	1-10	4-10	1-9	3-11	2-10
	Mean	5.08	7.56	6.88	4.86	5.15	5.86	5.54
Trivalent	Range	0	1-3	1-5	1-3	1-3	0-3	1-5
	Mean	0	0.54	0.54	0.61	0.52	0.56	0.70
Qudri-valent	Range	0	0-1	0-1	0	0-1	0	0
	Mean	0	0.02	0.04	0	0.02	0	0
X-ma/PMC	Range	36.4-42.0	32.8-41.2	36.2-40.6	37.3-41.2	36.4-40.4	38.3-41.3	37-39.2
	Mean	40.74±2.44	38.04±3.17	38.96±1.82	37.98±1.39	38.28±1.62	37.97±1.32	38.56±0.93
X-ma/II	Range	1.73-2	1.56-1.96	1.72-1.93	1.78-1.96	1.73-1.92	1.82-1.97	1.76-1.87
	Mean	1.94±0.12	1.81±0.15	1.85±0.09	1.73±0.08	1.82±0.08	1.76±0.08	1.84±0.08

Table 19. Continued.

Configaration and X-ma distribution		Duration (hours) 72 Temperature (°C) 35 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-9	1-8	1-9	2-8	1-8	2-8
	Mean	0	1.52	0.96	0.98	0.99	1.2	1.1
Bivalent Ring	Range	12-21	10-21	10-19	10-21	9-21	10-19	10-21
	Mean	16.06	13.66	13.51	14.44	13.59	14.02	13.68
Bivalent Rod	Range	5-9	2-9	2-10	2-10	3-11	2-10	3-11
	Mean	6.01	5.76	5.48	5.44	6.10	4.66	6.01
Trivalent	Range	0	1-5	1-5	1-5	0-3	1-5	1-3
	Mean	0	0.74	0.44	0.42	0.43	0.90	0.93
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	36.6-40	36-39.4	36.5-41	34.8-40.8	39.2-42.1	34-39	37.4-42
	Mean	40.0±2.42	37.6±1.45	37.21±1.28	37.96±2.37	38.62±1.02	37.08±2.18	38.23±1.38
X-ma/II	Range	1.75-2	1.71-1.88	1.68-1.86	1.66-1.94	1.87-2	1.62-1.86	1.78-2
	Mean	1.96±0.14	1.79±0.08	1.68±0.09	1.81±0.11	1.76±0.08	1.77±0.10	1.71±0.08

Table 19. Continued.

Configaration and X-ma distribution		Duration (hours) 144 Temperature (°C) 35 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-9	3-9	1-9	3-9	1-9	1-8
	Mean	0	1.0	1.32	1.86	1.10	1.72	1.43
Bivalent Ring	Range	11-21	11-21	10-21	10-21	11-21	10-21	10-21
	Mean	13.89	13.89	14.06	14.16	13.38	13.98	12.99
Bivalent Rod	Range	2-9	2-9	2-11	2-10	2-10	2-10	4-10
	Mean	5.64	5.82	5.86	5.30	4.98	5.64	5.03
Trivalent	Range	0	1-5	1-5	1-5	1-5	1-5	1-3
	Mean	0	0.44	0.61	0.54	0.57	0.52	0.49
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	36.8-40.2	36.8-40.8	35.9-41.6	36.8-40.2	37.8-41.2	37.8-39.6	36.9-42.3
	Mean	38.26±1.35	38.4±1.57	37.1±1.42	38.24±1.36	38.01±1.28	39.04±0.71	38.0±1.21
X-ma/II	Range	1.75-1.91	1.75-1.94	1.71-1.98	1.75-1.91	1.80-1.96	1.81-1.95	1.78-1.93
	Mean	1.82±0.06	1.83±0.08	1.81±0.06	1.82±0.06	1.81±0.07	1.80±0.06	1.85±0.05

Table 19. Continued.

Configaration and X-ma distribution		Duration (hours) 288 Temperature (°C) 35 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-9	1-9	1-9	1-8	1-8	1-8
	Mean	0	1.66	1.69	2.08	1.09	1.38	1.18
Bivalent Ring	Range	12-21	10-21	10-21	10-19	11-21	10-21	10-21
	Mean	16.0	14.0	14.03	13.60	13.16	13,78	14.08
Bivalent Rod	Range	5-9	2-9	3-11	2-9	4-10	2-10	1-10
	Mean	5.06	5.42	6.03	4.70	5.71	5.76	5.76
Trivalent	Range	0	1-5	1-5	1-5	1-5	1-5	1-3
	Mean	0	0.50	0.62	0.68	0.78	0.60	0.38
Quadrivalent	Range	0	0	0	0-1	0	0-1	0-1
	Mean	0	0	0	0.04	0	0.02	0.02
X-ma/PMC	Range	38.2-42.2	37.4-40.4	37.1-43.3	35.2-39.2	36.4-40.2	36.4-39.8	36.8-40.2
	Mean	40.28±1.08	38.84±1.09	38.93±1.08	37.44±1.45	37.96±1.25	38.44±1.37	38.76±1.26
X-ma/II	Range	1.85-1.97	1.78-1.92	1.77-2.06	1.68-1.87	1.73-1.91	1.73-1.90	1.75-1.91
	Mean	1.92±0.06	1.85±0.05	1.87±0.06	1.78±0.07	1.89±0.07	1.83±0.07	1.85±0.06

In case of 72 hours duration for all the temperature and radiation doses more or less similar pattern was observed as for radiation dose. Ring bivalent was more in the control than the other doses for all the temperatures (^{o}C) and duration of temperature treatment.

The mean chiasma frequency per PMC was highest (41.84 $\pm$ 4.91) in 72 hours at 30^{o}C for 20 kr with a range of 37.8-50.4. The mean chiasma frequency per bivalent varied little among the different treatments.

For 35^{o}C temperature the highest value (16.06) was found in control except in 144 hours in 15 kr. The values were not gradually increased for all the treatments, but fluctuated. Chiasma frequency per PMC and per bivalent were highest in control except 144 hours in 30 kr.

Chromosome association and chiasma frequency in Cocoit induced by gamma rays, temperature and duration of temperature (expt.3) are presented in Table 20.

Univalent and trivalent were absent in the control. Quadrivalent was also absent in all the treatments except at 35^{o}C in 72 (15 kr) , 144 (10 and 25 kr) and 288 (5,15, 20 and 30 kr) hours duration.

At 25^{o}C temperature for all the treatments the pattern

Table 20. Chromosome association and chiasma frequency at diakinesis/metaphase 1 of Cocoit induced by gamma rays, temperature and duration of temperature (Expt. 3).

Configaration and X-ma distribution		Duration (hours) 72 Temperature (°C) 25 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	0-1	1-2	1-4	1-6	1-6	1-2
	Mean	0	0.04	0.16	0.28	0.50	0.44	0.40
Bivalent Ring	Range	10-14	8-14	8-14	8-14	8-14	8-14	8-14
	Mean	12.90	12.16	11.8	12.26	11.96	12.0	12.70
Rod	Range	2-4	1-6	1-6	1-6	1-6	1-6	1-6
	Mean	1.06	2.06	2.02	1.46	1.7	1.38	1.14
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.04	0.04	0.01	0.06	0.08	0.12
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	28-28	26.4-28	22.8-28	27.2-27.6	26.2-27.4	27-27.6	26.8-29.4
	Mean	28±0	27.36±0.73	26.6±2.17	27.44±0.17	27.04±0.54	27.32±0.23	27.60±1.03
X-ma/II	Range	2-2	1.89-2	1.63-2	1.94-1.97	1.87-1.96	1.93-1.97	1.91-2.1
	Mean	2±0	1.95±0.05	1.90±0.16	1.96±0.012	1.93±0.04	1.95+0.02	1.97±0.07

Contd. .....

Table 20. Continued.

Configaration and X-ma distribution		Duration (hours) 144 Temperature (°C) 25 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-6	1-6	1-6	1-4	1-6	1-6
	Mean	0	0.4	0.54	0.48	0.36	0.38	0.46
Bivalent Ring	Range	7-14	6-14	8-14	8-14	10-14	8-14	8-14
	Mean	11.24	12.02	12.66	12.82	12.46	12.56	12.34
Bivalent Rod	Range	2-7	1-6	1-6	1-6	1-4	1-6	1-6
	Mean	2.36	1.44	1.08	1.1	1.26	1.1	1.22
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.08	0.12	0.08	0.08	0.1	0.14
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	28-28	25.4-27.2	24.6-27.6	24.6-28	26.6-27.8	26.2-28	26.4-27.6
	Mean	28±0	26.56±0.699	26.6±1.17	26.88±1.39	27.4±0.49	27.24±0.73	27.12±0.501
X-ma/II	Range	2-2	1.81-1.94	1.76-1.97	1.76-2	1.9-1.99	1.87-2	1.89-1.97
	Mean	2±0	1.90±0.051	1.90±0.082	1.92±0.098	1.96±0.037	1.94±0.053	1.93±0.03

Contd. .....

Table 20. Continued.

Configaration and X-ma distribution		Duration (hours) 288 Temperature (°C) Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-6	1-6	1-6	1-6	1-4	1-6
	Mean	0	0.4	0.28	0.26	0.34	0.26	0.35
Bivalent Ring	Range	8-14	8-14	8-14	8-14	8-14	7-14	7-14
	Mean	11.64	12.18	11.9	12.5	12.64	12.22	12.46
Bivalent Rod	Range	1-5	1-6	1-6	1-6	1-6	1-7	1-7
	Mean	1.88	1.44	1.28	1.28	1.1	1.5	1.24
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.08	0.04	0.06	0.06	0.1	0.1
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	28-28	26.8-28	26.8-28.2	27-28	27.4-28.2	27-27.8	23-28
	Mean	28±0	27.36±0.54	27.52±0.61	27.56±0.43	27.76±0.33	27.44±0.33	26.4±2.01
X-ma/II	Range	2-2	1.91-2	1.91-2.01	1.93-2	1.96-2.01	1.93-1.99	1.64-2
	Mean	2±0	1.95±0.04	1.97±0.04	1.98±0.032	1.98±0.02	1.96±0.02	1.89±0.15

Contd. .....

Table 20. Continued.

Configaration and X-ma distribution		Duration (hours) 72 Temperature (°C) 30 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-6	1-4	1-6	1-2	1-4	1-6
	Mean	0	0.46	0.2	0.2	0.12	0.26	0.32
Bivalent Ring	Range	8-14	8-14	8-14	8-14	7-14	7-14	7-14
	Mean	11.74	12.04	12.4	12.74	12.38	12.34	12.42
Bivalent Rod	Range	1-5	1-6	1-6	1-6	1-7	1-7	1-7
	Mean	1.86	1.52	1.38	1.04	1.4	1.34	1.28
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.14	0.08	0.08	0.08	0.1	0.08
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	26.7-27.50	26.8-27.4	26.6-28	27.2-28	25-28	26.8-28.2	27-28
	Mean	27.16± 0.17	27.12± 0.23	27.32± 0.59	27.56± 0.30	27.12± 1.21	27.48± 0.58	27.44± 0.36
X-ma/II	Range	190-1.96	191-1.96	1.9-2	1.94-2	1.79-2	1.91-2.01	1.93-2
	Mean	1.94± 0.09	1.94± 0.02	1.95± 0.04	1.97± 0.02	1.94± 0.08	1.96± 0.04	1.96± 0.03

Contd. ....

Table. 20. Continued.

Configaration and X-ma distribution		Duration (hours) 144 Temperature (°C) 30 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-4	1-6	1-6	1-4	1-6	1-4
	Mean	0	0.34	0.36	0.36	0.35	0.28	0.42
Bivalent Ring	Range	10-14	8-14	9-14	9-14	10-14	9-14	9-14
	Mean	12.82	12.36	12.32	12.1	12.42	12.43	12.36
Rod	Range	2-4	1-6	1-5	1-6	1-4	1-5	1-5
	Mean	1.08	1.28	1.38	1.50	1.22	1.39	1.48
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.1	0.08	0.12	0.14	0.12	0.06
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	26.30-29.40	22.6-27.6	26.2-30.2	26.6-27.8	27-28	26.7-28.1	26.6-27.8
	Mean	26.90± 0.36	26.36± 2.11	27.76± 1.53	27.8± 0.49	27.56± 0.42	27.53± 0.62	27.4± 0.49
X-ma/II	Range	1.86-1.98	1.61-1.97	1.87-2.15	1.88-2	1.94-2	1.92-2.01	1.9-2.0
	Mean	1.92± 0.28	1.88± 0.15	1.98± 0.11	1.96± 0.04	1.97± 0.04	1.99± 0.04	1.93± 0.04

Contd. ....

Table 20. Continued.

Configaration and X-ma distribution		Duration (hours) 288 Temperature (°C) 30 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-6	1-4	1-6	1-6	1-6	1-6
	Mean	0	0.36	0.32	0.42	0.38	0.58	9-14
Bivalent Ring	Range	7-14	10-14	9-14	9-14	10-14	0.46	9-14
	Mean	11.24	12.74	12.63	12.39	12.46	12.46	12.37
Bivalent Rod	Range	2-7	1-2	1-2	1-5	1-3	1-5	1-5
	Mean	2.34	0.92	1.14	1.14	1.1	1.06	1.10
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.12	0.1	0.18	0.18	0.12	0.16
Quadrivalent	Range	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0
X-ma/PMC	Range	26.7-28.2	24.2-26.9	26.5-27.2	26.7-28.1	27-28	27.8-28	26-27.6
	Mean	26.82±0.61	26.71±1.29	26.23±1.29	27.17±0.49	27.65±0.43	27.27±0.67	27.04±0.71
X-ma/II	Range	1.78-1.94	1.67-1.86	1.71-1.98	1.78-1.92	1.97-2	1.93-2.01	1.86-1.97
	Mean	1.92±0.25	1.8±0.08	1.86±0.09	1.83±0.03	1.92±0.03	1.80±0.04	1.93±0.05

Contd. .....

Table 20. Continued.

Configaration and X-ma distribution		Duration (hours) 72 Temperature (°C) 35 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-3	1-6	1-2	1-4	1-3	1-6
	Mean	0	0.16	0.38	0.32	0.36	0.36	0.31
Bivalent Ring	Range	8-14	9-14	9-14	9-14	9-14	9-14	9-14
	Mean	11.64	12.27	12.48	12.47	12.39	12.41	12.33
Bivalent Rod	Range	1-5	1-5	1-5	1-5	1-5	1-5	1-5
	Mean	1.88	1.32	1.33	0.92	0.98	1.22	1.04
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.24	0.21	0.12	0.16	0.18	0.26
Quadrivalent	Range	0	0	0	0-1	0	0	0
	Mean	0	0	0	0.02	0	0	0
X-ma/PMC	Range	25.5-26.92	25.4-26.9	26.8-27.9	27.4-28.1	27.3-28	26.6-27.8	27.7-28.1
	Mean	26.90± 0.55	26.99± 0.23	27.6± 1.03	27.46± 0.67	27.51± 0.30	27.4± 0.72	27.81± 1.51
X-ma/II	Range	1.94-1.96	1.94-1.99	1.91-2.1	1.91-2	1.78-2	1.87-2	1.99-2.01
	Mean	1.92± 0.54	1.90± 0.15	1.97± 0.08	1.94± 0.03	1.83± 0.07	1.94± 0.05	1.99± 0.04

Contd. ....

Table 20. Continued.

Configaration and X-ma distribution		Duration (hours) 144 Temperature (°C) 35 Radiation dose (kr)						
		0	5	10	15	20	25	30
Univalent	Range	0	1-6	1-6	1-6	1-6	1-3	1-3
	Mean	0	0.36	0.34	0.34	0.40	0.16	0.54
Bivalent Ring	Range	10-14	9-14	9-14	10-14	9-14	10-14	10-14
	Mean	12.92	12.42	12.38	12.28	12.71	12.48	12
Bivalent Rod	Range	2-4	1-5	1-3	1-3	1-5	1-4	1-3
	Mean	1.06	1	0.96	0.92	0.94	0.8	0.92
Trivalent	Range	0	0-1	0-1	0-1	0-1	0-1	0-1
	Mean	0	0.12	0.19	0.14	0.12	0.12	0.26
Quadrivalent	Range	0	0	0-1	0	0	0-1	0
	Mean	0	0	0.02	0	0	0.02	0
X-ma/PMC	Range	26.80-27.10	27.1-28.2	26.8-27.7	27.2-28.2	23.7-26.9	25-28	27.1-28
	Mean	26.84± 0.23	28.17± 0.91	27.13± 0.24	27.47± 0.38	27.71± 1.53	27.13± 1.206	27.41± 0.41
X-ma/II	Range	1.89-1.98	1.93-2.01	1.92-1.97	1.95-2.01	1.69-1.92	1.78-2	1.97-2
	Mean	1.92± 0.19	1.98± 0.03	1.93± 0.02	1.97± 0.05	1.83± 0.16	1.94± 0.09	1.98± 0.05

Contd. .....

Table 20. Continued.

Configaration and X-ma distribution			Duration (hours) 288 Temperature (°C) 35 Radiation dose (kr)						
			0	5	10	15	20	25	30
Univalent		Range	0	1-3	1-6	1-6	1-6	1-6	1-6
		Mean	0	0.47	0.51	0.74	0.54	0.84	0.80
Bivalent	Ring	Range	7-1	10-14	9-14	9-14	10-14	10-14	10-14
		Mean	11.36	12.32	12.27	11.9	12.08	11.92	11.98
	Rod	Range	2-7	1-3	1-5	1-5	1-3	1-4	1-2
		Mean	2.34	0.87	1.1	1.3	1.22	1.3	1.1
Trivalent		Range	0	0-1	0-1	0-1	0-1	0-1	0-1
		Mean	0	0.18	1.06	0.26	0.24	0.24	0.32
Quadrivalent		Range	0	0-1	0	0-1	0-1	0	0-1
		Mean	0	0.02	0	0.02	0.04	0	0.04
X-ma/PMC		Range	25.1-27.14	27.7-28.1	27.1-28	25.1-26.2	26.6-27.1	25.4-27.2	25.2-26.6
		Mean	26.42±0.83	27.61±0.71	27.41±1.11	26.11±0.53	26.13±0.79	26.44±0.80	26.16±0.55
X-ma/II		Range	1.92-1.94	1.92-2.01	1.89-2	1.72-1.87	1.90-1.93	1.81-1.94	1.80-1.90
		Mean	1.89±0.19	1.89±0.03	1.97±0.31	1.88±0.07	1.86±0.06	1.89±0.06	1.87±0.04

was similar as in Table 16. Ring bivalent was highest in the control (12.90) with a range of 10-14 in 72 hours duration. Otherwise the values were gradually increased but fluctuated for all the treatments.

The mean chiasma frequency per PMC and per bivalent was highest in control and for all the treatments. The values were more or less similar.

At 30°C , ring was highest (12.74) in 15 kr and in 72 hours with a range of 8-14 and the lowest value was 11.74 with a range of 8-14 in control. But the rod was highest in control (1.86) with a range of 1-5 and the lowest value (1.04) was obtained in 15 kr with a range of 1-6.

The mean chiasma frequency per PMC and per bivalent was highest in 15 kr (27.56 $\pm$ 0.30 and 1.97 $\pm$ 0.02) with a range of 27.2-28 and 1.94-2 in 72 hours duration.

For 144 hours duration at the same temperature the ring was highest in the control. But for 288 hours duration the mean was gradually increased and fluctuated for ring. Otherwise means were more or less similar in all the treatments.

At 35°C temperature for 72 hours duration mean was highest in 10 kr (12.48) with a range of 9-14 and the lowest value was in the control for ring. Rod was highest in the control.

For the mean chiasma frequency per PMC and per bivalent the means were found to increase gradually but fluctuated in all the treatments. The mean value per PMC was highest in 5 kr and 144 hours duration (28.17 ± 0.91) with a range of 27.1 - 28.2 and the lowest value was 26.11 ± 0.53 in 15 kr and 288 hours duration. The mean value per bivalent was highest (1.97±0.31) in 10 kr and 288 hours with a range of 1.89-2 and the lowest mean was 1.83±0.07 in 20 kr and 72 hours with a range of 1.78-2.

Between the two varieties, univalent, bivalent, trivalent and chiasma frequency per PMC were more in Sonalika than Cocoit, but quadrivalent and chiasma frequency per bivalent were similar in both the varieties.

Pollen Grain Abnormality :

Effect Of Gamma Rays :

Percentages of pollen grain abnormalities in Sonalika and Cocoit induced by gamma ray (expt.1) are given in Table 21. For the study of pollen grain abnormality (in order to find out its relationship with meiotic irregularity) the data from normal as well as abnormal pollen grains were recorded from two varieties with different treatments. The normal pollen grains were typically characterised by two peg shaped generative nuclei and one oval vegetative nucleus. The abnormal pollen grains viz., mononucleate, binucleate abnormal trinucleate and tetranucleate

Table 21. Percentages of pollen grain abnormalities in Sonalika and Cocoit induced by gamma rays (Expt. 1).

Radiation dose (kr))	No. of PGS	% of abnormal PGS	Percentage of different abnormal pollen grains			
			Mononucleate	Binucleate	Trinucleate	Tetranucleate
			Sonalika			
0	100	3.03	1.81	2.43	-	-
5	100	3.63	2.92	2.14	-	-
10	100	3.97	3.56	2.92	-	0.81
15	100	4.09	3.14	2.36	0.57	0.99
20	100	4.01	2.75	2.75	-	0.99
25	100	4.09	2.43	3.14	-	0.99
30	100	4.21	2.50	3.39	-	-
			Cocoit			
0	100	2.98	1.99	2.22	-	-
5	100	3.49	2.43	2.43	-	0.57
10	100	4.05	2.81	2.81	-	0.81
15	100	3.80	2.92	2.43	-	-
20	100	4.05	3.03	2.69	-	-
25	100	3.85	1.99	2.98	0.81	1.15
30	100	4.25	2.56	3.14	0.99	0.81

pollen grains were classified according to the number and morphology of nuclei in the mature pollen grains and they are shown in Plate 3.

The percentage of abnormal pollen grains increased gradually with the increase of radiation doses in Sonalika. But in Cocoit percentage of abnormal pollen grains increased with fluctuations.

In case of the percentage of different abnormal pollen grains of Sonalika, the highest percentage (3.39%) was found in 30 kr for binucleate and the lowest percentage was 0.57% in 15 kr for trinucleate.

In Cocoit, the highest percentage was 3.14% in 30 kr for binucleate and the lowest percentage was 0.57% in 5 kr for tetranucleate.

The relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika and Cocoit in expt.1 is shown in Figures 5 and 6. In both the varieties, pollen grain abnormality and pollen sterility increased with the increase of meiotic abnormality. The correlation study revealed that meiotic abnormality had highly significant and positive correlation with both pollen grain abnormality and pollen sterility (Figures 5 and 6). The regression study showed

Plate 3. Photomicrographs showing pollen grain abnormalities in tetraploid and hexaploid wheat treated by gamma rays and temperature.

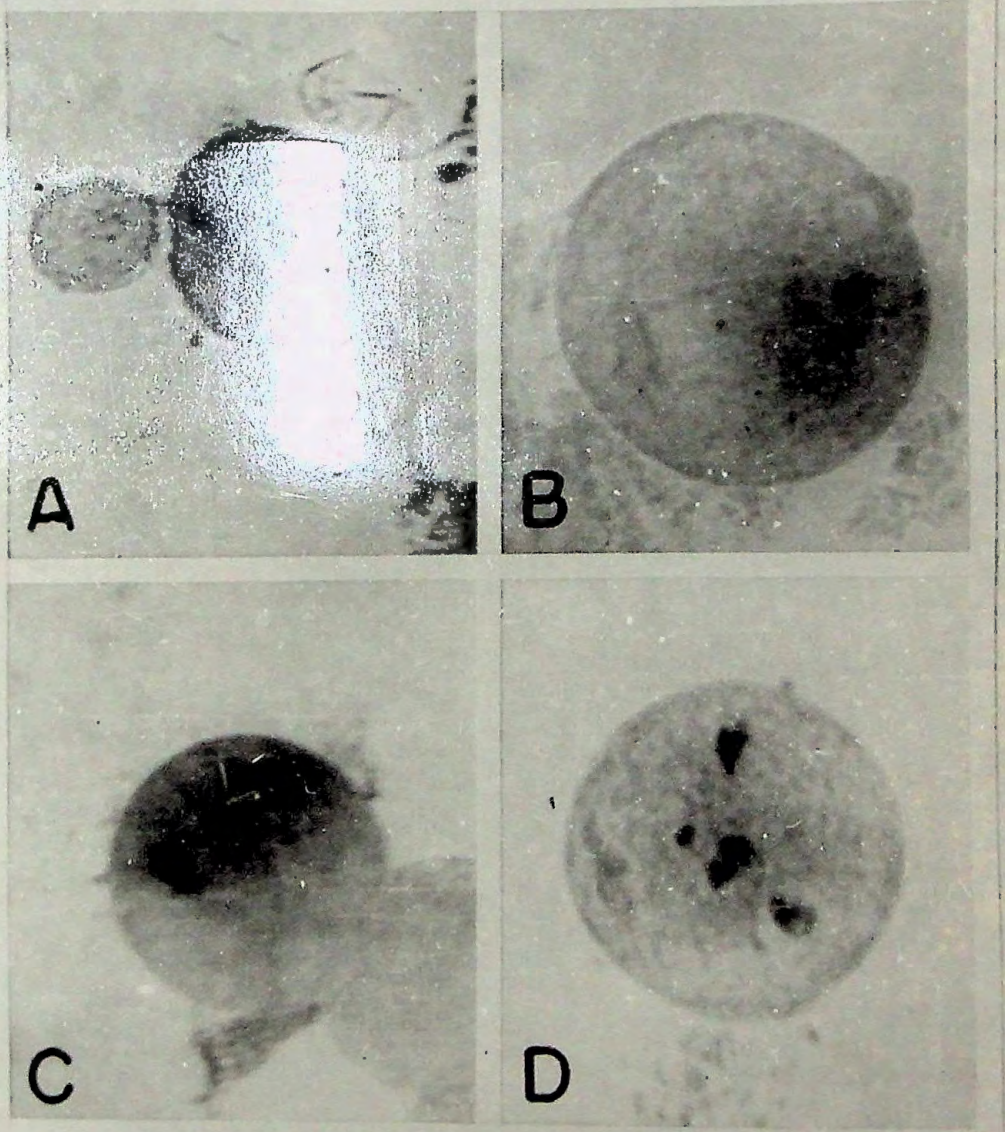
A. Normal pollen grain with two peg-shaped nuclei.

B. Abnormal binucleate pollen grain.

C. Trinucleate pollen grain.

D. Tetranucleate pollen grain.

PLATE-3



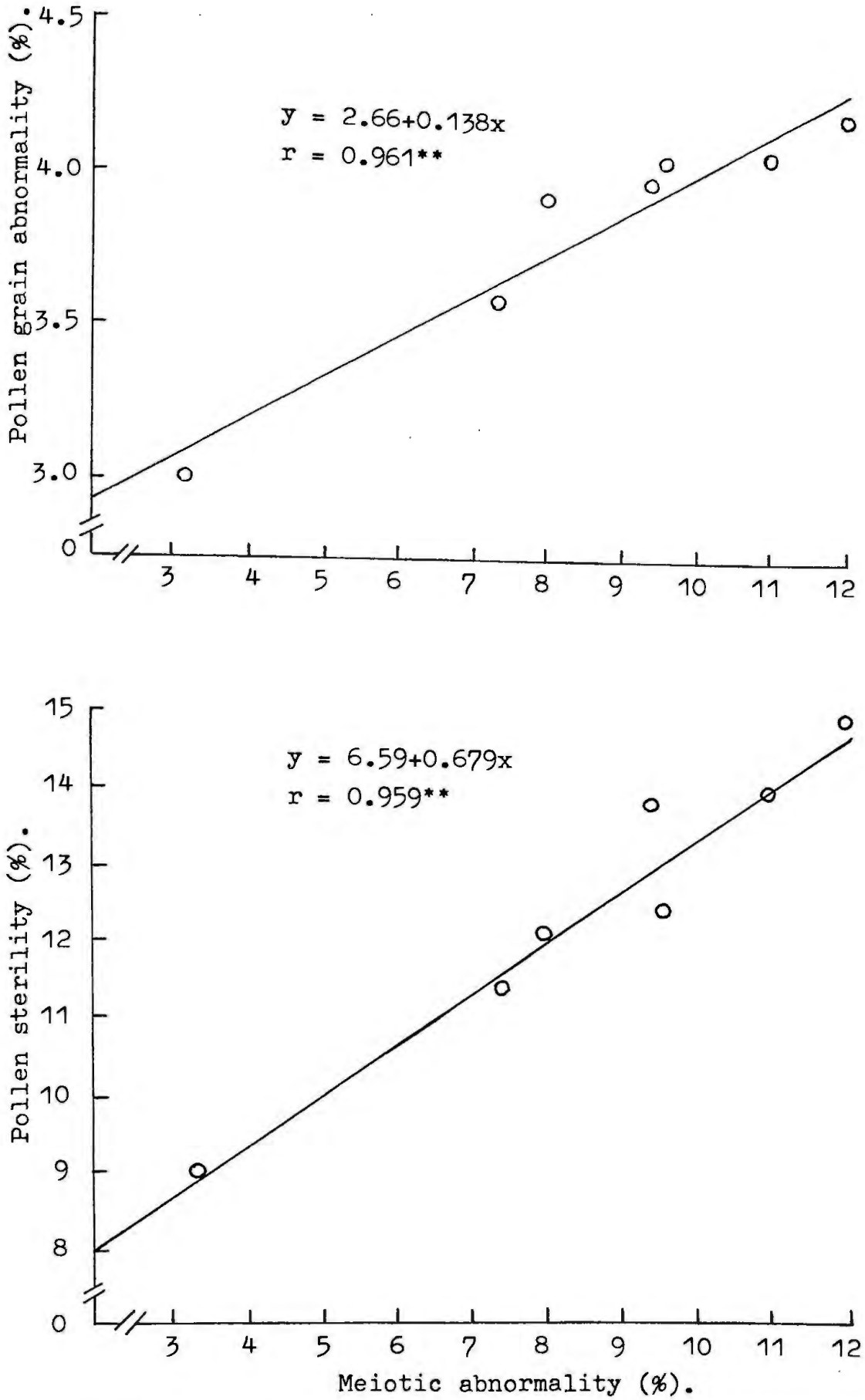
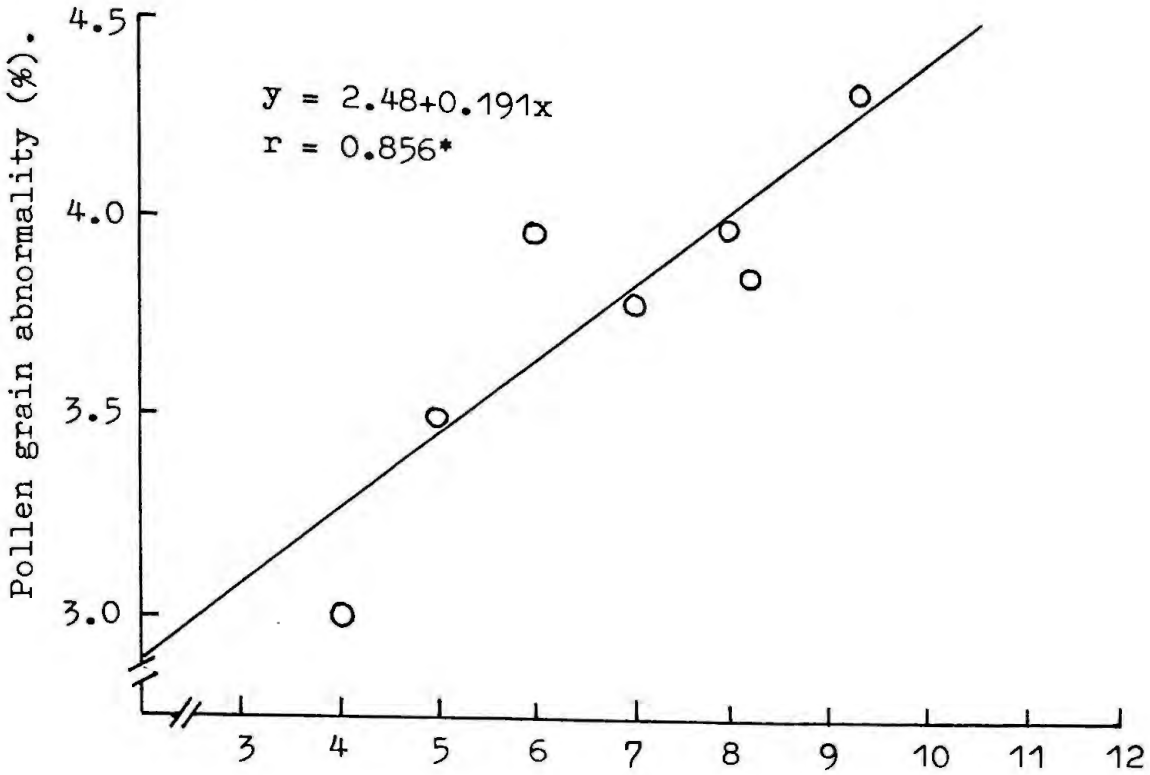


Figure 5. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika induced by gamma rays (Expt.1).



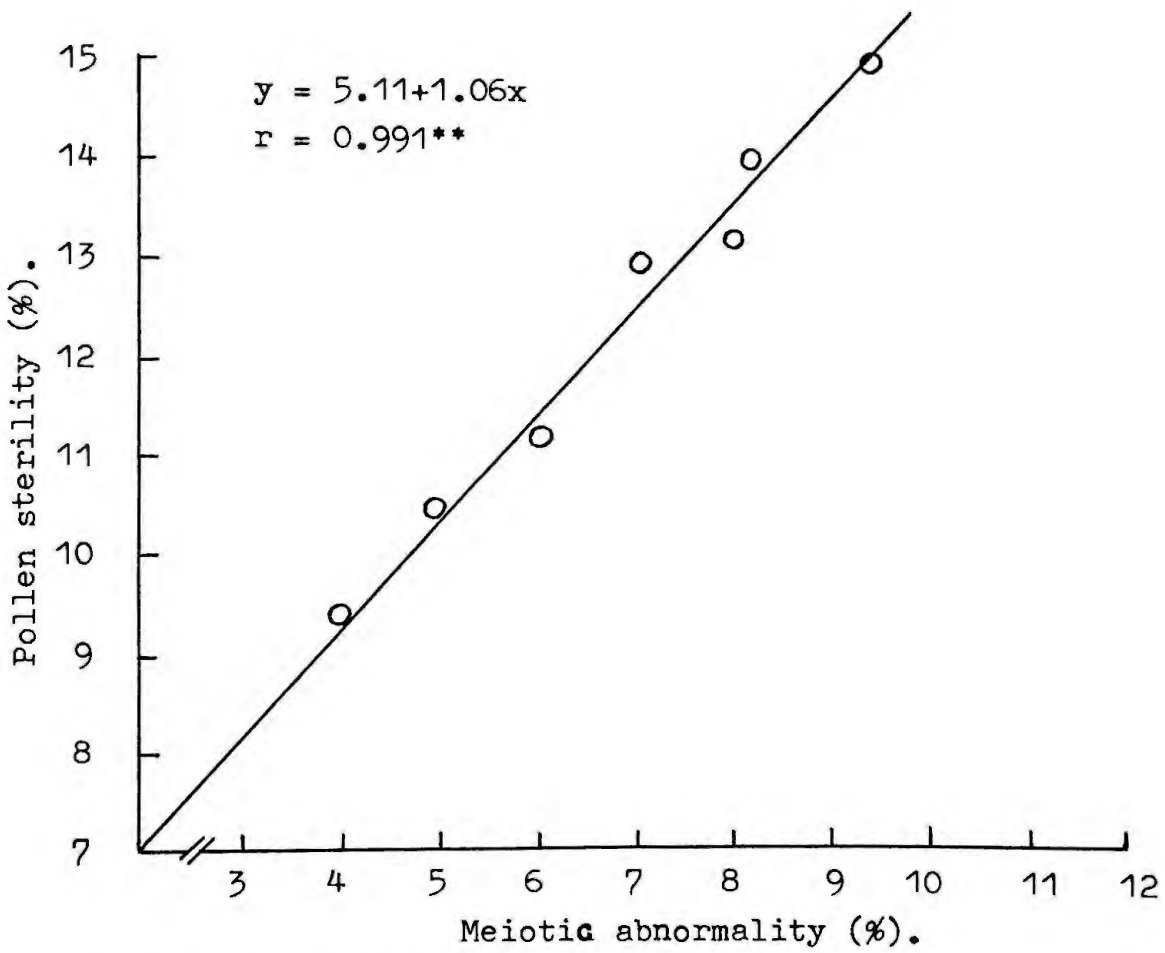


Figure 6. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in cocoit induced by gamma rays (Expt.1).

that the rate of increase of both pollen grain abnormality and pollen sterility was higher in Cocoit than Sonalika.

Effect Of Temperature (^{o}C) And Duration Of Temperature Treatment :

Percentages of pollen grain abnormalities in Sonalika and Cocoit induced by temperature (^{o}C) and duration of temperature treatment (expt.2) are given in Table 22. In Sonalika percentages of abnormal pollen grains were highest at $30^{o}C$ in both 72 and 144 hours of duration, but at $35^{o}C$ in case of 288 hours duration. At all the three temperatures (^{o}C) the highest percentages of abnormal cells were observed at 288 hours duration. Similar pattern was observed for Cocoit. There were no clear patterns of mononucleate and binucleate abnormal pollen grains with respect to temperature (^{o}C) and duration of temperature treatment. Trinucleate and tetranucleate pollen grains were generally absent in 72 hours duration.

The relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika and Cocoit induced by temperature and duration of temperature in expt. 2 is shown in Figures 7 and 8. In both the varieties it was also observed that the pollen grain abnormality and pollen sterility increased with an increase of meiotic irregularity in each treatment. The correlation study revealed that meiotic abnormality

Table 22. Percentages of pollen grain abnormalities in Sonalika and Cocoit induced by temperature and duration of temperature (Expt. 2).

Duration (hour)	Temperature (°C)	No.of PGS	% of abnormal PGS	Percentage of different abnormal pollen grains			
				Mononucleate	Binucleate	Trinucleate	Tetranucleate
				Sonalika			
	25	100	3.63	2.29	2.81	-	-
72	30	100	3.76	2.75	2.56	-	-
	35	100	3.72	2.56	2.63	-	0.57
	25	100	3.67	2.92	2.81	0.99	-
144	30	100	4.01	2.07	3.34	0.57	0.57
	35	100	3.67	2.81	3.14	-	-
	25	100	4.29	2.56	3.39	-	0.57
288	30	100	4.13	2.43	3.14	0.99	0.57
	35	100	4.33	3.29	2.56	-	1.15
				Cocoit			
	25	100	3.72	2.56	2.69	-	-
72	30	100	3.85	2.81	2.81	-	0.57
	35	100	4.01	2.56	3.09	-	-
	25	100	4.13	3.03	2.81	-	-
144	30	100	4.29	3.14	2.69	0.99	0.57
	35	100	4.17	3.03	2.56	1.15	0.57
	25	100	4.37	2.69	3.39	0.57	-
288	30	100	4.25	2.87	2.87	-	1.28
	35	100	4.33	2.56	3.24	0.81	0.99

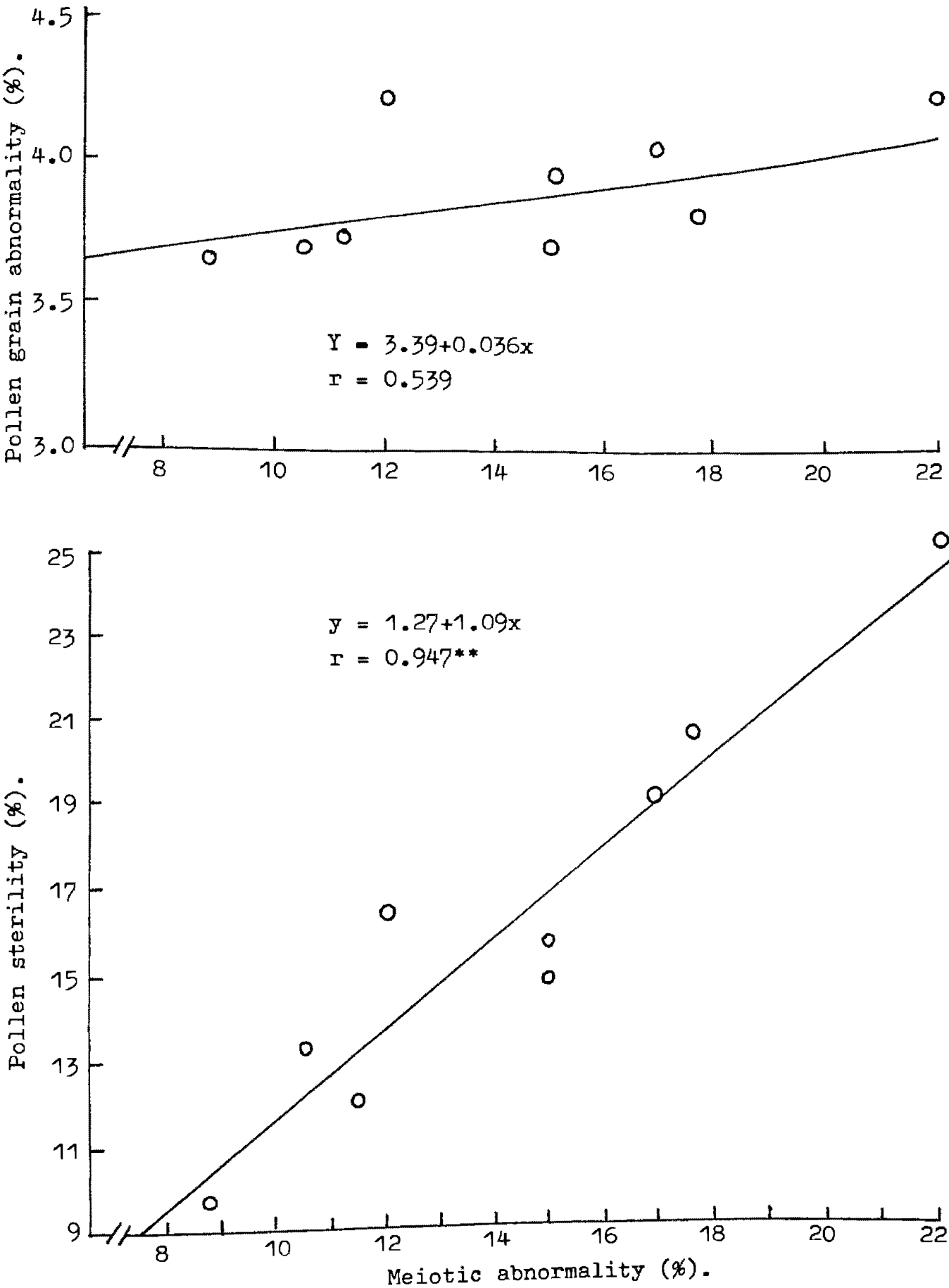


Figure 7. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika induced by temperature and duration of temperature (Expt.2).

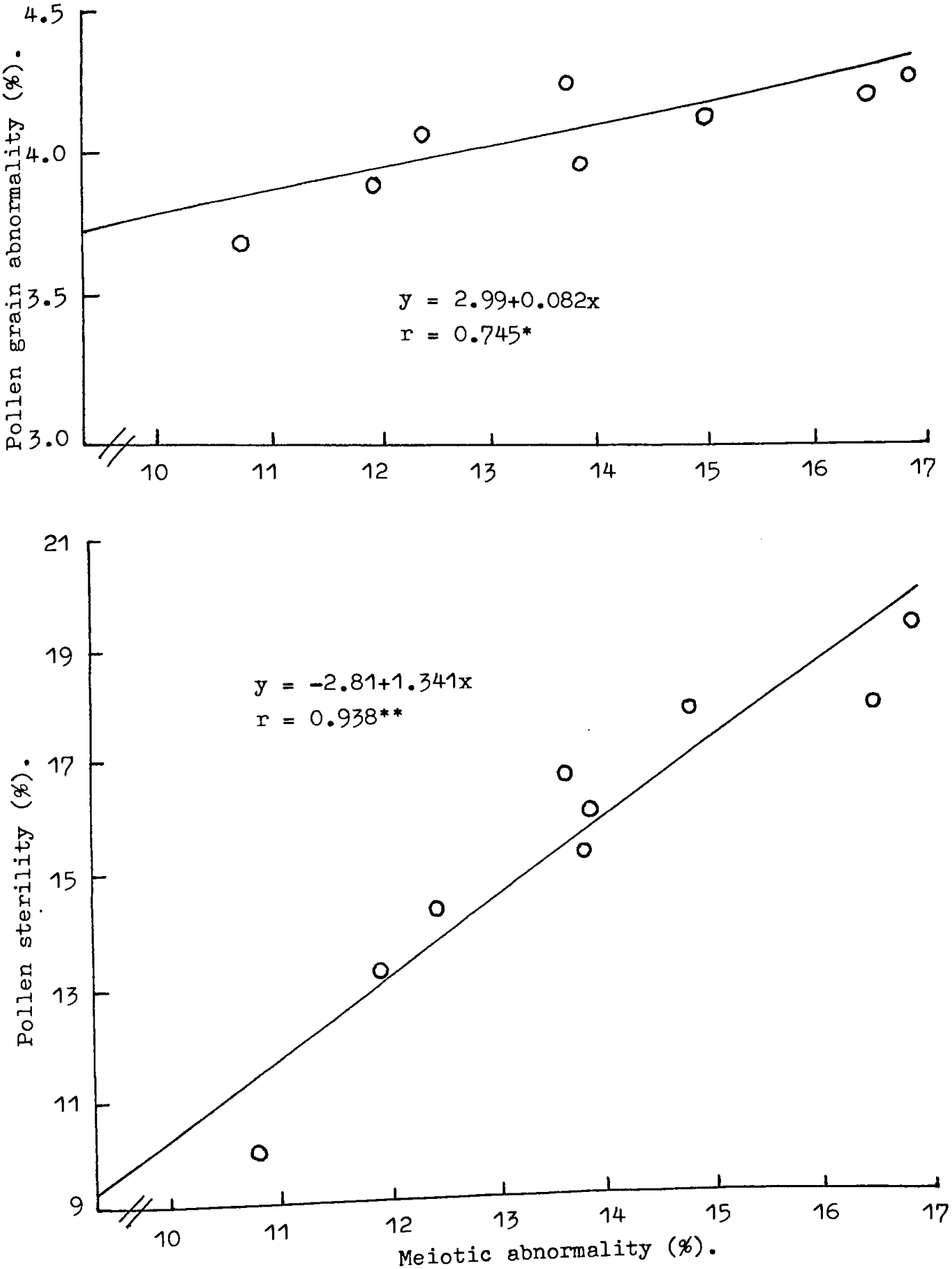


Figure 8. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Cocoit induced by temperature and duration of temperature (Expt.2).

had positive correlation witn pollen grain sterility in both the varieties and with pollen grain abnormality in Cocoit only. The regression study indicated that the rates of increase of pollen grain abnormality and pollen sterility were higher in Cocoit than Sonalika.

Effect Of Gamma Rays, Temperature (^{o}C) And Duration Of Temperature Treatment :

Percentages of pollen grain abnormalities in Sonalika induced by gamma rays, temperature (^{o}C) and duration of temperature treatment (expt.3) are given in Table 23.

In all the three durations of temperature treatment there was a general trend of increase of the percentage of cells with the increase of temperature and radiation doses. Post radiation temperature and duration of temperature increased the percentage of abnormal pollen grains. Mononucleate and binucleate pollen grains were present in all the treatments. Trinucleate and tetranucleate pollen grains were absent in some treatments, especially in the control and lower level of radiation.

Percentages of pollen grain abnormalities in Cocoit induced by gamma rays, temperature (^{o}C) and duration of temperature treatment in expt. 3 (Table 24) showed similar pattern as in Sonalika.

In case of 72 hours duration of temperature treatment

Table 23. Percentages of pollen grain abnormalities in Sonalika induced by gamma rays, temperature and duration of temperature (Expt. 3).

Temperature (°C)	Radiation dose (kr)	No.of PGS	% of abnormal PGS	Percentage of different abnormal pollen grains			
				Mono-nucleate	Binucle-ate	Trinu-cleate	Tetranu-cleate
			72 hours				
25	0	100	3.24	2.56	1.99	-	-
	5	100	4.17	3.39	2.43	-	-
	10	100	3.97	3.03	2.43	0.81	-
	15	100	4.01	2.56	2.63	1.40	0.81
	20	100	4.37	2.69	3.39	-	0.57
	25	100	4.40	2.50	3.39	0.81	0.99
	30	100	4.59	2.36	3.63	1.28	0.81
30	0	100	3.53	2.69	2.22	0.57	-
	5	100	4.66	3.09	3.09	0.81	1.40
	10	100	4.55	2.56	3.39	1.62	-
	15	100	4.62	2.14	3.85	1.28	0.57
	20	100	4.73	2.43	3.63	1.28	1.28
	25	100	4.29	2.98	2.75	0.81	1.15
	30	100	4.62	2.43	3.49	1.15	1.40
35	0	100	3.72	2.56	2.69	-	-
	5	100	4.76	3.09	3.49	0.99	-
	10	100	4.62	2.14	2.85	1.28	0.57
	15	100	4.80	2.92	3.49	1.28	0.81
	20	100	4.87	2.87	3.39	1.81	0.81
	25	100	4.93	3.53	3.14	1.40	-
	30	100	5.07	3.14	3.63	-	1.62

Table 23. Continued.

144 hours

	0	100	3.80	2.69	2.69	-	-
	5	100	4.48	2.87	3.34	-	-
	10	100	4.62	2.14	3.85	1.40	-
25	15	100	4.83	2.98	3.44	1.62	-
	20	100	4.62	2.81	3.34	0.81	1.28
	25	100	4.44	2.92	2.81	1.62	0.81
	30	100	4.80	2.87	3.39	1.72	0.57
	0	100	3.93	2.65	2.87	0.81	-
	5	100	4.55	2.63	3.34	1.28	0.99
	10	100	4.83	2.98	3.39	1.40	0.99
30	15	100	4.48	2.56	3.39	1.40	-
	20	100	4.52	2.87	2.69	1.62	1.52
	25	100	4.52	2.81	3.19	1.15	0.99
	30	100	5.00	2.69	4.05	1.15	-
	0	100	4.05	2.75	2.87	-	0.81
	5	100	4.40	2.14	3.53	0.99	1.15
	10	100	4.73	3.14	2.63	1.62	1.72
35	15	100	4.80	2.56	3.63	1.40	1.15
	20	100	5.00	2.98	3.67	1.40	0.81
	25	100	4.80	2.56	3.63	-	1.81
	30	100	5.16	2.56	3.97	1.72	1.15

Contd. ....

Table 23. Continued.

			288 hours				
	0	100	3.93	2.56	2.87	-	0.81
	5	100	4.44	2.56	3.24	1.40	0.81
	10	100	4.87	2.63	3.14	2.07	1.62
25	15	100	4.66	2.75	3.34	1.28	1.15
	20	100	4.59	2.87	3.14	1.15	1.28
	25	100	4.76	2.29	3.63	1.52	1.40
	30	100	4.80	2.98	3.39	1.28	0.99
	0	100	4.09	2.36	3.34	-	-
	5	100	4.73	2.56	3.63	1.28	0.99
	10	100	4.69	3.14	3.29	1.15	-
30	15	100	5.10	2.29	2.98	0.99	3.29
	20	100	4.69	2.92	3.39	1.15	0.81
	25	100	4.83	2.69	3.03	1.99	1.72
	30	100	4.97	2.22	3.03	2.43	2.74
	0	100	4.13	2.69	3.14	-	-
	5	100	4.97	2.56	2.87	2.14	2.29
	10	100	4.83	2.69	3.03	1.99	1.72
35	15	100	5.13	1.99	3.49	2.14	2.36
	20	100	5.00	2.69	3.49	1.62	1.72
	25	100	5.38	3.85	3.44	1.40	0.57
	30	100	5.29	2.43	2.43	3.24	2.36

Table 24. Percentages of pollen grain abnormalities in Cocoit induced by gamma rays, temperature and duration of temperature (Expt.3).

Temperature (°C)	Radiation dose (kr)	No.of PGS	% of abnormal PGS	Percentage of different abnormal pollen grains			
				ononucleate	Binucleate	Trinucleate	Trinucleate
				72 hours			
25	0	100	3.34	2.56	2.14	-	-
	5	100	4.25	2.36	3.14	1.52	0.57
	10	100	3.63	3.14	3.14	1.40	0.57
	15	100	4.37	2.98	2.56	1.72	0.81
	20	100	4.44	3.14	2.69	1.40	0.81
	25	100	4.40	2.75	2.98	1.72	-
	30	100	4.52	2.56	3.09	1.72	1.15
30	0	100	3.49	2.63	2.29	-	-
	5	100	4.29	3.14	2.29	1.40	1.15
	10	100	4.33	2.50	3.53	-	-
	15	100	4.48	2.56	3.03	1.62	1.28
	20	100	4.40	2.98	2.92	0.99	0.99
	25	100	4.44	3.09	2.81	0.99	1.15
	30	100	4.52	3.03	2.69	1.52	1.28
35	0	100	3.72	2.56	2.56	0.81	-
	5	100	4.21	2.29	3.34	0.57	0.99
	10	100	4.62	2.87	3.44	1.15	-
	15	100	4.62	2.81	3.76	0.81	1.40
	20	100	4.76	2.14	3.63	1.72	1.40
	25	100	4.80	2.56	3.63	1.40	1.15
	30	100	4.80	2.87	2.92	1.81	1.72

Contd. :.....

Table 24. Continued.

144 hors

	0	100	3.76	2.75	2.43	-	0.81
	5	100	4.44	2.98	3.29	-	-
	10	100	4.55	3.03	3.09	1.40	-
25	15	100	4.59	2.36	3.63	1.28	0.81
	20	100	4.62	3.76	2.22	0.99	1.15
	25	100	4.62	3.67	2.50	0.81	1.40
	30	100	4.66	2.63	3.49	1.28	0.99
	0	100	3.93	2.36	3.03	0.57	0.57
	5	100	4.52	2.22	3.39	1.15	1.62
	10	100	4.52	2.50	3.09	1.90	2.36
30	15	100	4.80	2.56	3.14	2.14	1.40
	20	100	4.52	2.43	3.24	1.62	1.15
	25	100	4.66	2.50	3.19	1.90	1.40
	30	100	4.76	2.07	3.44	1.99	1.62
	0	100	4.09	2.56	3.14	1.81	-
	5	100	4.62	2.69	3.03	1.52	1.62
	10	100	4.62	2.63	3.39	0.99	1.40
35	15	100	4.69	3.09	2.92	1.40	1.40
	20	100	4.83	2.98	3.29	1.52	1.15
	25	100	4.93	3.49	3.49	-	-
	30	100	5.13	2.92	3.49	1.72	1.62

Contd. .....

Table 24. Continued.

				288 hours			
	0	100	3.97	2.43	3.03	0.81	-
	5	100	4.62	2.50	3.63	-	1.40
	10	100	4.73	3.44	2.87	1.15	0.99
25	15	100	4.80	3.24	2.87	1.52	1.28
	20	100	4.73	3.14	3.09	1.15	1.28
	25	100	4.44	2.43	3.63	1.28	1.52
	30	100	4.69	2.56	3.76	1.28	1.72
	0	100	4.13	2.43	3.63	-	1.15
	5	100	4.73	2.43	3.72	1.90	1.52
	10	100	4.62	2.22	3.76	1.62	1.72
30	15	100	4.80	2.14	4.05	1.15	0.81
	20	100	5.10	2.36	4.05	1.15	1.62
	25	100	5.03	1.99	4.44	1.28	-
	30	100	4.87	2.69	3.49	1.52	1.40
	0	100	4.25	2.56	3.14	1.28	-
	5	100	4.69	3.67	3.44	-	-
	10	100	4.97	1.90	2.43	3.09	2.36
35	15	100	4.93	2.36	3.63	1.40	1.90
	20	100	5.10	3.03	2.36	1.40	3.03
	25	100	4.97	2.07	3.49	1.99	2.07
	30	100	5.29	2.36	3.39	2.29	2.36

percentages of abnormal pollen grains were increased with the increase of radiation doses and temperature (^{o}C). The highest percentage was 3.76% in 15 kr at 35^{o}C for binucleate and the lowest value was 0.57 in the control at 35^{o}C, and 5 and 10 kr at 25^{o}C for trinucleate and tetranucleate.

In case of 144 hours duration of temperature treatment percentage of abnormal pollen grains was highest (5.13%) at 35^{o}C in 30 kr. Pollen grains had the highest abnormality (3.76%) in 20 kr at 25^{o}C for mononucleate, and the trinucleate and tetranucleate had the lowest value (0.57%) at 30^{o}C in the control.

In case of 288 hours duration the abnormal pollen grains were gradually increased with the increase of radiation dose and temperature but fluctuated. The highest value was 4.44% in 25 kr at 30^{o}C for binucleate and the lowest value was 0.81% for both trinucleate and tetranucleate in the control at 25^{o}C and 15 kr at 30^{o}C.

The relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika and Cocoit induced by gamma rays, temperature and duration of temperature in expt.3 are shown in Figures 9 and 10.

The frequency of meiotic irregularity and pollen sterility in both the varieties appeared to bear the same relationship as

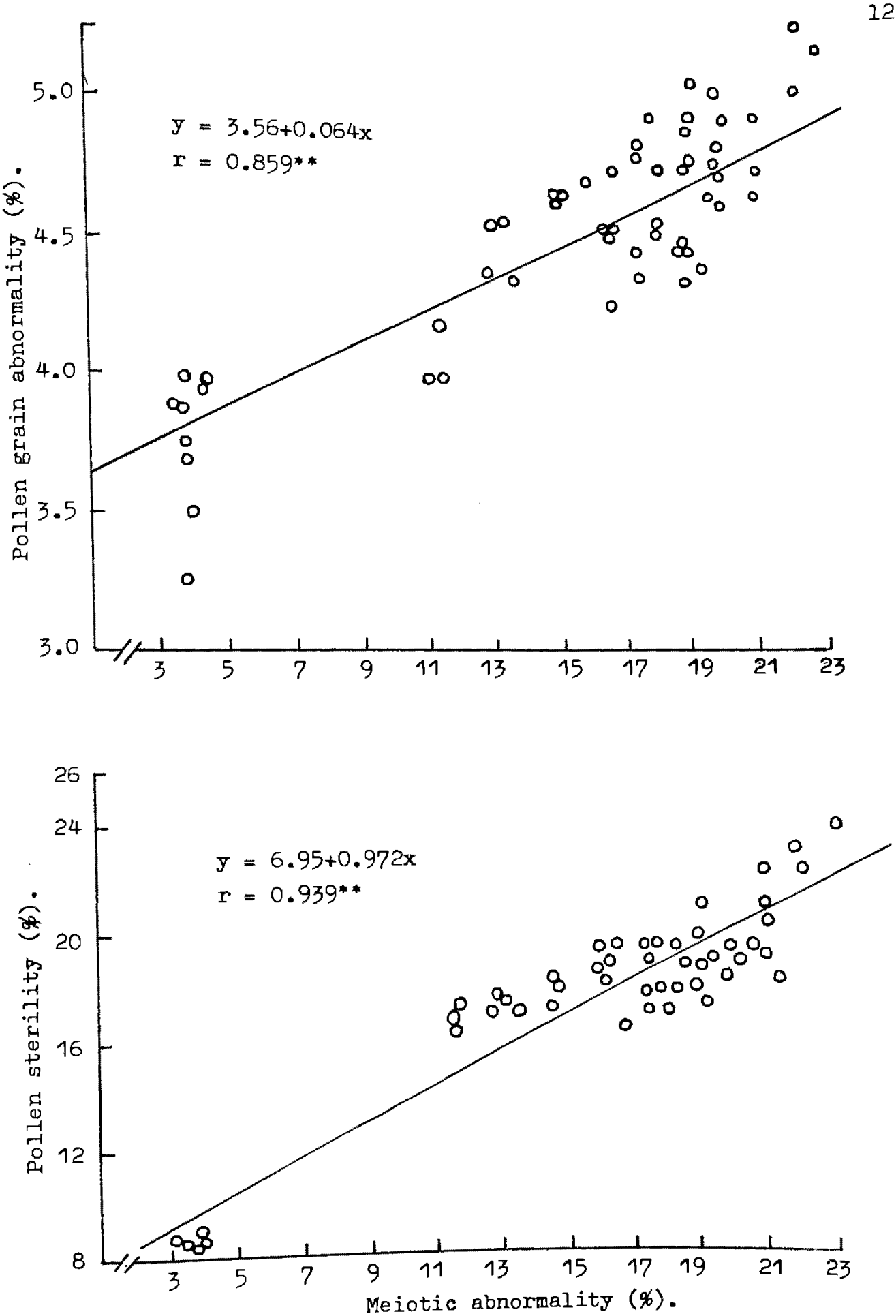


Figure 9. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3)

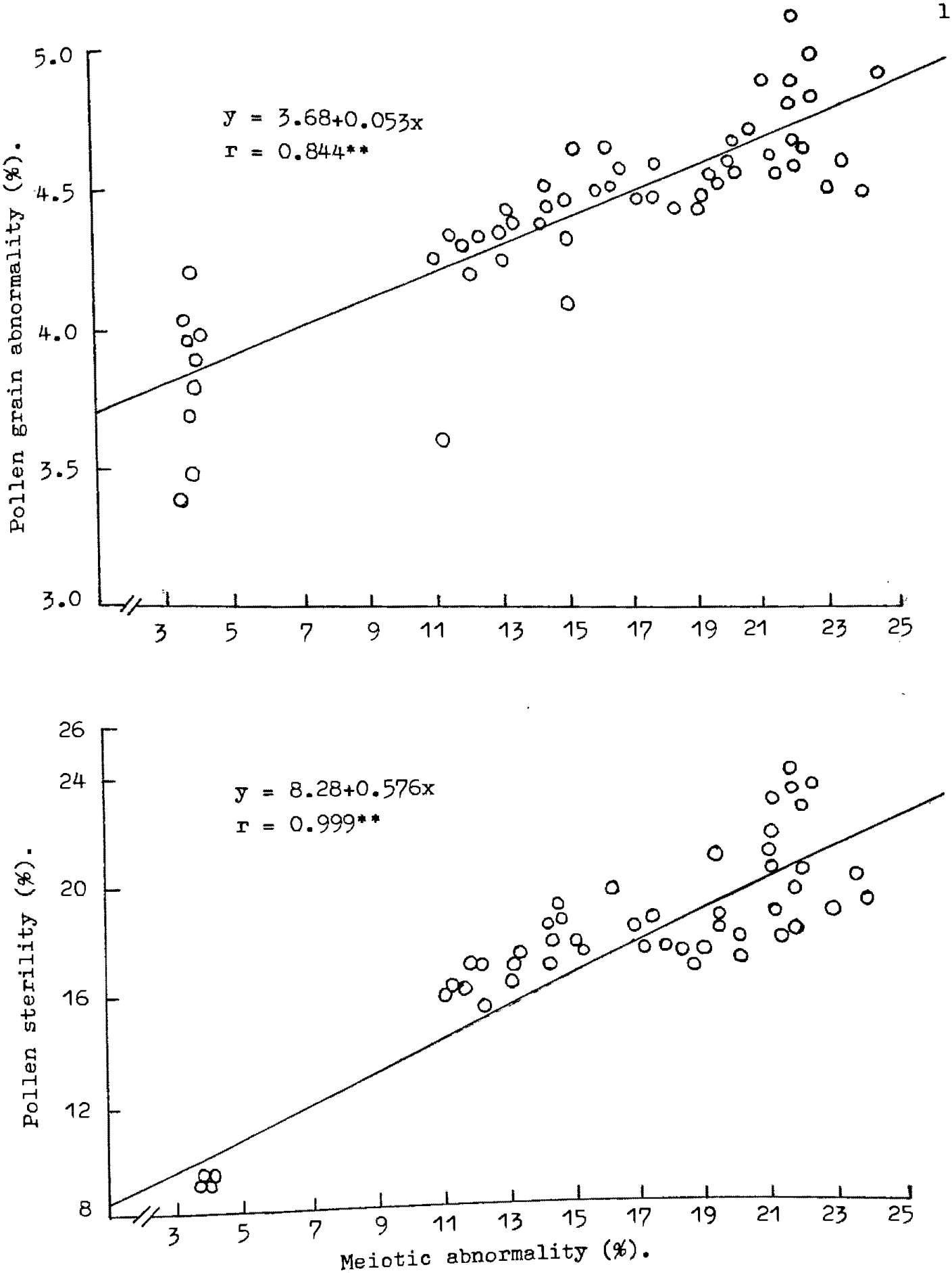


Figure 10. Relationship of pollen grain abnormality and pollen grain sterility with meiotic abnormality in Cocoit induced by gamma rays, temperature and duration of temperature (Expt.3)

that of pollen grain sterility. The gradual increase of meiotic abnormality, pollen grain abnormality and pollen sterility was observed from lower to higher dose of radiation in each treatment. It was also observed that the pollen grain abnormality and pollen sterility increased with an increase of meiotic irregularity in each treatment and their frequency appeared to be in close agreement with the frequency of meiotic irregularity of the corresponding treatment. For both the varieties pollen grain abnormality and pollen grain sterility were significantly and positively correlated with meiotic abnormality. The regression analysis indicated pollen sterility appeared to bear a closer relationship with meiotic abnormality than pollen sterility in both the varieties.

Yield And Yield Components Study :

Effect Of Gamma Rays :

Grain yield and its components in hexaploid and tetraploid wheat as affected by gamma rays (expt.3) are given in Table 25. For better presentation, grain yield/plant is also shown in Figure 11.

No. of tillers/plant, plant height, no. of spikes/plant, no. of spikelets/main spike, no. of grains/main spike and grain yield per plant of both the varieties were found to decrease gradually with the increase of radiation doses.

Table 25. Effect of gamma rays on grain yield and its components of hexaploid and tetraploid wheat (Ext. 3).

	Radiation dose (Kr)							
	0	5	10	15	20	25	30	LSD 5%
				Sonalika				
No. of tillers per plant	6.0	6.3	5.7	5.2	4.4	3.9	3.9	2.42
Plant height (cm)	75	69	63	59	58	52	46	8.75
No. of spikes per plant	6.6	6.6	6.0	5.9	4.7	3.7	3.7	1.24
No. of spikelets per main spike	18.0	14.7	14.3	13.0	12.2	10.9	9.1	2.33
No. of grains per main spike	46	42	40	39	36	30	27	2.01
Grain yield per plant (g)	8.2	6.3	5.1	4.3	4.2	3.2	2.9	1.22
				Cocoit				
No. of tillers per plant	9.7	8.2	8.4	7.4	5.9	6.3	4.9	2.96
Plant height (cm)	63	55	55	54	53	48	45	7.25
No. of spikes per plant	12.0	10.0	7.9	7.1	6.9	5.8	4.8	3.01
No. of spikelets per main spike	24.3	18.6	17.4	16.4	17.0	16.0	14.2	2.12
No. of grains per main spike	49	45	42	41	40	37	35	2.56
Grain yield per plant (g)	11.4	9.8	8.3	7.3	6.2	5.3	4.3	1.63

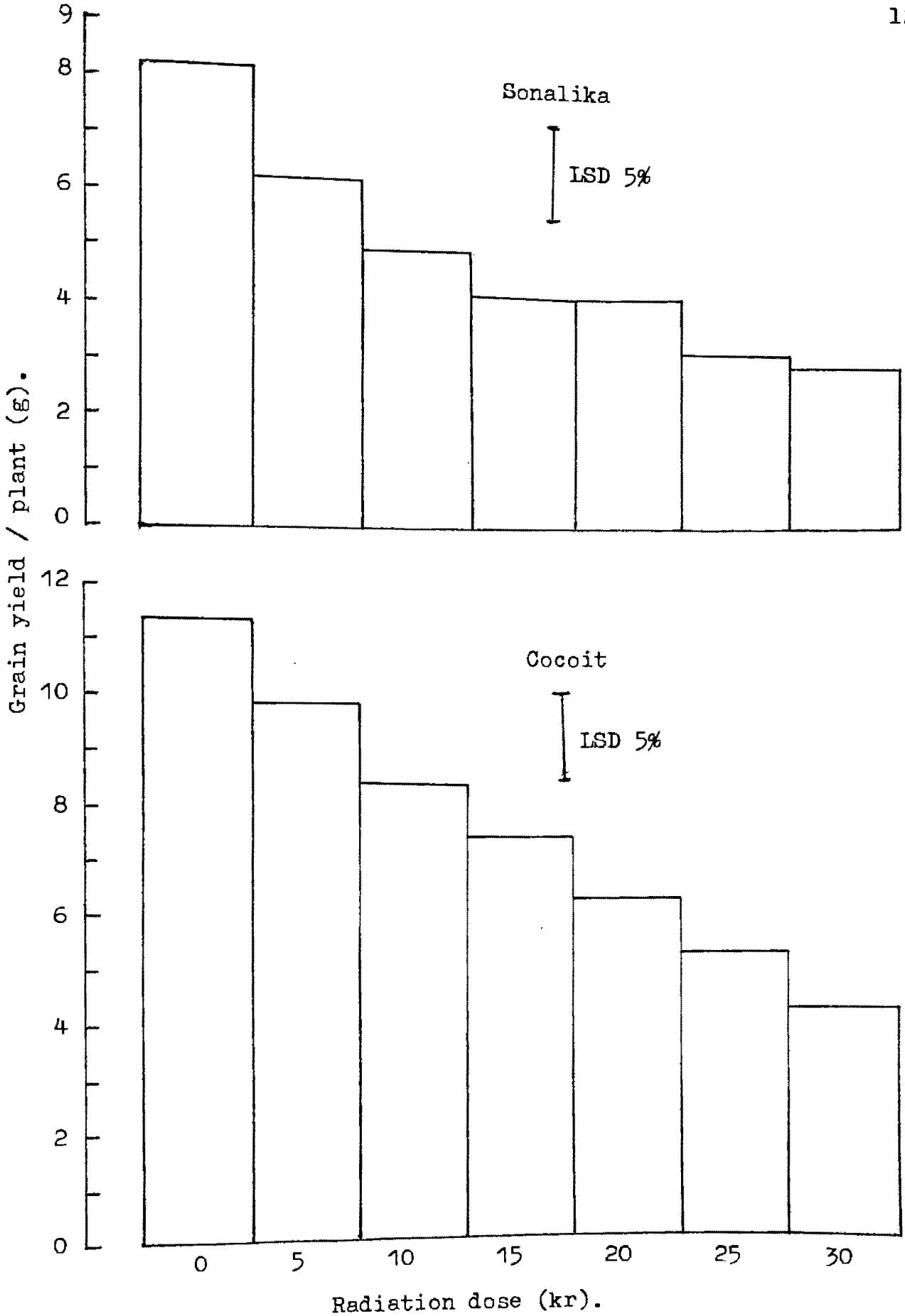


Figure 11. Effect of gamma rays on grain yield of Sonalika and Cocoit (Expt.3).

Between the two varieties, highest plant height was obtained in Sonalika but the other characters showed high values in Cocoit.

Effect Of Temperature (^{o}C) And Duration Of Temperature Treatment :

Effects of temperature (^{o}C) and duration of temperature treatment on grain yield and its components of hexaploid and tetraploid wheat (expt.3) are given in Table 26.

There were no significant effect of temperature (^{o}C) and duration of temperature treatment on grain yield and its components.

Effect Of Gamma Rays, Temperature (^{o}C) And Duration Of Temperature Treatment :

Interacting effects of gamma rays, temperature (^{o}C) and duration of temperature treatment on grain yield and its components of Sonalika and Cocoit (expt.3) are given in Tables 27 and 28 , respectively.

In case of 72 hours duration, no. of grains/main spike and grain yield of Sonalika were lowest at $35^{o}C$ and 30 kr. Such trend was not observed for 144 and 288 hours duration. Slight reduction of plant height and no. of grains/main spike was

Table 26. Effect of temperature and duration of temperature on grain yield and its components of hexaploid and tetraploid wheat (Expt. 3).

	Temperature (°C)				Duration (hour)			
	25	30	35	LSD 5%	72	144	288	LSD 5%
				Sonalika				
No.of tillers per plant	5.1	4.9	5.1	NS	4.6	4.9	5.6	NS
Plant height (cm)	61	61	59	NS	60	63	58	NS
No. of spikes per plant	5.6	5.8	4.8	NS	5.3	5.4	5.5	NS
No.of spikelets per main spike	12.6	13.9	13.0	NS	13.6	12.6	13.3	NS
No.of grains per main spike	38	39	36	NS	41	35	37	NS
Grain yield per plant (g)	4.8	4.8	5.0	NS	4.8	4.6	5.2	NS
				Cocoit				
No.of tillers per plant	7.0	7.4	7.4	NS	7.0	7.5	7.3	NS
Plant height (cm)	51	54	53	NS	53	55	51	NS
No.of spikes per plant	8.0	7.6	7.8	NS	7.6	8.2	7.5	NS
No. of spike-lets per main spike	17.7	18.4	17.8	NS	17.7	18.1	18.1	NS
No. of grains per main spike	43	42	39	NS	44	42	41	NS
Grain yield per plant (g)	7.3	7.3	7.8	NS	8.0	7.0	7.4	NS

Table 27. Interacting effect of gamma rays, temperature and duration of temperature on grain yield and its components of Sonalika (Expt. 3).

Temperature (°C)	Radiation dose (kr)	No.of tillers per plant	Plant height (cm)	No.of spikes per plants	No.of spile lets per main spike	No. of grains per main spike	Grain yield per plant (g)
				72 hours			
25	0	6	76	7	17	48	8.1
	5	5	63	6	15	46	6.6
	10	4	57	6	14	50	5.5
	15	4	52	5	12	52	4.9
	20	4	52	4	11	37	4.2
	25	4	50	4	11	35	2.7
	30	4	46	4	10	31	2.6
30	0	6	75	8	19	46	7.8
	5	6	69	7	16	49	6.7
	10	5	65	6	12	47	5.3
	15	4	60	6	12	43	4.2
	20	4	62	5	14	45	4.2
	25	3	52	4	12	34	2.7
	30	4	45	4	11	36	2.6
35	0	6	75	7	18	45	8.6
	5	6	68	6	15	42	7.2
	10	5	67	7	15	46	4.5
	15	5	62	6	16	39	4.1
	20	4	63	4	15	37	3.8
	25	4	54	2	11	29	2.6
	30	4	47	3	10	30	1.7

Contd. .....

Table 27. Continued.

144 hours

	0	6	76	7	17	48	8.1
	5	7	75	8	15	41	6.2
	10	7	69	6	15	42	5.7
25	15	5	72	6	11	34	3.7
	20	4	68	6	10	32	3.4
	25	4	60	4	8	30	2.5
	30	4	53	4	6	24	2.3
	0	6	75	8	19	46	7.8
	5	6	71	6	13	40	6.0
	10	5	63	7	15	39	4.7
30	15	5	58	6	14	40	3.4
	20	4	64	5	14	35	3.1
	25	4	55	5	13	29	3.0
	30	3	46	4	10	28	3.1
	0	6	75	7	18	45	8.6
	5	6	75	5	13	37	6.7
	10	6	68	4	13	35	4.6
35	15	6	61	5	13	30	3.4
	20	3	57	4	10	32	3.8
	25	3	50	3	9	30	3.5
	30	3	46	4	8	29	3.2

Contd. ....

Table 27. Continued.

		288 hours					
	0	6	76	7	17	48	8.1
	5	7	75	8	16	42	4.5
	10	6	65	7	15	39	4.1
25	15	6	55	6	14	40	4.6
	20	6	51	5	12	35	5.2
	25	5	48	4	10	28	4.1
	30	4	45	4	8	22	3.5
	0	6	75	8	19	46	7.8
	5	7	65	7	16	43	6.0
	10	6	63	6	16	46	5.7
30	15	6	63	7	13	42	5.6
	20	5	58	5	12	40	4.5
	25	4	52	4	12	32	3.8
	30	4	47	3	10	25	3.2
	0	6	75	7	18	45	8.6
	5	7	65	6	13	40	6.9
	10	7	52	5	14	41	5.4
35	15	6	51	6	12	36	5.2
	20	6	48	4	12	34	5.5
	25	4	49	3	12	30	4.2
	30	4	42	3	9	26	3.6

Table 28. Interacting effect of gamma rays, temperature and duration of temperature on grain yield and its components of Cocoit (Expt. 3).

Temperature (°C)	Radiation (kr)	No. of tillers per plant	Plant height (cm)	No. of spikes per plant	No. of spikelets per main spike	No. of grains per main spike	Grain yield per plant (g)
				72 hours			
25	0	9	62	11	22	52	10.2
	5	8	50	13	14	48	9.4
	10	8	56	8	16	46	7.5
	15	7	57	7	14	48	6.8
	20	7	58	6	16	46	7.1
	25	6	55	5	16	42	6.8
	30	6	52	5	16	41	6.4
30	0	10	65	12	25	48	11.5
	5	9	58	10	17	48	10.7
	10	7	50	7	16	42	10.8
	15	7	52	7	17	42	9.2
	20	7	52	6	18	40	7.2
	25	7	52	5	17	36	5.4
	30	4	43	4	10	32	3.2
35	0	10	63	13	26	47	12.4
	5	8	52	11	20	48	10.4
	10	9	52	8	16	42	8.5
	15	8	46	5	15	30	7.2
	20	6	48	7	14	32	6.5
	25	6	42	6	16	34	4.8
	30	4	47	4	14	26	5.2

Contd. ....

Table 28. Continued.

144 hours

25	0	9	62	11	22	52	10.2
	5	9	61	10	18	41	10.4
	10	8	58	9	19	37	8.3
	15	8	53	10	20	42	6.3
	20	7	48	8	19	42	6.3
	25	6	46	7	18	36	4.2
	30	5	42	6	14	36	3.4
30	0	10	65	12	25	48	11.5
	5	8	58	9	18	46	9.3
	10	8	61	7	18	46	7.2
	15	6	58	6	16	45	5.5
	20	7	55	7	18	45	4.4
	25	7	48	6	12	43	4.7
	30	6	45	5	14	36	3.2
35	0	10	63	13	26	47	12.4
	5	9	61	11	17	44	9.2
	10	9	58	8	19	44	8.6
	15	8	59	8	18	44	7.2
	20	7	59	9	19	42	6.2
	25	7	56	6	15	36	5.6
	30	4	48	4	15	29	4.2

Contd. .....

Table 28. Continued.

288 hours

	0	9	62	11	22	52	10.2
	5	8	52	8	18	45	10.6
	10	8	53	8	20	42	8.4
25	15	8	50	7	15	41	7.6
	20	7	46	7	18	42	5.2
	25	6	38	6	16	42	4.3
	30	5	40	5	18	45	4.0
	0	10	65	12	25	48	11.5
	5	7	55	10	22	42	8.9
	10	9	56	8	16	40	7.6
30	15	6	58	6	18	42	6.1
	20	7	52	7	15	40	6.2
	25	7	46	7	19	35	5.3
	30	6	42	6	15	37	4.4
	0	10	63	13	26	47	12.4
	5	8	50	8	23	48	9.4
	10	10	56	8	17	40	7.8
35	15	9	56	8	15	38	7.8
	20	5	55	5	16	37	6.7
	25	5	51	4	15	32	6.2
	30	4	48	4	12	35	4.5

observed with an increase of the duration of temperature treatment.

In case of Cocoit, effects of temperature (^{o}C) and duration of temperature treatment was less pronounced (Table 28). The lowest grain yield (3.2 g) was obtained at 30 kr, 30^{o}C and 144 hours duration. The lowest no. of grains/main spike (26) was observed at 30 kr, 35^{o}C and 72 hours duration of temperature treatment. This indicated that post-radiation ageing effect was less spectacular for grain yield and its components.

DISCUSSION

D I S C U S S I O N

The results obtained in the present study are discussed as follows :

Mitotic study

There is considerable correlation of the loss of seed viability, spontaneous chromosome aberrations, sensitivity to ionizing radiation and mutation frequency with the ageing of seeds. It seems probable that chromosome aberrations are involved in loss of viability and increase in mutation rate, but the factors involved in increased chromosome aberration frequency and increased sensitivity to ionizing radiation with the age of seed are unknown. In the present investigation, the effects of gamma radiation and artificial ageing induced by high temperature and their interactions on cytological and yield characters of tetraploid and hexaploid wheats were studied.

From the results of the effect of gamma rays on interphase chromosome volume (ICV), it was observed that ICV increased with the increase in gamma rays dose in both Sonalika (hexaploid) and Cocoit (tetraploid) (Tables 1 and 2 and Figure 1). However, the rate of increase of ICV was higher in Cocoit (2.631 um^3/kr) than Sonalika (1.707 um^3/kr).

The effect of temperature (^oC) and duration of temperature treatment on ICV was significant for both the varieties (Tables 3 and 4). The highest ICV was found at 35^oC and 288

hours duration of temperature, and the lowest values were observed at 25°C and 72 hours of the duration of temperature treatment. The interacting effects of gamma rays, temperature and duration of temperature on ICV indicated that the highest ICV was obtained at 30 kr radiation, 35°C temperature and 288 hours duration of temperature treatment (Tables 6 and 7).

Yamakawa and Sparrow (1965, 1966) reported that ICV is a reliable index of radiosensitivity in plants. Their work established a positive correlation between radiation sensitivity and chromosome volume in plant cells. Sparrow et al. (1968) found that increase in mutation rate per roentgen in five higher plants was highly correlated with an increase in both ICV and DNA content per chromosome. Nayer et al. (1970) also reported that radiosensitivity of plants measured in terms of meiotic abnormalities in pollen mother cells growing in high radiation area of Kerela coast and adjoining regions in the South India was found to show significant positive correlation with ICV. Underbrink et al. (1973) reported positive roles of ICV, nuclear volume and ploidy on the degree of pollen abortion induced by radiation.

ICV is considered to be a reliable index of mutagen sensitivity in plant cells. ICV is related to the alteration in cell membrane configuration and permeability, modification of

chromosomal proteins and changes in sensitivity to chemicals.

Percentages of dividing cells in root tips of both the varieties generally decreased and abnormal cells increased with the increase of gamma rays (Tables 1 and 2 and Figure 2). The rate of decrease of the percentage of dividing cells was higher in Cocoit and the rate of increase of the percentage of abnormal cells was higher in Sonalika (Figure 2).

In both Sonalika and Cocoit, the highest percentage of abnormality was found at 35°C and 288 hours duration of temperature treatment and the lowest values were at 25°C and 72 hours duration of temperature treatment. The reverse result was obtained for the percentage of dividing cells (Tables 3 and 4).

Cytological studies of mitosis revealed that both gamma rays and temperature were capable of inducing the chromosomal aberrations in both the tetraploid and hexaploid varieties (Appendices 1-4 and Plate 1). Most of the abnormal cells were characterized by inhibited chromosomes (C-metaphase), disturbed anaphase, bridges, clumping, fragments, lagging chromosomes, rings and micronuclei.

Barber and Callan (1942) observed that the progress of cell division might be modified or suppressed by a great variety of agents. Subnormal temperature is known to interfere with the

mitotic spindle in plant cells (Darlington and La Cour, 1940). Shkvarnikov (1936, 1939), Shkvarnikov and Navashin (1934, 1935) and Navashin and Shkvarnikov (1933a,b) found that the treatment of fresh seeds of wheat and Crepis with temperature of 50-60°C for 20 days had a comparable effect on the production of chromosome aberrations with that of ageing at room temperature for 6-7 days. On the other hand, Smith (1943, 1946) reported that exposing seeds of cereals to temperatures of 50-70°C for 5-15 days or 80°C for 45-80 minutes had little, if any, effect upon the frequency of chromosome aberrations.

In the present experiment, the frequency of abnormal cells at different stages of mitosis were found to correlate with gamma rays, temperature and duration of temperature treatment. The frequency of abnormal cells were recorded at metaphase, anaphase and telophase. Maximum abnormalities were observed at metaphase. Main abnormalities were fragments, laggards, inhibited chromosome and micronuclei. Specially bridges were structurally easily obserable at anaphase and telophase. Binucleate and trinucleate cells were observed, but tetranucleate cells were very rare. Jain and Sarbhay (1987) found a considerable fall in the mitotic index of Lens and Pisum induced by chlorinated hydrocarbon. Mitotic abnormalities like clumped chromosomes, fragments, micronuclei, laggards and bridges have been observed by many workers in studying the chromosome breaking abilities of different toxic materials (Swaminathan et al.,

1962 ; Bose and Shaha, 1970 ; Bose and Bandyopadhyay, 1977 ; Bandyopadhyay and Bose, 1979 ; 1980).

Any physical factor may disturb the respiratory pathways of plants which results abnormalities. It is reported that the rate of mitosis is closely related to the resultant level of ATP. Rosch (1950) observed inhibition of mitosis in root tip cells of Allium cepa when irradiated with slow neutrons or x-rays.

Jain and Sarbhoy (1987) stated the probable cause of lagging chromosomes, that the chromosomes start contraction at metaphase and anaphase while as a result of pesticide treatment the chromosomes could not reach to the poles and remained scattered in the cytoplasm. Klasterska et al. (1976) suggested that chromosome stickiness arises due to improper folding of chromosome fibres into single chromatid and chromosome subsequently leads to the loss of genetic material, and then the micronuclei is found.

At anaphase and telophase stages bridges were most frequent type and they were found in all the treatments. The separation of the chromatid at mid-prophase of mitosis is a strong deviation from the normal one. Generally, the chromatids separate only at late metaphase after some biochemical reactions take place between the two sister chromatids (Sybenga, 1974). When a pair of fragments were found in the cell at anaphase

apart from those which were single (chromatid) may have arisen due to breakage of chromosome rather than chromatids (Caldercott and Smith, 1952). Yagyu and Morris (1957), Prasad (1972), Kalloo (1972), Shaikh and Godward (1974) and Singh and Godward (1974) reported that the paired bridges at anaphase were found and it was due to the fusion between broken chromosomes rather than broken chromatids. Goplan & Njagi (1984) reported the formation of similar anaphase bridges in Vicia faba root tip cells with a variety of agents.

In the present investigation, the rate of increase of ICV per unit gamma rays was higher in the tetraploid (Cocoit) than the hexaploid (Sonalika) wheat. But the percentages of dividing cells and abnormal cells were more or less similar in the two varieties. Stadler (1929) and Froier et al.(1941) have shown that polyploid cereal seeds are able to survive in more severe x-ray treatment than the related diploid species. In addition, Smith (1946) made a direct comparison between the effects of heat and x-rays on a wide variety of diploid and polyploid cereals and concluded that diploids were as tolerant of high temperatures as polyploids, but the polyploids showed greater tolerance to x-rays.

Meiotic study

Meiotic study in the present investigation indicated that the percentages of dividing PMCs generally decreased, and

abnormal PMCs , pollen sterility and pollen grain volume increased with the increase of gamma rays in both the varieties (Tables 8 and 9 and Figure 3). It was also observed that the effect of gamma rays on the tetraploid and hexaploid varieties was not pronounced in respect of these meiotic characters.

Percentages of abnormal PMCs, pollen sterility and pollen grain volume increased and dividing PMCs decreased with the increase of temperature (^{o}C) and duration of temperature treatment (Tables 10-12). In both the varieties, the highest percentages of abnormal PMCs, pollen sterility and pollen grain volume were observed at $35^{o}C$ and 288 hours duration of temperature treatment (Table 11). In case of the percentage of dividing PMCs, the highest value was observed at $25^{o}C$ and 72 hours duration and the lowest value at $35^{o}C$ and 288 hours duration.

The results of meiotic study indicated that chromosome fragment, lagging chromosome, bridge and micronuclei were the main chromosomal aberrations in the pollen mother cells. The percentages of fragments and lagging chromosomes were higher than the bridges and micronuclei (Appendix Tables 5-7).

Tarar and Dayansagar (1980) observed varying degree of meiotic irregularities in plants induced by gamma rays. Gupta and Gupta (1977) reported that gamma rays and EMS induced structural changes in the chromosomes of Crotalaria juncea.

They observed quadrivalents, multivalents, fragments and laggards from the treated plants. Structural changes in both mitotic & meiotic cells of four species of legumes were reported by Shaikh *et al*. (1980). They observed bridges, fragments, micronuclei, laggards and degenerated cells in the mitotic cells, and fragments of nucleolus, univalents, rings & fragments in the meiotic cells. Gamma rays induced chromosomal abnormalities in the first meiosis of two tetraploid wheat varieties were reported by Shaha *et al*. (1980). The abnormalities observed by them were laggards, unequal distribution of chromosomes at anaphase I and formation of micronuclei at telophase I. Shaikh (1972) noticed increased percentage of abnormal cells in *Lathyrus sativus* & *Vicia ervilia* treated with gamma rays.

Sudhakaran (1971) and Jayabalan and Rao (1987) reported that the aberrant behaviours of bivalents and multivalents which lag in different stages might be due to delayed terminalization or stickiness of the ends of the chromosome. Chromosome bridges arise by failure of terminilazation in a few cells. Such bridges have been reported by Sax (1960).

Cells from the control plants were also found with different kinds of aberrations similar to the aberration of gamma rays and temperature treated plants, but in low frequencies. Giles (1954) interpreted the occurence of such aberrations in the untreated plants as spontaneous in origin & the frequency

of such aberations is usually very low as compared to the frequency of treated plants.

The correlation study revealed that the positive correlation between the gamma rays dose & percentage of pollen sterility was significant for both the varieties (Figure 4). Percengate of pollen sterility increased with the increase of temperature (^{o}C) & duration of temperature treatment (Table 12). Alam & Kabir (1983) reported that pollen grain abnormality & pollen sterility increased with an increase of meiotic irregularity & their frequency appeared to be in close agreement with frequency of meiotic irregularity. Jayabalan & Rao (1987) reported that the frequency of meiotic abnormalities & pollen sterility demonstrated a linear relationship with concentration of the mutagens. Bennet and Rees (1972) observed that the pollen maturation time in rye & wheat decreased as temperature increased from 15 to 25^{o}C. Qian & Liang (1986) studied the effect of low temperature and genotypes on pollen development in wheat and stated that duration of pollen maturation is influenced both by temperature and genotype.

Effect of gamma rays on chromosome association & chiasma frequency were recorded at diakinesis/first metaphase and indicated that univalent was absent in control of both the varieties (Tables 15 and 16). Frequency of ring bivalent was more than rod. Quadrivalent was not observed in the control as well as in any

of the radiation doses. Chiasma frequency of all the radiation induced material doses/was less than the control. Mean chiasma frequency per PMC and per bivalent varied little among the different temperature regimes & duration of temperature treatment (Tables 17 and 18).

Lawrence (1960) studied the effect of irradiation on developmental stages of microsporogenesis for chiasma frequency in Lilium and Tradescantia. His study indicated that the sensitive periods restricted to late zygotene and early pachytene stage. He stated that the chiasma frequency following mutagenic treatments might occur at two stages namely during DNA synthesis and the second sensitive period at or slightly before the stage during which chiasma formation is generally considered to occur. In the former case, the decrease in the frequency of chiasmata may be due to the disturbance in chromosome coiling, failure or restricted pairing at pachytene and delay in DNA synthesis, while in the latter it may affecting the process leading to chiasma formation.

Yield and Yield Components

Grain yield and some of its components of both the varieties were affected by gamma rays. It had retarding effect (Table 25). But post-radiation temperature (^{o}C) & duration of temperature treatment had no significant effect on grain yield & its components (Table 26).

Killion and Constantin (1971) reported that gamma irradiation reduced plant survival, height and grain yield. Grain yield was more severely affected than plant height. Similar results were reported for wheat by Davies (1968) and Matsumura & Fujii (1963), for barley by Davies (1970) and Hwrmelin (1967, 1970) and for rice by Kawai & Inoshita (1965).

Davies (1968) observed that some enhancement of tillering in wheatwas caused by gamma irradiation and increased tillering was always associated with some retardation in the development of the main axis and thus, enhanced tillering can be attributed to be release of apical dominance. The interruption of the production of auxin or its transport from the apical meristem can therefore be inferred. However, despite evidence that auxin synthesis may be particularly sensitive to radiation (Gordon, 1957 ; Leopold & Thimann, 1949) the present result cannot be regarded as evidence that the primary effect of radiation is necessarily on the mechanism of auxin synthesis. The alternative interpretation is that the primary effect of radiation was on the development of meristematic cells, effects on auxin supply being a consequence of this as supported by the findings of Davies (1968). However tillering was reduced with the increase of gamma rays in the present investigation.

The adverse effect of gamma rays on seedling height might

be the result of mitotic inhibition (Rajput, 1970 ; Deyson, 1956 ; Gray, 1956) or due to physiological changes (Pele & Howard, 1956). Conger & Stevenson (1969) reported that there existed a parallelism between the reduction in seedling height and chromosomal damage in irradiated barley seeds.

In the present study, the effect of constant temperature (^{o}C) and duration of temperature treatment on grain yield and its components was non-significant. Post-radiation temperature effect was not pronounced. But cytological study indicated that temperature increased chromosomal aberrations.

The reduction in the weight of the seeds per plant caused by radiation in the present study is only a partial measure of the extent to which the value of crops would be affected. The reduction in grain size would affect its milling quality and, in addition, the germination of seed could be considerably impaired.

Seeds of tetraploid & hexaploid wheats had been included in this study to ascertain the effect of ploidy on susceptibility to gamma rays and temperature. From the result of the present experiment it is difficult to arrive at any conclusion. However, cytological data, indicated that for a given dose of radiation there may be a decrease in sensitivity with increasing the level of ploidy.

SUMMARY

SUMMARY

This investigation was undertaken to study the post-irradiation ageing effect on chromosomal structural changes and yield in wheat. The wheat materials used were Triticum aestivum L. cv. Sonalika (hexaploid) and T. durum Desf. cv. Cocoit (tetraploid).

Air-dried seeds of these two wheat varieties were subjected to 5, 10, 15, 20, 25 and 30 kr of gamma rays from 650, 50,000 Curie Co^{60} source at the dose rate of 297 kr/hour. Artificial ageing of the seeds was made by three constant temperature (25, 30 and 35°C) treatment for three different durations (72, 144 and 288 hours). Control seeds were neither irradiated nor treated with temperature.

Three experiments were conducted in this study viz., (i) effect of gamma rays, (ii) effect of temperatures (°C) along with treatment duration (hrs) and (iii) effect of gamma rays, temperatures (°C) and durations (hrs) of temperature treatment.

For the study of mitosis, treated and untreated seeds were allowed to germinate on moist filter paper in petri dishes in the laboratory at room temperature. Healthy root tips were fixed in 1:3 aceto-alcohol and preserved in 70% ethanol. Root tip cells were stained following the schedule of haematoxylin method.

For the study of meiosis and grain yield, plants were raised in the experimental field following the split plot design with three replications. Young inflorescences of these field-grown plants were fixed in Carnoy's fixative and chromosomes were stained with 2% acetocarmine. Data for grain yield were recorded from the undisturbed plants at the time of harvest. For pollen sterility potassium iodide solution was used.

For the study of pollen grain abnormality ripe yellow anthers from the same plants used for meiotic study were fixed following the schedule of Jagathesan and Sreenivashan (1966) and using lenco-basic fuchsin as stain.

Gamma rays were found to increase significantly interphase chromosome volume (ICV) and percentage of abnormal cells, and also found to decrease percentage of dividing cells in root tips of both the varieties. Like gamma rays, temperatures (^{o}C) and durations (hrs) of temperation treatment had similar effects on these three characters. The highest ICV and percentage of abnormal cells were observed at 30 kr, 35^{o}C and 288 hrs. of treatment duration. Less variability was observed for percentage of dividing cells.

Cytological studies of mitosis revealed that both gamma rays and temperature were capable to induce structural changes of chromosome in both the tetraploid and hexaploid varieties. Most of

the abnormal cells were characterized by inhibited chromosomes (C-metaphase), disturbed anaphase, bridges, clumping, fragments, lagging chromosomes, rings and micronuclei.

Percentage of dividing pollen mother cells (PMCs) studied from the plants raised from irradiated seeds was lower than that of control. But percentage of abnormal pollen mother cells, pollen sterility and pollen grain volume were found to increase by gamma rays. Similar effects were observed in PMCs of those plants which were raised from the temperature treated seeds. Post-irradiation ageing also affected these characters.

Meiotic study indicated that the chromosome fragments, laggards, bridges and micronuclei were the main chromosomal aberration in pollen mother cells of both the varieties. It also indicated that the frequency of these abnormalities were increased with the increase of the doses of inducing factors.

Data on chromosome association and chiasma frequency revealed that bivalents were predominants in all the treatments. Trivalents were obtained but with less frequency. Quadrivalent was totally absent. Predominancy of ring bivalent was observed than rod. Mean chiasma frequency per PMC and per bivalent varied little among the plants treated with different degrees of temperature and different durations (hrs) of temperature treatment.

Study on pollen grain cytology indicated that the abnormality of pollen grain increased with the increase of the doses of gamma rays in Sonalika, but in Cocoit it fluctuated. Temperature (^{o}C) and duration of (hrs) of temperature treatment showed more or less similar effects. The abnormalities were mono-, abnormal bi-, tri - and tetranucleate. Mono - and abnormal binucleate were of most frequent followed by tetra then trinucleate. Meiotic abnormality in both the varieties were found to show positive and significant relationship with both pollen grain abnormality and pollen sterility.

Grain yield and some of its components of both the varieties were found to reduce by gamma rays. But post-irradiation ageing (temperature and duration of temperature treatment) had no significant effect on grain yield and its components. The effect of polidy on gamma rays and temperature was not pronounced.

REFERENCES

REFERENCES

Abdalla, F.H. and E.H. Roberts. 1968. Effects of temperature, moisture, and oxygen on the induction of chromosome damage in seeds of barley, broad beans, and peas during storage. Ann. Bot. 32 : 119-136.

Abidi, Z.H. and M.I. Haq. 1970. Radiation induced mutations effect of gamma irradiation upon pollen fertility, pollen size and meiotic behaviour in Brassica campestris L. Agric. Pak. 21 : 47-56.

Akbar, M., M.I. Inoue, H. Hasegawa and S. Hori. 1976. Comparative radiosensitivity in Indica and Japonica rice. The nucleus (Pak.) 13 : 25-29.

Akhter, F.N., G. Kabir, M.A. Mannan and N.N. Shaheen. 1992. Aging effect of wheat and barley seeds upon germination, mitotic index and chromosomal damage. J. Islamic Acad. Sci.(Turkey) 5 : 44-48.

Alam, S. and G. Kabir. 1983. Studies on pollen grain abnormality in barley (Hordeum vulgare L.). Bangladesh J. Bot. 12 : 19-27.

Bandopadhyay, B. and S. Bose. 1979. Induced morphological variants in Phaseolus aureus L. Sci. Cult. 45 : 284-286.

Barber, H.N. and H.G. Callan. 1942. The effects of cold and colchicine on mitosis in the newt. Proc. Roy. Soc. B. 258-271.

Bennett, M.D. and H. Rees. 1969. Induced and developmental variation in chromosomes of meristematic cells. Chromosoma. 27 : 226-244.

Bhadra, S.K. and M.M. Mia. 1975. Comparative radiosensitivity of diploid and colchicine induced tetraploid Corchorus capsularis L. Bangladesh J. Bot. 4 : 155-159.

Bhattacharyya (Ganguli), S. and S. Sen-Mandi. 1985. Studies into causes of non-germination of aged wheat seeds. Ann. Bot. 56 : 475-479.

Biebl, R. and I.Y. Mostafa. 1965. Water content of wheat and barley seeds and their radiosensitivity. Radiation Bot. 5 : 1-6.

Bose, S. and A. Shaha. 1970. Cytogenetic effects of X-rays and chemicals in tomato, Studies in the M_1 generation. Nucleus. 13 : 29-40.

Bose, S. and B. Bandyopadhyay. 1977. Cytological effects of pre- and post-irradiation treatments with ethylene glycol, ethyl methane sulphonate and hydroxamine in pigeon pea (Cajanus cajan). Sci. Cult. 43 : 274-275.

Caldecott, R.S. and L. Smith. 1952. A study of X-ray induced chromosomal aberrations in barley. Cytologia 17 : 225-242.

Caldecott, R.S., B.H. Beard and C.O. Gardner. 1954. Cytogenetic effects of X-ray and thermal neutron irradiation on seeds of barley. Genetics. 39 : 240-259.

Cartledge, J.L., L.V. Barton and A.F. Blakeslee. 1936. Heat and moisture as factors in the increased mutation rate from Datura seeds. Proc. Am. Phil. Soc., 76 : 663-685.

Conger, A.D. and H.Q. Stevenson. 1969. Correlation of seedling height and chromosomal damage in irradiated barley seeds. Radiation Bot. 9 : 1-4.

D'Amato, F., 1951. Spontaneous chromosome aberrations in seedlings of Pisum sativum. Caryologia, 3 : 285-93.

Darlington, C.D. and L.F. LaCour. 1940. Nucleic acid starvation of chromosomes in Trillium. J. Genet. 40 : 185-213.

Davies, C.R. 1968. Effects of gamma irradiation on growth and yield of agricultural crops-I. Spring sown wheat. Radiation Bot. 8 : 17-30.

Deyson, G. 1956. Les features de mito inhibition vegetable. In: Les features de la crossance cellulaire. 241-279.

Donini, B., G.T.S. Mugnozza and F. D'Amato. 1964. Effects of chronic gamma irradiation in Durum and bread wheats. Radiation Bot. 4 : 387-393.

Emery, D.A., E.G. Boardman and R.E. Stucker. 1970. Some observation on the radiosensitivity of certain varietal and hybrid genotypes of cultivated peanuts (Arachis hypogaea L.). Radiation Bot. 10 : 267-272.

Epel, D. 1963. The effect of carbon monoxide inhibition on ATP level and the rate of mitosis in the sea urchin eggs. J. Cell Biol. 17 : 315-317.

Froier, K., O. Gelin and O. Gustafsson. 1941. The cytological response of polyploidy to X-ray dosage. Bot. Notiser. 2 : 199-216.

Ganguli, S. and S. Sen-Mandi. 1990. Some physiological differences between naturally and artificially aged wheat seeds. Seed Sci. and Technol. 18 : 507-514.

Giles, N.H. 1954. Radiation induced chromosomal aberrations in Tradescantia. In : A. Hollander (ed.) Radiation Biology. McGraw Hill Book Co. N.Y.

Gilyarovskaya, T.T. 1973. The effect of different terms of barley seeds storage on changes in the spectrum of chromosome aberrations induced by gamma-irradiation. Genetika. 9(7) : 12-20.

Gopalan, H.N.B. and G.D.E. Njagi. 1984. A F_2 induced chromosome aberrations in Vicia faba root meristematic cells. Cytologia 49 : 209-214.

Gordon, S.A. 1957. The effects of ionizing radiation on plants. Biochemical and physiological aspects. Quart. Rev. Biol. 32 : 3-14.

Gray, L.H. 1956. Biochemical damage from ionizing radiation. Proc. Int. Conf. Peaceful uses of Atomic Energy. Geneva. 11 : 209-212.

Gunthardt, H., L. Smith., M.E. Haferkamp and R.A. Nilan. 1953. Studies on aged seeds II. Relation of age of seeds to cytogenetic effects. Agron. J. 45 : 438-441.

Gupta, P.K. and R. Gupta. 1977. Gamma rays and EMS induced structural changes in chromosomes of Crotalaria juncea L. Chromosome Information Ser. No. 22 : 12-13.

Haque, A., M.A. Ali, M. Waxuddin. and M.A. Khan. 1976. Squash method for the mitotic chromosomes of grasses. Curr. Sci. 45 : 382-383.

Hermelin, T. 1967. Effects of acute gamma irradiation in barley at different ontogenetic stages. Hereditas 57 : 298-302.

Hermelin, T. 1970. Effects of acute gamma irradiation on growing barley plots. Hereditas 65 : 203-226.

Jagathesan, D. and G.R.K. Sastry. 1963. Studies on the effects of ionizing radiations in diploid and tetraploid species of Gossypium. Indian J. Genet. Plant Breed. 23 : 290-299.

Jagathesan, D. and T.V. Sreenivasan. 1966. A pollen squash technique for Saccharum and related genera. Stain Tech. 41 : 43-47.

Jain, H.K. and R.K. Sarbhoy. 1987. Cytological studies on the effect of some chlorinated pesticides. I. Effect on somatic chromosome of Lens and Pisum. Cytologia 52 : 47-63.

Jayabalan, N. and G.R. Rao. 1987. Gamma radiation induced cytological abnormalities in Lycopersicon esculentum Mill. Var. Pusa Ruby. Cytologia 52 : 1-4.

Kalloo, S. 1972. Chromosomal alternations in mitotic and meiotic system as influenced by gamma rays in Pisum. Cytologia 37 : 643-651.

Kapoor, M.I., B.C. Joshi and A.T. Natarajan. 1965. Effect of chronic gamma irradiation on epidermal hairs of some varieties of wheat and barley. Radiation Bot. 5 : 265-269.

Kawai, T. and T. Inoshita. 1965. Effects of gamma ray irradiation on growing rice plants. I. Irradiation at four main developmental stages. Radiation Bot. 5 : 233-255.

Killion, D.D. and M.J. Constantin. 1971. Acute gamma irradiation of the wheat plant : Effects of exposure, exposure rate, and developmental stage on survival, height, and grain yield. Radiation Bot. II : 367-373.

Klasterlka, I., A.T. Natarajan and C. Ramel. 1976. An interuption of the origin of chromatid aberrations and chromosome stickiness as a category of chromatid aberrations. Hereditas, 83 : 153-158.

Konzak, C.F. and W.R. Singleton. 1952. Relationship of ploy-ploidy to the effects of thermal neutron exposure. Genetics, 37 : 596-597.

Lawrence, C.W. 1960. The effect of the irradiation of different stages in microsporogenesis on chiasma frequency. Heredity, 16 : 83-89.

Leopold, A.C. and K.V. Thimann. 1949. The effect of auxin on flower initiation. Amer. J. Bot. 36 : 342-347.

Mackey, J. 1959. Mutagenic response in Triticum at different levels of ploidy. Proc. 1st Internatl. wheat Genetics Symp. Winninpeg. : 88-111.

Matsumura, S. 1961. Radiation genetics in wheat-VII. Comparison of radiation effects of beta- and gamma rays on diploid wheat. Radiation Bot. 1 : 155-164.

Matsumura, S. and T. Fujii. 1963. Effects of accute and chronic irradiations on growing wheat. Seiken Ziho. 15 : 59-66.

Matsumura, S., S. Kondo and T. Mabuchi. 1963. Radiation genetics in wheat. VIII. The RBE of heavy particles from B/10 (N,α) Li^7 reaction for cytogenetic effect in einkorn wheat. Radiation Bot. 3 : 29-40.

Natarajan, A.T. and M.M. Maric. 1961. The time-intensity factor in dry seed irradiation. Radiation Bot. 1 : 1-9.

Navashin, M.S. 1933. Ageing of seeds as a cause of chromosome mutations. Planta, 20 : 233-43.

Navashin, M.S. and P. Shkvarnikov. 1933a. Process of mutation in resting seed accelerated by increased temperature. Nature, Lond., 132 : 482-483.

Navashin, M.S. and P. Shkvarnikov. 1933b. The acceleration of the process of mutation in seeds increased by temperature. Priroda, Leningrad, No. 10 : 54-55.

Navashin, M.S. and H.N. Gerassimova. 1936a. Nature und Ursachen der Mutationen, I. Das Verhalten und die Zutologie der Pflanzen, die aus infolge Alterns mutierten keimen stammen. Cytologia, 7 : 324-362.

Navashin, M.S. and H.N. Gerassimova. 1936b. Nature und Ursachen der Mutationen. III. Uber die chromosomenmutationen, die in den Zellen von ruhenden Pflanzenkeimen bei deren Altern auftreten. Cytologia, 7 : 437-465.

Nayer, G.G., K.P. George and A.R. Gopal-Ayengar. 1971. The relation between cytological abnormalities and interphase chromosome volume in plants growing in a high radiation area. Radiation Bot. II : 175-178.

Nichols, C. 1941. Spontaneous chromosome aberration in Allium. Genetics, 26 : 89-100.

Nilan, R.A. 1956. Factors governing plant radiosensitivity. Atomic Energy Conf. Rept. No. TID-7516 : 151-162.

Nilan, R.A. and H.M. Gunthardt. 1956. Studies on aged seeds.III. Sensitivity of aged wheat seeds to X radiation. Caryologia, 8 : 316-322.

Ouang, T.Y. and W.T. Chang. 1958. Mutation in rice induced by X-raidation. Proc. 2nd Intern. Conf. Peaceful uses of Atomic Energy, New York : United Nations. 27 : 223-226.

Pele, S.R. and A. Howard. 1956. Effects of fractioned X-ray doses on DNA synthesis and growth in Vicia faba roots. In : Progress in Radiobiology. Oliver and Boyd.

Peto, F.H. 1933. The effect of ageing and heat on the chromosomal mutation rate in maize and barley. Can.F. Res. 9 : 261-264.

Prasad, M.V.R. 1972. A comparison of mutagenic effectiveness and efficiency of gamma rays, EMS, NMU and NG. Indian J. Genet. Plant Breed. 32 : 361-367.

Qian, C.M. and G.H. Liang. 1986. Effects of low temperatures and genotypes on pollen development in wheat. Crop Sci. 26 : 43-46.

Rahman, M.S. and M.M. Mia. 1970. Effect of gamma-irradiation on the seeds of Corchorus capsularis L. and C. olitorius L. Pak. J. Bot. 2 : 19-24.

Rahman, M.M. 1972. Effects of low and high doses of gamma-rays on Allium sativum, Ipomoea batatas and Solanum melongena. Nuclear Science and Applic. 6 : 6-8.

Roberts, E.H. and F.H. Abdalla. 1967. The influence of temperature, moisture, and oxygen on period of seed viability in barley, broad beans, and peas during storage. Ann. Bot. 32 : 97-117.

Roberts, E.H. 1973. Loss of seed viability : Chromosomal and genetical aspects. Seed Sci. and Technol. I : 515-527.

Rosch, E.M. 1950. Nuclear cell division in Allium cepa as influenced by slow neutrons and X-ray. Bot. Get. 112 : 331-348.

Sadykhov, A.M. 1973. Sensitivity of wheat seeds of different age of chemical mutagens. Genetika. 9 : 25-30.

Sax, K. and H.J. Sax. 1961. The effect of age of seed on the frequency of spontaneous and gamma ray induced chromosome aberrations. Radiation Bot. 1 : 80-83.

Sax, K. and H.J. Sax. 1963. The effect of chronological and physiological ageing of onion seeds on the frequency of spontaneous and X-ray induced chromosome aberrations. Radiation Bot. 4 : 37-41.

Shaha, A.K., A.J. Miah and S.K. Bhadra. 1980. Meiotic anomalies induced by gamma rays and EMS in wheat of different ploidy levels. Abst. 4th & 5th Annual Bangladesh Sci. Conf. Rajshahi. p. 109.

Shaikh, M.A.Q. 1970. Morphological abnormalities detected in the M_1 generation of Vicia ervilia and Lathyrus species following gamma irradiation of dry seeds. The Nucleus (Pak.) 7 : 183-189.

Shaikh, M.A.Q. 1972. Dose-effect relationships of gamma radiation as determined by chromosomal aberrations and nuclear damage in Lathyrus sativus L. and Vicia ervilis L. Willd. Bangladesh J. Bot. 1 : 65-74.

Shaikh, M.A.Q. and M.B.E. Godward. 1972a. The mitotic consequences of radiation induced chromosome. Breaks in Lathyrus sativus and Vicia ervilia. Cytologia. 37 : 489-495.

Shaikh, M.A.Q. and M.B.E. Godward. 1972b. The meiotic consequences of radiation induced chromosome breaks in Lathyrus sativus and Vicia ervilia. Cytologia. 37 : 497-505.

Shaikh, M.A.Q., M.A. Rashid, Z.U. Ahmed and S. Begum. 1980. Radiation effect on chromosome structural changes, growth and development of four species of legumes. Abst. 4th and 5th Annual Bangladesh Sci. Conf. Rajshahi p. 72.

Shkvarnikov, P. and M.S. Navashin. 1934. Under die Beschleunigung des Mutation svorganges in ruhenden samen unter dem Einfluss von Temperatur erhohung. Planta, 2 : 720-736.

Shkvarnikov, P. and M.S. Navashin. 1935. Acceleration of the mutation process in resting seeds under the influence of increased temperatures. Biol. ZH. 4 : 25-28.

Shkvarnikov, P. 1936. Einfluss hoher temperatur auf die Mutationsrate bei Weizen. Planta, 25 : 471-480.

Shkvarnikov, P. 1939. Mutation in seeds and its significance in seed production and plant breeding. Bull. Acad. Sci. USSR. Biol. Ser : 1009-1054.

Sinha, S.S.N. and M.B.E. Godward. 1972a. Radiation studies in Lens culinaris. Indian J. Genet. Plant. Breed. 32 : 331-339.

Sinha, S.S.N. and M.B.E. Godward. 1972b. Radiation studies in Lens culinaris meiosis : Abnormalities induced due to gamma radiation and its consequences. Cytologia. 37 : 685-695.

Smith, L. 1943. Relation of polyploidy to heat and X-ray effects in cereals. J. Hered., 34 : 130-134.

Smith, L. 1946. A comparison of the effect of heat and X-rays on dormant seeds of cereals, with special reference to polyploidy. J. agric. Res., 73 : 137-158.

Sparrow, A.H., R.L. Guany, J.P. Miksche and L.A. Schairer. 1961. Some factors affecting the responses of plants to acute and chronic radiation exposures. In effects of ionizing radiations on seeds, pp: 289-320. IAEA, Vienna.

Sparrow, A.H. and G.M. Woodwell. 1962. Prediction of the sensitivity of plants to chronic gamma irradiation. Radiation Bot. 2 : 9-26.

Sparrow, A.H., L.A. Schairer and R. C. Sparrow. 1963. Relationship between nuclear volumes, chromosome numbers and relative radiosensitivities. Science 141 : 163-166.

Sparrow, A.H. 1965. Comparisons of the tolerance of higher plant species to acute and chronic exposures of ionizing radiation. Jap. J. Genetics. 40 : 12-37.

Sparrow, A.H., R.C. Sparrow, K.H. Thompson and L.A. Schairer. 1965. The use of nuclear and chromosomal variables in determining and predicting radiosensitivities. In the use of Induced Mutations in Plant Breeding, pp. 101-132. Radiation Botany, 5, Suppl. Pergamon Press. Oxford.

Sparrow, R.C. and A.H. Sparrow. 1965. Relative radiosensitivities of woody and herbaceous spermatophytes. Science 147 : 1449-1451.

Stadler, L.J. 1929. Chromosome number and the mutation rate in Avena and Triticum. Proc. Natn. Acad. Sci. USA. 15 : 876-881.

Stadler, L.J. 1932. On the genetic nature of induced mutations. Proc. 6th Intern. Congr. Genetics. 1 : 811-819.

Stadler, L.J. 1954. The gene. Science 120 : 811-818.

Sudhakaran, I.V. 1971. Meiotic abnormalities induced by gamma rays in Vicia rosa L. Cytologia 36 : 67-79.

Swaminathan, M.S., V.L. Chopra and S. Bhaskaran. 1962. Chromosome aberration and the frequency and spectrum of mutation induced by ethyl methane sulphonate in barley and wheat. Indian J. Genet. 22 : 192-207.

Sybenga, J. 1974. General Cytogenetics. North Holland Pub. Co.

Tarar, J.L. and V.R. Dayansagar. 1980. Comparison of ethyl methane sulphonate and radiation induced meiotic abnormalities in Turnera ulmifolia L. Var. Augustifolia. Cytologia. 45 : 221-231.

Underbrink, A.G., A.H. Sparrow, V. Pond, C.S. Takahashi and A. Kappas, 1973. Radiation induced pollen abortion in several commelinaceous taxa ; Its relation to chromosomal parameters. Radiation Bot. 13 : 215-227.

Van't Hof J. and A.H. Sparrow. 1963. A relationship between DNA content, nuclear volume and minimum mitotic cycle time. Proc. Natl. Acad. Sci. 49 : 897-902.

Vijayalakshmi, U. and J.T. Rao. 1960. Effects of gamma rays on germination and growth in some species and hybrids of Saccharum. Curr. Sci. 29 : 397.

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

Yamakawa, K. and A.H. Sparrow. 1965. Correlation of ICV and reduction of viable seed set by chronic gamma irradiation of 21 cultivated plants during reproductive stages. Radiation Bot. 5 : 557-565.

Yamakawa, K. and A.H. Sparrow. 1966. The correlation of ICV with pollen abortion induced by chronic gamma irradiation. Radiation Bot. 6 : 21-28.

APPENDICES

Appendix 1. Mitotic index and percentages of different abnormalities in root tip cells of Sonalika and Cocoit induced by gamma rays (Expt.1).

Radiation dose (Kr)	Total No. of cells studied	% of dividing cells	% of abnormal cells	% of C-metaphase	% of disturbed anaphase	% of bridge	% of clumping	% of fragment	% of laggard	% of micronuclei
					Sonalika					
0	1864	29.70	3.40	1.06	0.50	0.75	-	0.59	0.50	-
5	1595	31.20	8.90	2.01	1.90	1.22	-	1.90	1.06	0.68
10	1832	31.30	9.60	2.93	2.06	1.42	0.83	1.33	1.03	-
15	1925	31.10	9.60	3.00	2.18	1.45	1.02	1.10	-	0.85
20	1938	30.80	10.20	3.07	2.50	1.50	1.50	1.40	0.20	0.93
25	1640	28.60	11.10	3.88	2.85	1.50	0.57	1.50	0.32	-
30	1928	27.80	11.40	4.08	2.96	1.66	1.70	-	1.00	0.98
					Cocoit					
0	1863	30.00	3.30	0.96	0.53	0.50	0.81	0.30	0.20	-
5	1845	32.00	5.20	1.85	0.95	0.75	0.50	0.40	0.40	0.35
10	1855	31.10	4.80	1.96	0.95	0.45	0.53	0.49	-	0.42
15	2019	31.00	5.70	1.99	1.02	0.92	0.62	0.52	0.63	-
20	1840	30.30	5.70	1.02	1.05	-	0.70	0.66	0.75	0.62
25	2143	29.00	6.40	2.12	1.16	0.94	0.72	0.64	0.82	-
30	1684	27.40	9.10	2.60	2.00	1.00	0.90	0.81	0.98	0.86

Appendix 2. Mitotic index and percentages of different abnormalities in root tip cells of Sonalika and Cocoit induced by temperature and duration of temperature (Expt.2).

Duration (in hour)	Temperature ($0^{o}C$)	Total no.of cells studied	% of dividing cells	% of abnormal cells	% of metaphase	% of disturbed anaphase	% of bridge	% of clumping	% of fragment	% of laggard	% of micronuclei
					Sonalika						
	25	2104	31.00	10.00	3.52	2.50	1.81	0.55	0.71	0.91	-
72	30	2126	28.00	12.00	3.80	2.80	1.90	0.91	1.40	0.90	0.29
	35	2070	23.00	16.00	4.31	4.97	3.21	1.01	0.90	1.20	0.40
	25	2099	29.00	13.00	3.20	4.03	1.93	1.31	1.31	1.22	-
144	30	2031	24.00	16.00	4.36	3.00	3.60	1.40	1.55	1.50	0.59
	35	2105	20.00	19.00	4.49	4.97	3.07	1.49	2.68	1.50	0.80
	25	2115	27.00	16.00	4.51	5.92	-	1.63	2.70	2.24	-
288	30	2097	20.00	21.00	4.89	6.89	3.86	1.69	1.69	2.98	-
	35	2091	16.00	23.00	5.06	6.94	3.69	1.76	1.71	2.92	0.92
					Cocoit						
	25	2184	32.00	10.90	2.02	2.94	1.50	0.72	2.80	0.92	-
72	30	2228	28.90	14.00	2.23	2.89	1.96	0.98	3.98	1.96	-
	35	2182	24.30	16.20	3.63	3.56	2.94	0.83	3.00	1.84	0.40
	25	2226	30.40	13.40	3.66	3.88	2.59	0.73	-	1.88	0.66
144	30	2157	24.90	17.10	3.74	3.86	2.76	0.94	3.95	1.85	-
	35	2192	20.60	19.20	3.45	3.94	3.90	0.98	4.06	1.99	0.88
	25	2177	27.30	17.10	3.96	4.04	3.67	0.88	2.59	1.06	0.90
288	30	2203	23.50	19.90	4.08	4.24	3.93	1.81	2.94	1.98	0.92
	35	2164	19.20	22.30	5.09	5.02	4.65	1.33	3.24	2.01	0.96

Appendix 3. Interacting effect of gamma rays, temperature and duration of temperature on mitotic index and percentages of different abnormalities in root tip cells of Sonalika (Expt.3).

Temperature (0^0C)	Dose/ Kr	Total no.of cells studied	% of dividing cells	% of abnormal cells	% of C-metaphase	% of disturbed anaphase	% of bridge	% of clumping	% of fragment	% of laggard	of of ring
					72 hours						
	0	2193	29.90	3.30	1.03	1.11	0.91	0.45	0.80	-	-
	5	2189	28.50	8.60	2.54	2.50	1.05	0.50	1.51	0.50	-
	10	2119	27.80	9.00	2.58	2.60	1.09	0.60	1.60	0.53	-
25	15	2078	30.50	10.10	2.70	2.94	1.60	0.90	1.20	0.73	0.03
	20	2161	27.30	10.10	2.90	3.20	0.82	0.98	1.36	0.84	-
	25	2203	28.20	10.10	2.90	3.34	1.53	0.95	0.60	0.78	-
	30	2123	29.90	10.30	2.99	3.07	1.69	0.69	0.60	0.93	0.23
	0	2122	30.10	3.30	0.53	1.10	0.15	0.51	1.00	-	-
	5	2201	30.60	10.40	3.02	3.39	1.16	0.95	1.50	0.13	0.25
	10	2173	29.60	11.30	3.14	3.50	1.80	0.92	1.60	-	0.34
30	15	2129	29.30	11.50	3.02	3.76	1.15	-	1.64	0.93	-
	20	2163	29.30	11.60	3.46	3.53	1.98	0.95	1.68	-	-
	25	2173	27.90	11.50	3.54	3.10	1.90	0.90	1.70	0.94	0.42
	30	2099	29.20	11.70	3.74	3.23	0.90	0.96	1.94	0.93	-
	0	2163	29.90	3.20	0.86	0.91	0.91	0.12	0.20	0.20	-
	5	2219	28.70	11.30	3.31	3.80	1.80	-	1.96	-	0.43
	10	2171	27.90	11.60	3.85	3.92	-	0.98	1.97	0.98	-
35	15	2133	27.30	11.70	3.08	3.96	0.80	0.95	1.86	0.05	-
	20	2222	28.00	11.50	3.87	3.01	1.77	0.98	1.87	-	-
	25	2188	27.40	11.70	3.93	4.02	0.40	-	1.90	0.94	0.51
	30	2173	28.00	12.00	3.97	4.11	1.94	-	0.98	1.00	-

Contd. ....

Appendix 3. Continued.

144 hours

	0	2066	29.60	3.20	0.54	0.91	0.85	0.45	0.45	-	-
	5	2033	27.90	11.90	2.98	2.69	1.96	0.60	1.77	1.90	-
	10	2019	27.20	11.80	3.32	2.88	1.97	0.77	1.86	1.90	0.10
25	15	2113	26.90	12.90	3.47	2.88	1.90	0.84	0.60	2.40	0.21
	20	2093	24.30	12.80	3.49	2.95	1.99	0.93	1.00	2.21	0.22
	25	2067	25.10	13.30	3.57	3.04	1.76	0.59	1.93	2.41	-
	30	2031	26.40	13.90	3.75	3.23	1.87	0.99	1.33	2.46	0.37
	0	2103	29.10	3.10	0.43	0.50	0.65	0.54	0.90	0.08	-
	5	2022	26.90	14.10	3.83	3.47	1.97	1.27	1.07	2.43	-
	10	2081	26.20	14.40	3.98	3.53	2.50	-	1.99	2.00	0.40
30	15	2013	26.50	14.90	3.99	3.98	2.89	1.29	-	2.75	-
	20	2119	24.80	15.40	4.00	4.06	2.40	-	1.96	2.98	-
	25	2106	27.20	15.40	4.07	4.09	3.05	1.71	1.98	-	0.50
	30	2202	25.60	16.30	4.97	3.06	2.70	1.97	-	2.85	0.75
	0	2213	29.70	3.30	1.20	0.56	0.41	-	0.69	0.44	-
	5	2067	25.80	16.00	4.84	4.13	3.07	0.74	0.76	2.86	-
	10	2051	24.10	16.20	3.99	4.36	2.34	-	1.83	2.94	0.74
35	15	2112	24.20	16.30	4.04	4.47	2.91	1.97	-	2.04	0.87
	20	2080	26.20	16.60	4.99	4.56	2.39	-	1.67	2.99	-
	25	2027	26.40	17.40	5.07	4.99	3.48	0.78	0.99	2.09	-
	30	2123	26.00	17.40	5.09	5.03	3.56	1.86	1.86	-	-

Contd. ....

Appendix 3. Continued.

288 hours

	0	2217	29.50	3.50	0.70	0.65	0.90	0.36	0.44	0.45	-
	5	2256	27.30	18.60	4.02	3.46	2.46	1.89	3.90	2.87	-
	10	2312	26.30	19.10	4.18	3.54	2.61	1.96	3.93	2.57	0.31
25	15	2278	25.10	18.20	4.22	3.66	3.03	1.93	3.94	2.00	0.42
	20	2221	22.80	17.50	4.38	3.86	2.73	1.96	3.96	-	0.61
	25	2327	25.00	18.40	4.86	3.98	1.97	1.96	1.95	2.68	-
	30	2306	25.80	18.40	4.43	4.79	2.83	-	3.76	2.59	-
	0	2213	29.30	3.20	0.92	0.02	0.90	0.53	0.73	0.10	-
	5	2258	23.80	17.80	4.72	4.65	2.74	0.74	1.69	2.59	0.67
	10	2228	23.60	18.20	4.65	4.01	1.34	0.97	3.47	2.97	0.79
30	15	2153	24.90	19.30	4.56	4.48	3.98	1.89	3.59	-	0.80
	20	2173	23.70	19.20	5.04	4.67	3.57	2.04	-	3.01	0.87
	25	2187	22.60	19.20	5.15	4.86	3.74	2.28	-	3.17	-
	30	2213	24.30	19.50	4.29	4.59	3.09	2.88	3.67	-	0.98
	0	2228	29.40	3.30	0.73	0.85	0.27	0.77	0.68	-	-
	5	2153	25.20	19.40	5.24	4.86	3.69	2.07	2.98	0.56	-
	10	2167	23.50	19.50	5.53	4.85	3.71	1.86	3.75	-	-
35	15	2158	23.40	20.00	5.50	4.88	3.84	-	3.81	2.29	0.98
	20	2228	25.50	20.60	5.73	4.99	2.97	2.95	3.96	-	-
	25	2256	24.10	20.70	5.79	4.75	0.96	2.00	3.99	3.21	-
	30	2268	23.20	20.90	5.81	5.06	3.69	2.36	3.03	0.85	1.04

Appendix 4. Interacting effect of gamma rays, temperature and duration of temperature on mitotic index and percentages of different abnormalities in root tip cells of Cocoit (Expt.3).

Temperature ($0^{o}C$)	Dose/ Kr	Total no. of cells studied	% of dividing cells	% of abnormal cells	% of C-metaphase	% of disturbed anaphase	% of bridge	% of clumping	% of fragment	% of laggard	% of micronuclei
					72 hours						
	0	2218	29,90	3.80	0.92	0.89	0.87	-	0.50	0.52	-
	5	2263	29.70	9.50	2.94	2.64	1.66	-	1.20	1.06	-
	10	2288	29.30	10.00	2.86	2.60	1.56	0.20	1.46	1.32	-
25	15	2167	29.40	9.00	2.61	2.85	1.39	0.51	1.49	-	0.05
	20	2178	28.70	9.60	2.74	2.82	1.70	0.55	1.71	-	0.08
	25	2253	30.70	10.30	2.96	2.89	1.90	0.62	-	1.49	0.44
	30	2273	29.60	10.40	2.08	2.92	1.91	-	1.86	1.63	-
	0	2268	29.80	3.70	1.21	1.10	0.65	0.07	0.05	0.62	-
	5	2281	29.30	9.10	2.81	2.74	0.88	0.79	-	1.88	-
	10	2172	29.80	9.10	2.99	2.89	0.69	-	1.92	-	0.66
30	15	2178	29.20	10.00	3.31	2.86	1.95	0.96	-	0.92	-
	20	2206	30.70	11.60	3.32	2.91	1.96	-	0.68	1.92	0.81
	25	2218	32.00	11.90	3.48	2.98	1.98	0.97	1.99	-	0.50
	30	2217	29.50	11.10	3.47	3.02	1.93	0.95	-	0.82	0.91
	0	2173	29.90	3.80	0.73	0.84	0.42	0.41	0.85	0.55	-
	5	2153	29.90	10.00	3.01	3.00	1.36	0.53	2.01	-	-
	10	2306	28.50	9.90	3.98	1.08	1.93	0.67	-	1.26	0.98
35	15	2178	29.20	10.90	3.98	-	2.02	0.86	2.03	2.01	-
	20	2317	28.80	11.60	2.51	3.14	2.90	0.96	2.08	-	1.01
	25	2218	30.80	13.00	4.06	3.28	2.00	-	1.63	2.03	-
	30	2212	30.20	13.30	4.12	3.48	2.93	0.89	1.76	-	1.12

Contd. ...

Appendix 4. Continued.

144 hours

	0	2309	29.00	3.40	0.79	0.49	0.56	0.46	0.65	0.45	-
	5	2256	28.10	11.70	3.21	2.82	1.67	0.53	2.00	1.47	-
	10	2312	27.30	11.90	3.20	3.00	1.88	0.74	2.00	-	0.08
25	15	2216	27.50	12.90	3.52	2.92	1.96	-	2.58	1.62	0.30
	20	2229	26.70	12.90	3.98	3.26	2.06	1.81	-	1.79	-
	25	2258	26.50	13.30	3.98	3.53	2.18	0.93	2.68	-	-
	30	2314	26.50	14.10	4.04	3.78	2.35	0.73	0.79	1.85	0.56
	0	2193	28.60	3.60	0.74	0.94	0.62	0.75	-	0.55	-
	5	2258	27.60	14.10	4.01	3.84	0.98	1.78	2.87	-	0.62
	10	2253	26.60	14.30	4.04	3.70	2.65	1.90	-	2.01	-
30	15	2409	27.70	15.20	4.20	3.40	2.71	1.98	2.89	-	-
	20	2312	28.00	15.70	4.36	3.39	2.07	2.04	2.96	-	0.88
	25	2263	26.40	15.70	4.08	4.01	-	2.34	2.98	2.29	-
	30	2271	27.10	16.40	4.75	4.12	2.17	1.45	2.99	-	0.92
	0	2329	28.80	3.60	0.83	0.32	0.63	0.45	0.72	0.65	-
	5	2153	27.30	16.00	3.40	4.26	2.25	2.45	2.82	-	0.92
	10	2273	26.60	16.30	4.78	4.75	2.86	1.55	-	2.36	-
35	15	2301	27.10	16.70	4.81	4.83	-	0.61	2.84	2.65	0.96
	20	2278	26.80	16.60	5.04	4.65	2.99	-	2.90	-	1.02
	25	2173	26.70	16.70	5.09	4.65	1.88	2.09	2.95	0.04	-
	30	2216	25.80	17.30	5.13	4.70	1.76	2.96	-	2.75	-

Contd. ....

Appendix 4. Continued.

288 hours

	0	2153	29.20	3.60	0.83	0.58	0.73	0.83	0.83	-	-
	5	2178	28.30	16.60	3.24	3.81	3.05	1.95	2.91	1.45	0.19
	10	2263	25.00	16.90	3.42	3.81	3.16	1.86	2.78	1.61	0.26
25	15	2273	25.00	17.70	3.51	3.96	3.30	1.98	2.83	1.80	0.32
	20	2307	25.30	17.80	3.88	3.98	3.57	2.45	2.96	0.96	-
	25	2317	25.90	18.10	3.99	4.06	3.42	2.65	2.98	-	-
	30	2209	24.20	18.30	4.06	4.11	3.29	2.00	3.01	1.93	-
	0	2218	29.40	3.60	1.22	0.94	0.32	0.35	0.72	0.05	-
	5	2231	25.20	18.30	4.88	4.64	3.36	2.86	-	1.95	0.61
	10	2156	24.20	18.70	4.93	4.57	3.09	0.85	3.24	1.99	-
30	15	2163	24.20	18.80	3.83	4.31	3.47	2.91	3.39	-	0.89
	20	2262	23.50	18.90	4.96	4.43	3.74	2.77	-	2.01	-
	25	2306	24.10	19.20	3.96	3.97	3.97	2.84	3.54	-	0.92
	30	2213	23.40	19.50	4.98	4.84	3.88	-	3.66	2.14	-
	0	2173	28.90	3.60	0.94	0.85	0.72	0.39	-	0.70	-
	5	2268	25.80	19.50	4.99	4.98	3.70	0.93	3.85	-	1.05
	10	2187	22.90	19.50	5.02	5.19	3.38	2.98	-	2.93	-
35	15	2271	22.70	19.60	5.08	5.23	3.57	2.97	1.63	-	1.12
	20	2196	24.10	20.20	5.12	5.43	2.91	0.95	3.83	1.96	-
	25	2188	24.00	20.40	5.23	5.51	-	2.67	2.87	2.94	1.18
	30	2216	23.40	20.50	5.30	5.62	2.92	-	3.82	2.84	-

Appendix 5. Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Sonalika and Cocoit induced by gamma rays (Expt.1).

Dose (kr)	Total No.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metaphase I and II		% of abnormal Anaphase I and II			% of abnormal Telophase I and II		
				Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
						Sonalika					
0	2262	29.30	3.30	1.10	1.20	-	0.52	0.02	-	0.46	-
5	2225	27.20	7.40	2.00	3.00	0.20	-	1.00	1.00	-	0.20
10	2269	28.00	8.10	3.00	3.00	0.50	0.67	0.50	0.03	0.07	0.03
15	2235	28.10	9.70	3.00	2.40	1.30	1.00	1.50	0.05	0.40	0.05
20	2281	29.40	9.40	3.50	3.50	1.05	1.25	0.10	0.30	0.40	0.30
25	2256	29.40	11.00	4.00	3.40	-	0.20	2.70	0.60	0.04	0.06
30	2273	29.40	12.00	3.70	4.40	0.63	0.47	1.43	0.75	0.55	0.07
						Cocoit					
0	2261	31.00	4.00	2.00	1.20	-	0.05	0.75	-	-	-
5	2296	29.30	5.00	1.03	1.30	-	-	2.20	-	0.47	-
10	2237	29.30	5.00	1.03	1.30	-	-	2.20	-	0.47	-
15	2278	29.40	7.00	1.00	3.50	-	0.04	1.30	0.07	0.06	1.03
20	2263	30.00	8.00	2.50	1.20	-	0.20	2.00	1.30	0.75	0.05
25	2245	29.20	8.20	3.60	0.10	2.20	1.00	0.50	0.27	0.03	0.50
30	2256	29.30	9.40	2.80	1.20	1.30	0.20	2.30	0.20	-	1.40

Upper and lower values indicate the % of abnormalities in the first and the second meiotic division, respectively for Appendices 5,6,7 and 8.

Appendix 6. Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Sonalika and Cocoit treated by temperature and duration of temperature (Expt.2).

Duration (hour)	Temperature (°C)	Total no.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metaphase I & II		% of abnormal Anaphase I & II			% of abnormal Telophase I & II		
					Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
					Sonalika							
	25	2238	30.10	8.70	2.90	1.30	0.30	-	2.40	-	0.80	1.00
72	30	2291	28.00	11.40	3.00	2.60	-	1.20	2.10	0.90	1.20	0.40
	35	2219	25.70	14.90	4.05	2.85	0.95	0.67	2.83	0.75	1.43	1.37
	25	2262	28.00	10.50	3.62	0.88	0.60	1.30	1.84	2.17	0.07	0.02
144	30	2251	24.30	15.10	3.05	2.87	0.93	0.76	3.90	0.75	0.45	2.39
	35	2302	22.90	17.70	5.07	3.98	0.83	0.96	2.31	0.90	0.58	2.57
	25	2226	24.10	12.00	2.96	1.95	0.78	2.26	1.30	1.37	0.95	0.43
288	30	2275	21.50	17.10	3.45	3.86	2.97	0.90	2.95	0.72	0.71	1.54
	35	2258	18.90	22.10	7.06	3.97	1.55	1.89	4.06	1.36	1.56 0.02	2.63
					Cocoit							
	25	2221	29.90	10.70	3.87	1.43	0.27	1.52	1.37	0.24	0.80	1.20
72	30	2262	28.40	11.90	2.94	2.87	1.76	0.34	1.72	0.67	0.37	1.23
	35	2296	27.10	13.90	3.03	3.97	0.74	1.92	0.85	0.86	1.59	0.94
	25	2271	27.30	12.40	2.86	1.95	0.53	1.52	2.45	0.76	0.35	2.18
144	30	2223	27.30	13.70	1.86	1.59	0.82	0.72	3.83	0.86	0.65	3.37
	35	2263	26.10	14.80	3.81	1.97	0.83	1.88	0.83 0.73	2.66	0.71	1.38
	25	2295	26.20	13.60	2.96	1.97	1.97	0.80	2.95	0.99	1.64	0.32
288	30	2256	25.00	16.50	3.03	2.25	0.68	2.49	3.82	0.76	0.82	2.65
	35	2285	23.90	16.90	2.57	3.96	1.96	1.95	1.96	0.88	0.86	2.76

Appendix 7. Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Sonalika induced by gamma rays, temperature and duration of temperature (Expt.3).

Temperature (°C)	Dose (kr)	Total no.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metaphase I & II		% of abnormal Anephase I & II			% of abnormal Telophase I & II		
					Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
					72 hours							
	0	2283	29.50	3.70	1.21	0.10	0.50	0.07	1.03	0.29	-	0.50
	5	2256	28.70	11.30	3.65	1.83	1.42	0.53	1.56	0.79	0.28	1.24
	10	2219	26.30	11.20	2.85	1.65	0.65	0.69	2.45	0.39	1.20	1.32
25	15	2263	25.80	11.60	3.67	2.85	0.35	0.55	2.76	0.47	0.30	0.65
	20	2295	24.30	12.60	2.03	1.92	0.54	1.41	1.72	0.76	1.89	2.33
	25	2235	23.10	13.60	3.92	1.41	2.34	0.27	1.07	2.44	0.60	1.55
	30	2303	22.10	13.40	2.82	1.89	0.56	1.72	3.93	0.57	0.32	1.62
	0	2211	29.10	4.00	1.10	0.10	-	0.04	0.15	0.03	0.55	0.53
	5	2226	27.40	14.50	3.23	2.39	1.86	0.75	1.97	0.93	1.37	2.00
	10	2262	25.80	14.30	2.36	3.79	0.73	0.81	2.27	2.26	0.49	0.59
30	15	2296	24.70	14.30	4.97	2.29	0.95	0.56	3.51	0.72	0.47	0.83
	20	2273	23.10	13.20	3.06	2.79	0.45	0.35	2.96	0.36	0.58	2.65
	25	2281	22.30	16.70	2.13	3.52	2.82	0.73	2.03	1.43	0.68	3.97
	30	2256	21.10	16.30	4.97	3.82	0.56	0.82	3.73	0.90	0.93	0.57
	0	2243	28.70	3.80	1.20	0.87	-	0.53	0.55	-	-	0.58
	5	2269	25.70	15.80	5.65	3.97	0.91	0.78	2.05	0.67	0.82	0.95
	10	2221	25.20	16.50	5.02	3.85	0.93	0.65	2.87	0.82	0.93	1.43
35	15	2253	24.90	16.80	5.34	4.06	0.83	0.63	3.04	0.67	0.61	1.62
	20	2250	22.80	17.50	6.71	3.55	0.52	0.90	3.55	0.82	0.84	0.61
	25	2291	21.40	17.40	5.31	3.16	1.34	0.96	4.96	0.84	-	0.83
	30	2261	20.10	17.80	6.04	3.96	0.65	0.97	4.64	0.69	0.53	0.32

Appendix 7. Continued.

Temperature (°C)	Dose (kr)	Total no.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metaphase I & II		% of abnormal Anaphase I & II			% of abnormal Telophase I & II		
					Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
					144 hours							
	0	2273	29.20	3.80	1.29	0.54	0.70	0.10	0.37	0.30	0.50	-
	5	2256	27.40	17.60	2.52	2.69	1.04	0.87	3.97	1.06	0.76	2.69
	10	2233	25.30	16.70	3.42	2.93	1.43	0.32	3.04	1.75	0.87	2.94
25	15	2261	24.70	18.10	3.08	3.06	1.74	1.47	3.42	1.67	0.95	2.72
	20	2268	22.00	18.30	3.47	3.06	1.94	0.73	2.36	0.83	0.93	1.98
	25	2243	20.30	17.40	3.97	3.72	1.89	0.59	2.93	1.64	1.04	1.62
	30	2221	18.60	18.70	4.18	4.27	1.89	1.74	3.03	1.97	1.58	2.04
	0	2243	27.70	3.50	1.10	0.95	-	0.08	0.85	0.52	-	-
	5	2275	25.90	17.90	2.87	3.04	1.78	0.89	3.06	1.25	1.62	2.19
	10	2296	24.40	18.50	3.31	2.72	1.67	0.57	2.55	1.79	1.78	3.06
30	15	2262	22.20	19.20	4.44	2.78	1.65	0.84	2.07	0.98	1.88	3.99
	20	2271	20.40	19.00	4.97	2.38	0.94	1.92	2.22	1.81	1.89	0.57 2.26
	25	2306	19.70	18.80	4.14	3.52	1.58	1.78	0.53 2.82	2.00	1.07	2.99
	30	2278	17.30	19.20	3.92	3.72	2.68	0.64	3.07	2.19	2.98	-
	0	2226	26.50	3.90	1.07	-	0.60	0.67	0.10	0.04	-	0.24 0.42
	5	2278	24.10	19.20	4.05	3.31	1.98	0.40	2.78	0.52	2.81	3.32
	10	2255	21.90	19.50	4.55	3.92	2.07	0.87	2.88	1.42	-	3.79
35	15	2233	20.40	18.40	4.72	3.99	0.86	1.26	1.06	0.88	2.89	2.82
	20	2282	20.10	19.30	4.63	3.99	2.17	-	2.17	1.54	1.98	0.32 2.82
	25	2253	18.50	18.90	4.44	4.37	0.97	1.06	1.08	0.86	3.06	3.09
	30	2266	16.80	19.30	5.01	3.97	2.38	1.94	-	1.58	0.56	3.86

Contd. .....

Appendix 7. Continued.

Temperature (°C)	Dose (kr)	Total no.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metephase I & II		% of abnormal Anaphase I & II			% of abnormal Telophase I & II		
					Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
							288 hours					
	0	2219	28.90	3.50	1.06	0.60	0.52	0.50	0.21	0.01	-	-
	5	2241	27.30	19.40	3.08	2.93	1.89	1.86	2.98	3.86	0.82	1.98
	10	2262	27.10	19.60	3.13	3.84	2.03	1.82	2.06	2.98	1.74	2.00
25	15	2281	27.40	19.70	3.83	3.62	2.06	1.32	3.43	-	2.38	3.06
	20	2211	26.90	18.20	3.93	3.15	2.84	1.87	2.02	2.64	0.93	0.82
	25	2267	27.00	19.70	3.78	3.73	-	0.86	2.76	1.85	2.76	3.71
	30	2243	26.70	19.80	3.47	3.51	2.36	0.25 1.27	-	2.86	2.54	3.79
	0	2251	28.90	4.10	1.20	1.00	0.52	0.55	0.14	0.07	0.62	-
	5	2233	27.40	21.80	3.96	3.83	2.84	0.98	3.77	1.78	0.88	3.84
	10	2278	26.90	20.30	3.94	2.77	2.51	1.57	2.67	0.83	2.96	3.05
30	15	2283	26.60	20.50	4.07	3.92	2.93	0.85	3.98	1.89	2.86	-
	20	2271	27.00	20.60	4.09	4.01	2.86	3.23	-	2.66	-	3.75
	25	2228	27.00	21.30	4.57	4.23	2.86	0.58	3.46	0.55	0.85	3.97
	30	2263	26.00	20.80	4.74	3.94	3.69	0.23 1.55	1.86	0.38	0.65	4.09
	0	2256	29.40	3.8	0.98	0.75	0.22	0.67	0.56	0.40	0.30	-
	5	2268	27.60	20.50	4.6	4.31	3.06	-	2.96	0.85	0.52	4.17
	10	2258	27.40	21.40	5.08	4.33	2.56	2.37	0.84	1.97	-	4.25
35	15	2233	27.40	22.10	5.47	4.52	0.88	2.97	2.07	0.53	1.32	4.34
	20	2282	27.20	21.30	5.66	4.66	2.54	0.36	2.38	1.17	-	4.53
	25	2251	27.00	22.10	5.82	4.99	2.03	0.96	0.66	0.86	1.54	4.82
	30	2228	27.20	22.60	6.08	5.03	0.98	0.69	0.42 1.28	1.92	0.98	4.94

Appendix 8. Percentages of dividing PMCs, abnormal PMCs and different abnormalities at different stages of Cocoit induced by gamma rays, temperature and duration of temperature (Expt.3).

Temperature (°C)	Dose (kr)	Total no.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metaphase I & II		% of abnormal Anaphase I & II			% of abnormal Telophase I & II		
					Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
							72 hours					
	0	2265	30.50	3.60	0.90	0.70	0.45	0.60	0.32	0.63	-	-
	5	2278	30.00	11.20	1.87	1.64	1.58	0.43	1.44	0.76	0.84	2.64
	10	2221	28.10	11.20	1.88	1.77	1.86	0.93	1.94	1.28	1.54	-
25	15	2258	27.30	11.90	2.85	1.84	0.39	0.67	2.76	0.32	0.25	2.82
	20	2283	26.40	12.20	2.98	2.02	-	0.32	2.09	1.25	0.62	2.92
	25	2262	25.00	11.40	2.83	2.36	0.92	1.07	0.83	0.22	0.18	2.99
	30	2268	23.40	13.10	3.65	0.49	2.82	-	0.93	1.85	0.49	2.87
	0	2273	30.10	3.60	0.96	0.70	0.39	0.65	0.90	-	-	-
	5	2219	29.70	13.20	3.71	2.54	1.82	0.36	1.03	0.50	0.50	2.74
	10	2234	27.50	12.10	3.86	2.73	2.54	0.65	0.92	0.64	0.76	-
30	15	2284	27.00	13.20	3.96	2.85	0.41	0.22	1.84	0.39	0.69	2.64
	20	2273	26.10	14.40	4.01	2.89	2.62	1.92	1.32	-	0.79	0.85
	25	2249	25.60	13.20	3.93	2.73	0.25	-	0.55	1.96	0.89	2.89
	30	2273	22.70	14.10	3.97	2.96	0.85	0.77	1.34	0.73	0.59	2.89
	0	2223	30.00	3.80	0.96	0.30	0.52	0.75	-	0.50	-	0.77
	5	2273	27.90	15.00	4.06	3.01	0.94	0.83	0.79	0.67	0.62	3.08
	10	2296	26.30	14.10	4.09	2.99	0.79	0.84	0.62	0.83	0.76	3.18
35	15	2271	25.60	14.50	4.24	0.59	2.84	1.02	1.73	0.55	0.85	2.68
	20	2260	24.30	15.90	4.46	2.96	1.11	0.39	1.84	0.80	1.05	3.29
	25	2280	23.40	14.40	4.62	3.06	0.74	0.36	1.05	0.64	0.79	3.14
	30	2295	21.00	14.40	4.87	3.18	1.19	0.94	-	0.87	0.38	2.97

Appendix 3 contd.

Temperature (°C)	Dose (kr)	Total no.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metaphase I & II		% of abnormal Anaphase I & II			% of abnormal Telophase I & II		
					Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
							144 hours					
	0	2256	29.90	3.80	0.98	0.82	0.47	0.53	0.50	0.50	-	-
	5	2271	25.50	15.20	2.34	1.89	2.15	1.92	2.36	1.53	1.62	1.39
	10	2243	27.10	16.80	2.69	1.96	2.64	2.84	2.03	1.00	1.75	1.89
25	15	2259	26.40	16.60	2.88	2.02	2.40	2.03	1.97	1.62	1.79	1.89
	20	2267	26.90	17.30	3.06	2.15	2.26	2.86	2.62	1.32	2.03	1.00
	25	2223	26.50	17.20	3.13	0.86	2.94	2.93	1.82	1.68	1.97	1.87
	30	2257	27.00	18.10	3.62	2.03	2.64	2.35	2.22	-	2.72	2.52
	0	2273	30.10	3.70	1.10	0.75	0.65	0.94	0.13	0.07	-	0.06
	5	2295	26.60	18.40	3.97	2.59	1.33	2.87	2.48	1.73	0.88	2.55
	10	2221	27.50	19.00	4.06	3.15	0.98	2.95	1.68	1.36	0.84	2.98
30	15	2258	27.30	20.00	4.07	3.06	1.65	2.66	1.79	0.98	2.96	2.83
	20	2269	26.50	19.30	4.07	3.18	1.84	2.74	2.00	1.84	1.23	2.04
	25	2236	30.20	20.50	4.47	3.42	2.72	2.79	0.36 -	2.92	1.21	2.97
	30	2281	29.30	19.70	4.69	2.86	2.92	2.36	2.07	0.93	0.86	2.49 0.52
	0	2236	30.30	4.00	1.04	0.40	0.73	0.52	0.59	0.60	-	0.12
	5	2283	27.80	19.60	4.69	3.65	2.48	1.58	2.90	-	1.36	2.94
	10	2243	26.70	19.40	3.98	2.94	1.92	2.85	2.95	0.96	0.82	2.98
35	15	2262	28.50	22.20	4.87	3.83	2.99	2.89	0.26	2.85	1.46	3.05
	20	2258	28.40	21.50	4.99	3.77	2.80	-	3.02	2.24	0.89	2.79
	25	2243	26.40	19.60	4.92	3.89	2.07	0.18	2.93	1.67	1.05	2.89
	30	2246	28.70	22.40	5.15	3.97	-	2.35	3.15	3.13	0.66	3.99

Contd. .....

Appendix 8. Continued.

Temperature (°C)	Dose (kr)	Total no.of cells study	% of dividing cells	% of abnormal cells	% of abnormal Metaphase I & II		% of abnormal Anaphase I & II			% of abnormal Telophase I & II		
					Fragment	Laggard	Fragment	Laggard	Bridge	Fragment	Laggard	Bridge
							288 hours					
	0	2251	29.90	3.70	0.99	0.88	0.49	0.83	0.21	0.70	-	-
	5	2269	26.60	19.50	3.03	3.53	2.98	2.88	2.33	2.79	-	1.96
	10	2278	27.40	20.40	3.63	3.34	2.96	2.72	2.44	2.52	0.83	1.96
25	15	2303	31.60	22.20	4.39	3.97	3.77	2.00	2.78	1.00	0.95	2.78
	20	2262	29.10	22.00	4.63	3.83	3.97	-	0.56 2.69	2.83	0.93	2.96
	25	2307	27.50	22.60	4.82	3.06	3.83	3.05	2.14	2.78	0.59	2.33
	30	2261	26.00	21.90	4.59	3.99	3.34	2.96	2.57	0.56	1.77	1.59 0.63
	0	2260	29.70	3.60	1.02	0.83	-	0.63	0.59	-	-	0.63
	5	2293	27.20	22.80	4.95	3.62	2.34	2.97	2.64	2.83	0.98	2.47
	10	2278	31.20	24.20	4.94	4.36	-	3.37	3.09	3.45	1.41	2.58
30	15	2283	26.00	22.80	5.03	3.94	1.43	1.06	3.34	3.96	1.48	2.56
	20	2258	29.50	24.00	5.34	2.94	1.97	2.56	2.74	2.81	0.97	3.73
	25	2267	27.30	21.10	4.34	3.84	0.78	1.44	0.94 2.85	3.98	-	3.77
	30	2306	27.80	21.00	4.96	3.53	2.77	2.98	1.43	0.42	1.84	2.97
	0	2296	29.80	3.60	0.86	1.01	-	0.60	1.13	-	-	-
	5	2271	26.80	21.10	4.56	3.25	3.97	2.57	2.85	1.94	1.00	0.96
	10	2292	28.90	21.20	4.66	-	3.54	3.38	2.88	0.94	1.97	3.83
35	15	2283	27.40	22.60	5.13	3.96	3.74	0.98	1.34	1.74	1.71	2.96
	20	2311	27.70	21.20	5.08	4.07	-	2.95	0.63 3.26	0.94	1.96	0.34 3.94
	25	2226	27.30	22.00	5.29	4.06	0.98	2.34	3.57	0.88	1.54	3.34
	30	2292	26.80	21.90	5.15	3.74	3.08	0.98	2.66	1.92	0.88	3.48