

**EFFECTS OF THE INSECTICIDE CARBICRON ON MEIOTIC CHROMOSOMES
AND OTHER MORPHOLOGICAL CHARACTERS OF WHEAT**

I hereby declare that the entire work submitted
as the thesis for the degree of Master of Philosophy at the
University of Rajshahi is the result of my own investigation.

A dissertation

Submitted to the Department of Botany,

University of Rajshahi,

in fulfilment of the requirements

for the degree of

MASTER OF PHILOSOPHY

by

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June, 1986.

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DECLARATION

CERTIFICATE

I hereby declare that the entire work submitted
as the thesis for the degree of Master of Philosophy at the
University of Rajshahi is the result of my own investigation.

has not been concurrently submitted in candidature of
any degree.

Mahkhaleque
(Dr. M.A.Khaleque) 5-8-86

Supervisor.

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(Salma Hossain) 2.8.86
Candidate

Dedicated to the memory of the late Professor
 Sultanul Alam under whose supervision the present
 work was initiated and completed but who could not
 see the final form of the dissertation. treated
 with the insecticide, Carbofuran - 100. The insecticide
 treatment also significantly reduced The author
 height, number of fertile tillers, number of spikelets
 per ear and number of grains per ear in both the wheat
 species. It is a hope to determine whether any of the
 observed cytological and morphological effects can be
 transmitted to subsequent generations, plants were grown
 from seeds of the treated plants in the following year. In
 the selfed progeny of the hexaploid wheat neither any
 increase in the proportion of chromosomal aberrations nor
 any significant effect on the morphological characters was
 detected. In tetraploid wheat a significant reduction in
 plant height and number of fertile tillers was detected but
 for chromosomal aberrations and other morphological traits
 no difference between progeny of treated and untreated
 families was found.

ABSTRACT

Chromosomal aberrations viz. sticky and contracted chromosomes, bridges, fragments and micro-nuclei were significantly increased in meiocytes of hexaploid and tetraploid wheat when seeds and/or plants were treated with the insecticide, Carbicron - 100. The insecticide treatment also significantly reduced plant height at heading, number of fertile tillers, number of spikelets per ear and number of grains per ear in both the wheat species. In an attempt to determine whether any of the observed cytological and morphological effects can be transmitted to subsequent generations, plants were grown from seeds of the treated plants in the following year. In the selfed progeny of the hexaploid wheat neither any increase in the proportion of chromosomal aberrations nor any significant effect on the morphological characters was detected. In tetraploid wheat a significant reduction in plant height and number of fertile tillers was detected but for chromosomal aberrations and other morphological traits no difference between progeny of treated and untreated families was found.

ACKNOWLEDGEMENT

The author wishes to express her sincere gratitude to the Late Professor Sultanul Alam of the Department of Botany, University of Rajshahi, for his advice and supervision throughout the course of this investigation.

The author is also grateful to Dr. M. A. Khaleque, Associate Professor of Botany, University of Rajshahi, for his helpful suggestions during the preparation of the manuscript.

The author is grateful to Dr. O. I. Joarder, Professor and Chairman, Department of Botany, University of Rajshahi, for his advice and encouragement.

Thanks are also due to Mr. Nurul Amin and Mr. Golam Kabir, Assistant Professor and Lecturer respectively and Mr. Kanon Kumar Roy of the Department of Botany, University of Rajshahi, for their help and assistance.

The author gratefully acknowledges the financial support of the NCST, Government of Bangladesh in the form of a Fellowship.

The Author

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In modern agriculture, even in an under-developed country, like Bangladesh, chemical insecticides and pesticides become a common factor in crop production. Almost every crop in the field comes in contact with these chemicals often on several occasions during its life-time.

The cry for increasing yield of every agricultural commodity demands the use of insecticides to protect the crops from the vicious attack of harmful insects. These insecticides, being poisonous and lethal

Research related to INTRODUCTION de decomposition, absorption, translocation, incorporation, metabolism and soil residues has been emphasized all. The chromosomes are of vital importance to all plants and animals. The genes, units of inheritance of characters, are integral part of the chromosomes. It is obvious that deviations from the normal chromosomal complement may affect the inheritance of characters of an organism. Many different types of changes in architecture of the chromosomes are known which involve variations both in chromosome numbers and chromosome structure and most of these affect inheritance of characters. Although such changes in chromosome architecture may give rise to variations useful in natural selection and breeding, the majority of changes of this type lead to the deterioration of quality and yield of crop plants. In agriculture, the stability of quality and high yield of a crop is very important. So plant breeders and farmers want that the quality and other agronomic characters of a selected high yielding variety (HYV) of a crop should remain unchanged from year to year. Change in the quality and characteristics of a crop, caused by an alteration in the chromosome architecture, will be inherited by the offspring, thus, affecting crops of future generations as well.

In modern agriculture, even in an under-developed country, like Bangladesh, chemical insecticides and pesticides become a common factor in crop production. Almost every crop in the field comes in contact with these chemicals often on several occasions during its life-time.

The cry for increasing yield of every agricultural commodity demands the use of insecticides to protect the HYV's from the vicious attack of harmful insects. These insecticides, being poisonous and lethal to the insects may also have some harmful effects on the crop plants themselves.

Research related to the insecticide decomposition, absorption, translocation, incorporation, metabolism and soil residues has been emphasized all over the world. However, basic research aimed at a better understanding of the application of the insecticides on chromosomal behaviour of various crops is lacking specially in case of tropical countries.

Transmittable changes in plants induced by insecticides may be caused by an alteration of the genetic architecture. A better understanding of the cytogenetic response of plants to insecticides and their relationships to the performance of these chemicals would help to enhance safe and effective control of insect pests.

The present investigation was undertaken to demonstrate (a) the effect of insecticide on meiotic chromosomes of treated plants; (b) the effects of the treatments on the morphological and yield contributing characters and (c) whether these effects on meiotic chromosomes, and morphological and yield characters are inherited by the offspring of the treated plants.

To achieve these goals, two species of wheat, hexaploid Sonalika and a variety of tetraploid Durum were subjected to different treatments of a systemic insecticide, Carbicron. The effect of these treatments on meiotic chromosomes and on a number of morphological characters were studied. The seeds from treated plants were sown next year to identify any heritable effects of the insecticide treatments of previous year.

Another phenomenon of the coalescence of chromosomes into bridges of various numbers and sizes during meiosis in barley plants arising from the seeds treated with a pesticide, Lorox, was reported by Grant (1966). In their study, as high as 1.04 of the pollen mother cells contained chromosome abnormalities. The same authors further reported

REVIEW OF LITERATURE

76.0 to 98.5% barley pollen ^{as} previous types of chromosomal abnormalities when the seeds were treated with another pesticide, Monuron (Tan & G). Chromosomal abnormalities due to treatment of chemicals used as insecticides and herbicides were reported as early 1950s (Unrau, 1953, 1954; Unrau and Corns, 1950; Brown, 1950; Doxey, 1949; Dunlap, 1951; McIlrath and Ergle, 1953; Sunneson, 1960; Tukey, 1950; Unrau and Larter, 1952; Wu and Grant, 1966). the induced chromosomal aberrations were stickiness,

Dunlap (1951) had shown that a 'stimulus' producing symptoms of 2, 4-D injury could be transmitted to the next generation via cotton seeds. There is also much evidence that such effects may persist in the vegetative parts of some plants after 2, 4-D treatment (Brown, 1950; McIlrath and Ergle, 1953; Tukey, 1950). Abnormalities induced by 'Dalofin' were found several generations after the herbicide was applied to barley (Sunneson, 1960). exhibited chromosomal aberrations when treated with different doses

of these Unrau and his associates had conclusively demonstrated that herbicide 2, 4-dichlorophenoxy acetic acid (2, 4-D) was responsible for inducing chromosomal aberrations in both meiotic and mitotic cells of barley and wheat (Unrau, 1953, 1954; Unrau & Corns, 1950). They reported that the herbicide might result in heritable changes in some morphological characters. Unrau and Larter (1952) also reported high percentage of pollen mother cells (PMC) of wheat and barley to be affected after spraying the plants with 2, 4-D before microsporogenesis.

Another phenomenon of the coalescence of chromosomes into masses of various numbers and sizes during meiosis in barley plants originating from the seeds treated with a pesticide, Lorox, was reported by Wu and Grant (1966). In their study, as high as 100% of the pollen mother cells contained chromosome abnormalities. The same authors further reported

76.0 to 98.5% barley pollen mother cells with various types of chromosomal abnormalities when the seeds were treated with another pesticide, Monuron (Wuu & Grant, 1967a). Pesticides were also found to cause chromosomal aberrations in meiotic cells when seeds of Vicia faba and Gossypium barbadense as demonstrated by Amer and his associates (Amer, 1965; Amer and Ali, 1968, 1969, 1974, 1980; Amer and Farah, 1968, 1974, 1975, 1976, 1980). In Vicia faba the induced chromosomal aberrations were stickiness, lagging chromosomes, fragments and anaphase bridges, univalents at diakinesis, disturbed second metaphase and anaphase, micronuclei at first and second anaphase and multi-polar second telophase.

Reddy and Ramanna Rao (1969) studied the cytological effects of two common insecticides 'Dimecron - 100' and 'Rogor - 40' on Vicia faba. They reported that both root tip cells in division as well as pollen mother cells exhibited chromosomal aberrations when treated with different doses of these two insecticides.

The cytological effects of the pesticides, 'Menazon', 'Bromuron' and tetrachloro-isophthato nitrite in Hordeum and Tradescantia was reported by Tomkin and Grant (1972). These chromosomal abnormalities were found to be specific and localized.

Ahmed and Grant (1972) also studied the effects of 'Phosdrin' and 'Bladex', two other pesticides on mitotic cells of root tips of Tradescantia and Vicia faba. Both of these pesticides produced similar chromosomal abnormalities.

Alam and his associates studied the effects of different insecticides on wheat and observed that various kinds of chromosomal abnormalities were caused by the insecticides, Carbicron, Dimecron and Vapona (Alam et al.,

morphological and yield contributing characters. The need of insecticides in modern agriculture can not be over emphasized. So, it is important to find out whether the increase in the occurrence of chromosomal aberrations have any effect on yield and quality of the crop or not.

Plant materials:

A hexaploid wheat (Triticum aestivum var. Sonalika, $2n = 42$) and a tetraploid wheat (Triticum durum, $2n = 28$) were used as the materials of this study. The pure breeding seeds were obtained from the Cytogenetics Laboratory, Department of Botany, University of Rajasthan.

Insecticide:

The insecticide used is commonly known as 'Darthuron - 100' which was collected from the Thana Agricultural Office, Pata, Rajasthan. The active ingredient of the insecticide is 3-(Dimethoxy-phosphinyloxy) N, N-dimethyl - cis - crotonamide with the empirical formula, $C_{12}H_{18}O_5N$ produced by CIBA Agrochemical Division.

This is a systemic insecticide based on enol phosphate dicrotophos. The chemical is taken up by the sprayed plants within a few hours of application. It has been widely used over a broad range of crops as a stomach poison against many sucking, chewing and mining insects.

MATERIALS AND METHODS

Preparation of chemicals for treatment MATERIALS

Plant materials: Treat doses (D_1 and D_2) were prepared by mixing 0.2 oz. and 0.4 oz. of Carbicron - 100 with 2.5 gallons of distilled water.

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Insecticide: Seeds were soaked in the prepared chemical only,

(b) Untreated seedlings were sprayed with the chemical, and

The insecticide used is commonly known as 'Carbicron - 100' which was collected from the Thana Agricultural Office, Paba, Rajshahi. The active ingredient of the insecticide is 3-(Dimethoxy-phosphinyloxy) N, N-dimethyl - cis - crotonamide with the empirical formula, $C_8H_{16}O_5PN$ is produced by CIBA Agrochemical Division. seeds were sprayed with distilled water.

This is a systemic insecticide based on enol phosphate dicrotophos. The chemical is taken up by the sprayed plants within a few hours of application. It has been widely used over a broad range of crops as a stomach poison against many sucking, chewing and mining insects.

D_0 : Seeds soaked in distilled water and sprayed with distilled water, used as controls.

STD_1 and STD_2 : Seeds soaked in two different doses of insecticides D_1 and D_2 respectively for 12 hours, without any spray.

STD₁ and STD₂ : See METHODS on untreated seeds of two weeks old sprayed with the two doses of insecticides D₁ and D₂ respectively.

Preparation of chemicals for treatment:

STD₁ and STD₂ : Seedlings from treated seeds (STD₁ & STD₂) were sprayed Two different doses (D₁ and D₂) were prepared by mixing 0.2 oz. and 0.4 oz. of Carbicron - 100 with 2.5 gallons of distilled water.

During 1981-82 winter one row each of D₀, STD₁, STD₂; D₀, STD₁.

Treatments: STD₁ and STD₂ were planted for both Sonalika and Durum. During 1982-83 winter, the experiment of 1981-82 was repeated along with the selfed seeds of 11 lines.

The insecticide was treated to the plant material in three different ways: Each of the treatments including the control row was assigned a

- random code as the experiment was conducted in a randomized block design during the collection of data. The following treatments were given:
- (a) Seeds were soaked in the prepared chemical only,
 - (b) Untreated seedlings were sprayed with the chemical, and
 - (c) Seedlings from seed-treated materials were again sprayed treatment same with the chemical.

In every case controls were kept where seeds were soaked in distilled water or seedlings from untreated seeds were sprayed with distilled water.

The dry seeds were either soaked in distilled water or in the insecticide. The following abbreviations were used to designate the different treatments of each of Sonalika and Durum wheat (Page 10):

D₀: Seeds soaked in distilled water and sprayed with distilled water, used as controls.

STD₁ and STD₂ : Seeds soaked in two different doses of insecticides D₁ and D₂ respectively for 12 hours, without any spray.

SPD₁ and SPD₂ : Seedlings from untreated seeds of two weeks old sprayed with the two doses of insecticides D₁ and D₂ respectively.

STPD₁ and STPD₂ : Seedlings from treated seeds (STD₁ & STD₂) were sprayed with the two doses of insecticides D₁ and D₂ respectively.

During 1981-82 winter one row each of D₀, SPD₁, SPD₂; D₀, STD₁, STD₂; D₀, STPD₁ and STPD₂ ^{plants} were planted for both Sonalika and Durum. During 1982-83 winter, the experiment of 1981-82 was repeated along with the selfed seeds of all these treatments from the previous year.

Each of the treatments including the control rows ^{was} assigned ^{to} a random code number and this number was always used for reference during the collection of cytological and morphological data. After the tabulation of these data were complete, the code numbers were replaced by the actual treatment names.

Sowing of seeds:

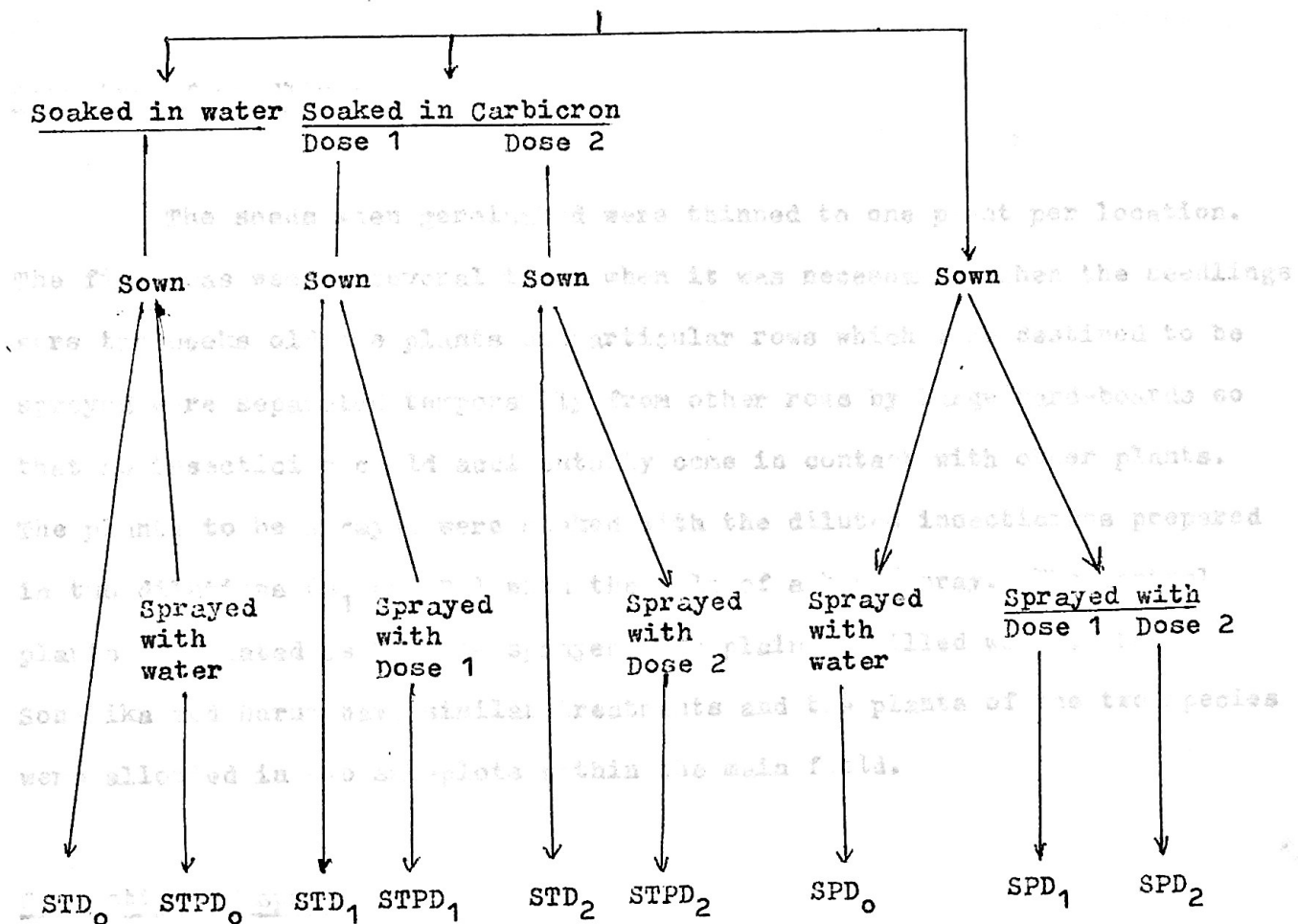
The dry seeds were either soaked in distilled water or in the insecticide of proper concentrations in petri-dishes for 12 hours. Then the solutions were decanted off and the treated seeds were washed thoroughly in tap water. The seeds for control (D₀) were soaked in distilled water for the same period so as the seeds for plants which would be sprayed later.

The field was ploughed repeatedly and pulverized thoroughly. Cow-dung and other fertilizers were added at standard doses. The seeds were sown in rows in a field with randomized block design. The distance between rows was 30 cm. and from plant to plant was 7 cm. Non-experimental rows

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 Page 10

were planted around the experimental field to minimize the edge-effect.
 The first set of the experiment was carried out during the winter of 1981-82.
Summary of the treatments used in the study

The seeds collected from the 1981-82 season were kept separate for each treatment and were grown untreated during the winter of 1982-83.
 The experiment of 1983-84 (Seeds of wheat (hexaploid/tetraploid) in the second year.



At the flag leaf stage, young inflorescences from the various treatments and the control plants were collected. The material first collected was checked for the presence of right stages of meiotic division. These collected inflorescences were, immediately fixed in a modified Carnoy's fixative. After 48 hours the materials were transferred to 70% ethanol and stored in a refrigerator for examination.

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The experiment of 1981-82 was also repeated during the second year. record

book. Photographs were taken from the desired preparations (Figs. 1 to 6).

Spraying of seedlings:

Collection of morphological data:

The seeds when germinated were thinned to one plant per location.

The field was weeded several times when it was necessary. When the seedlings

were two weeks old the plants of particular rows which were destined to be sprayed were separated temporarily from other rows by large hard-boards so

that no insecticide could accidentally come in contact with other plants.

The plants to be sprayed were soaked with the diluted insecticides prepared in two dilutions (D_1 and D_2) with the help of a hand-spray. The control

plants designated as D_0 were sprayed with plain distilled water. Both

Sonalika and Durum have similar treatments and the plants of the two species were allotted in two sub-plots within the main field.

Collection of spikes:

At the flag leaf stage, young inflorescences from the various treatments and the control plants were collected. The material first collected was checked for the presence of right stages of meiotic division. These collected inflorescences were, immediately fixed in a modified Carnoy's fixative. After 48 hours the materials were transferred to 70% ethanol and stored in a refrigerator for examination.

Preparation of slides:

Temporary slides were prepared by the acetocarmine smear method and the meiotic abnormalities were examined and noted. Cytological screening was made for all the stages of meiosis from Diakinesis to Telophase II. The different types of abnormalities were recorded in a record book. Photographs were taken from the desired preparations (Figs. 1 to 6).

Collection of morphological data: 1981 - 82 and 1982 - 83.

The morphological data on plant height, number of tillers per plant, number of spikelet per ear, number of seeds per ear and ~~weight of seeds per ear~~, were taken from ten randomly selected plants of each treatment and control rows.

Meiotic abnormalities of the Hexaploid wheat of 1981-82 and 1982-83

Meiotic studies of the pollen mother cells carried out revealed various types of chromosomal aberrations. Contraction and stickiness of the chromosomes were one of the common effects of the insecticide on the meiotic chromosomes. This contraction and stickiness of the chromosomes was the first noticeable response of the insecticide. The pollen mother cells were found to contain chromosomes with varying degrees of contraction forming masses of chromosomes. In the 1982-83 material, the percentages of PMCs with such contracted chromosome masses were 0.7, 4.4, 5.1, 5.3, 7.8, 8.0 and 9.6 in D_0 , STD_1 , STD_2 , STD_1 , STD_2 , STD_1 and STD_2 respectively. Therefore, this cytological aberration caused by the insecticide was not divergent in case of the different doses and treatments.

RESULTS

The results of the present study are reported under the following heads:

(1) D_1 Meiotic Abnormalities of the Hexaploid Wheat of 1981 - 82 and 1982 - 83.

(2) Meiotic Abnormalities of the Tetraploid Wheat of 1981 - 82.

(3) Morphological Data of 1981 - 82 and 1982 - 83.

(4) Performance of the Selfed Progeny of the Insecticide Treated Plants of 1981 - 82 during 1982 - 83.

(5) Correlation Analysis of Grain Data.

(1) Meiotic Abnormalities of the Hexaploid Wheat of 1981-82 and 1982-83

Meiotic studies of the pollen mother cells carried out revealed various types of chromosomal aberrations. Contraction and stickiness of the chromosomes were one of the common effects of the insecticide on the meiotic chromosomes. This contraction and stickiness of the chromosomes was the first noticeable response of the insecticide. The pollen mother cells were found to contain chromosomes with varying degrees of contraction forming masses of chromosomes. In the 1982-83 material, the percentage of PMCs with such contracted chromosome masses were 0.7, 5.9, 6.1, 8.5, 7.8, 8.0 and 9.6 in D_0 , STD_1 , STD_2 , SPD_1 , SPD_2 , $STPD_1$ and $STPD_2$ respectively. Therefore, this cytological aberration induced by the insecticide was not divergent in case of the different doses and treatments.

Table 1

The other common and recurrent aberrations observed were chromosome and chromatid fragments, chromosome bridges and micronuclei. A few photographs of different types of abnormalities are included in Figs. 1 to 6. At least five slides per treatment (D_0 , STD_1 , STD_2 , SPD_1 , SPD_2 , $STPD_1$ and $STPD_2$) were scored and a summary of the occurrence of these abnormalities from Metaphase I to Telophase II for 1981 - 82 and 1982 - 83, are shown in Tables 1 & 2 respectively. A total of 12,044 meiocytes were scored in 1981 - 82 and 20,652 meiocytes were examined in 1982 - 83.

In the 1981 - 82 experiment, a total of 11,953 meiocytes with normal chromosomes were scored out of which 7,452 (62.34%) belonged to the different stages of Meiosis I, whereas, 4,501 (37.66%) belonged to Meiosis II. On the other hand, of the total abnormal cells examined (1,091), 909 were from stages of Meiosis I (83.33%), whereas, only 182 (16.67%) belonged to Meiosis II.

In the 1982 - 83 experiment, out of 19,170 normal meiocytes scored, 14,431 (75.28%) belonged to Meiosis I and only 4,739 (24.72%) belonged to Meiosis II. Out of the 1982 meiocytes with chromosomal aberrations, 1,179 (79.55%) were in Meiosis I, whereas, only 303 (20.45%) cells belonged to Meiosis II.

When classified according to individual stages i.e., Metaphase, Anaphase, and Telophase, the most frequently encountered one was Metaphase (9,400 i.e., 45.52% of all cells studied). Next frequent was Telophase, 9,306 i.e., 45.06% of all the meiocytes scored. Cells belonged to the Anaphase were the least frequent, 1,946 i.e., only 9.42% of all cells. These figures are from the 1982-83 experiment, similar figures for 1981-82 experiments are 4,674 i.e., 38.81% of Metaphase, 6,043 i.e. 50.17% of Telophase and 2,327 i.e., 19.32% of Anaphase.

Table 1

Summary of meiotic cells studied for chromosomal aberrations in hexaploid wheat after Carbicron treatments in 1981-82 experiment.

Treatment	Division	Cells without aberrations			Cells with aberrations				Total normal cells	Total abnormal cells	Percentage of abnormal cells
		M	A	T	M	A	T				
D ₀	Meiosis I	745	467	544	69	57	4		3243	10132	3.3.91
	Meiosis II	214	483	790	1	-	1				
STD ₁	Meiosis I	626	162	1072	141	54	43		2267	267	11.10.54
	Meiosis II	222	121	64	13	14	2				
STD ₂	Meiosis I	144	100	648	37	40	40		1135	125	6.9.92
	Meiosis II	89	53	101	-	4	4				
SPD ₁	Meiosis I	442	108	220	40	42	14		870	114	6.11.59
	Meiosis II	44	24	32	11	5	2				
SPD ₂	Meiosis I	146	52	433	42	27	21		1494	123	6.7.61
	Meiosis II	204	126	533	14	8	11				
STPD ₁	Meiosis I	86	77	193	41	4	25		1346	138	6.9.30
	Meiosis II	267	156	637	21	10	37				
STPD ₂	Meiosis I	790	120	347	129	21	18		1598	192	7.10.73
	Meiosis II	85	59	197	11	3	10				

M = = Metaphase;

A = = Anaphase;

T = = Telophase.

Table 2

Summary of meiotic cells studied for chromosomal aberrations in hexaploid wheat after Carbicron treatments in 1982-83 experiment.

Treatment	Division	Cells without aberrations			Cells with aberrations			Total normal cells	Total abnormal cells	Percentage of abnormal cells
		M	A	T	M	A	T			
D ₀	Meiosis I	986	127	1066	51	9	23	2815	101	3.46
	Meiosis II	113	15	508	5	3	10			
STD ₁	Meiosis I	1229	225	1233	248	63	76	3150	426	11.89
	Meiosis II	145	48	270	19	11	9			
STD ₂	Meiosis I	1073	288	915	108	39	32	2846	201	6.60
	Meiosis II	330	71	169	16	1	5			
SPD ₁	Meiosis I	773	122	765	84	6	34	2483	174	6.55
	Meiosis II	364	78	381	29	2	19			
SPD ₂	Meiosis I	680	131	942	87	14	35	2365	153	6.08
	Meiosis II	257	81	274	11	4	2			
STPD ₁	Meiosis I	979	187	1239	90	20	37	3406	251	6.86
	Meiosis II	360	123	518	73	5	26			
STPD ₂	Meiosis I	895	162	414	61	14	48	2105	176	7.72
	Meiosis II	321	86	227	13	11	29			

M = Metaphase;

A = Anaphase;

T = Telophase.

Fig 1 Photomicrograph showing Metaphase I with lagging chromosomes in wheat induced by the insecticide Carbicron.

Fig 2 Photomicrograph showing Metaphase I with lagging chromosomes in wheat induced by the insecticide Carbicron.

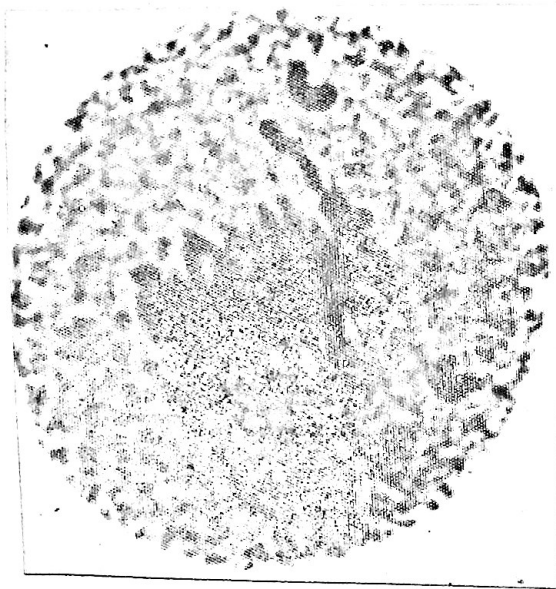


Fig 1

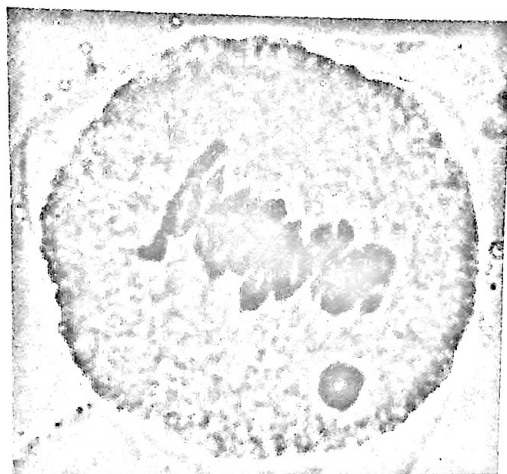


Fig 2

Fig 3 Photomicrograph showing Anaphase I with multiple bridges in meiocytes of wheat induced by the insecticide Carbicron.

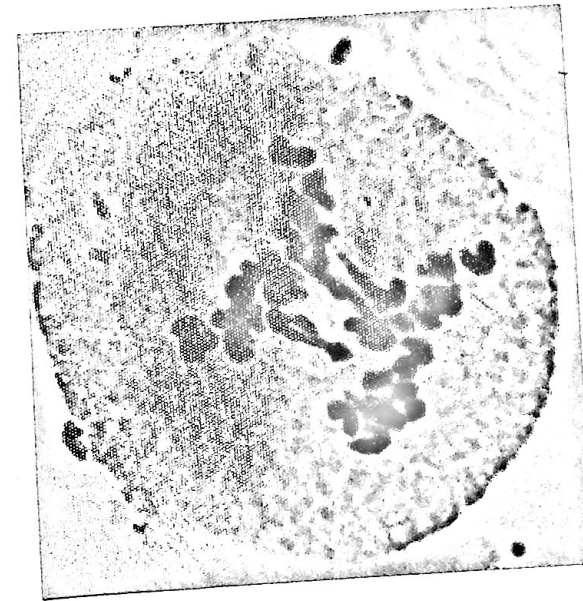


Fig 3

Fig 4 Photomicrograph of Anaphase I with multiple bridges in meiocytes of wheat induced by Carbicron.

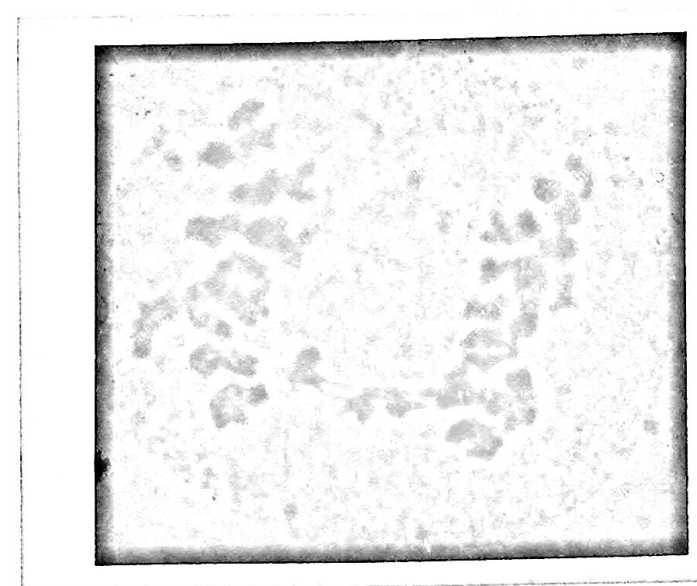


Fig 4

Fig 5 Photomicrograph of Anaphase I with single
bridge in wheat meiocytes caused by Carbionen.

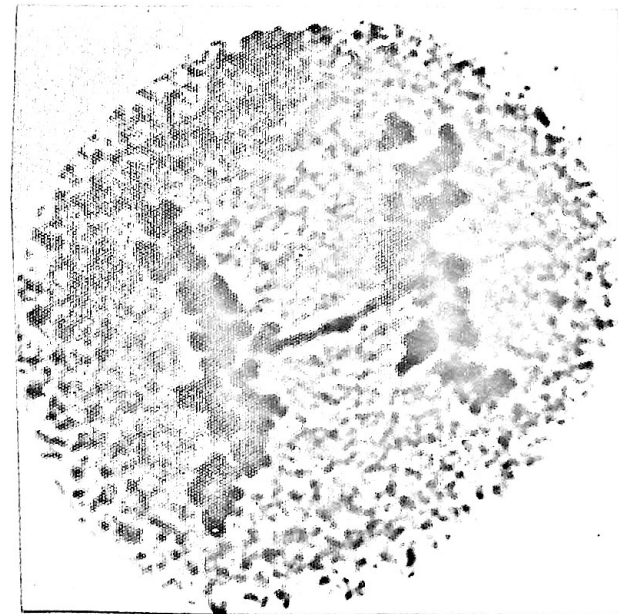


Fig 5

Fig 6 Photomicrograph of Telophase I with lagging
chromosomes of wheat in Carbionen treated
meiocyte.



Fig 6

Fig 6 a Photomicrograph of Telophase I with micro-
nuclei in wheat meiocytes treated with
Carbiclen.



Fig 7

The proportion of the abnormal cells when calculated for individual stages of meiosis, for 1981-82 data, the proportion of meiocytes with aberrations was for Metaphase 570 against 4,104 normal (0.1389), 289 against 2,038 normal (0.1418) for Anaphase and 232 against 5,811 (0.0399) for Telophase; similar data for 1982-83 were for Metaphase 895 abnormal against 8,505 normal meiocytes (0.1052), for Anaphase, 202 against 1744 (0.1158) and for Telophase 385 abnormal against 8,921 normal (0.0432).

When the data in Tables 1 & 2 were summarized for proportion of meiocytes with chromosomal aberrations separately for Meiosis I and II, the following picture emerged. In 1981-82 experiment, the total number of abnormal cells in Meiosis I was 909 against 7,452 normal ones, i.e., the proportion was 0.1220; whereas of Meiosis II, there were 182 abnormal cells and 4,501 normal cells, the proportion being 0.0404. Similar figures for 1982-83 experiment were 1,179 abnormal against 14,431 normal cells in Meiosis I, the proportion being 0.0817 whereas, for Meiosis II, there were 303 abnormal cells and 4,739 normal cells (0.0639).

The different types of chromosomal aberrations observed after the insecticide treatments in hexaploid wheat in the 1981-82 experiment are summarized in Table 3. From the untreated (control) material in all 3,375 meiocytes were scored and 132 were found to contain different types of chromosomal abnormalities. Here the percentage of abnormal cells was 3.91, but in the six treatments (STD_1 , STD_2 , SPD_1 , SPD_2 , $STPD_1$ and $STPD_2$) in all 10,969 meiocytes were scored and a total of 959 abnormal cells were detected which gives an overall percentage of 8.74. Thus, it becomes clear that insecticide treatments did increase the number of chromosomal abnormalities in the hexaploid wheat. The overwhelming majority of the chromosomal abnormalities observed were laggards (65.63% of all

the facilities), followed by bridges (15.77%) and micronuclei (12.19%). The least frequent abnormality was lagwards (6.42%).

Table 3

Different types of chromosomal aberrations observed after Carbinon treatments in hexaploid wheat during 1981 - 82.

Treatment	Chromosomal aberrations				Total normal cells	Total abnormal cells	Total cells studied	Percentage of abnormal cells
	Laggards	Frag-ments	Bridges	Micro-nuclei				
D ₀	91	19	21	1	3243	132	3375	3.91
STD ₁	205	9	31	22	2267	267	2534	10.54
STD ₂	71	7	30	17	1135	125	1260	9.92
SPD ₁	56	20	36	2	870	114	984	11.59
SPD ₂	63	12	34	14	1494	123	1617	7.61
STPD ₁	69	3	7	59	1346	138	1484	9.30
STPD ₂	161	-	13	18	1598	192	1790	10.73

between the control (D₀) and the treatment means contributed much to the 'none' item.

(2) Meiotic Abnormalities of the Tetraploid Wheat of 1981-82

A variety of tetraploid wheat, *tritica durum* (2n = 4x = 28) was included in the original experiment to find out whether there is any difference in the response of meiotic chromosomal behaviour to the inactivating treatment associated with chromosome number difference (28 vs. 42).

abnormalities), followed by bridges (15.77%) and micronuclei (12.19%). The least frequent abnormality was fragments (6.42%).

Similar results were obtained again in the 1982-83 experiment (Table 4). The percentage of abnormalities in the untreated material was only 3.46 but in the insecticide treated material the overall percentage of the chromosomal abnormalities was 7.78. Once again laggards were the most frequent aberrations observed (72.91% of all aberrations) followed by fragments (14.39%) and micronuclei (8.78%).

The results of Analysis of Variance of the 1981-82 and the 1982-83 data carried out on the percentages of different chromosomal aberrations caused by the various treatments of the insecticide are given in Tables 5 & 6. The percentages were transformed into angles following the angular (Arcsine) transformation procedure developed by Bliss (1937). The transformed data was analysed following randomized design. In both the 1981-82 and the 1982-83 data, the 'Dose' item was highly significant whereas, in the 1982-83 data 'Methods' item was significant at 5% level. Inspection of the treatment means given in Tables 3 & 4 clearly indicates that the difference between the control (D_0) and the Treatment means contributed much to the 'Dose' item.

(2) Meiotic Abnormalities of the Tetraploid Wheat of 1981-82

A variety of tetraploid wheat, Triticum durum ($2n = 4x = 28$) was included in the original experiment to find out whether there is any difference in the response of meiotic chromosomal behaviour to the insecticide treatment associated with chromosome number difference (28 vs. 42).

Table 4

Table 5

different types of chromosomal aberrations observed after Carbicron treatment in hexaploid wheat during 1982 - 83.

Treatment	Chromosomal aberrations				Total normal cells	Total abnormal cells	Total cells studied	Percentage of abnormal cells
	Laggards	Frag-ments	Bridges	Micro-nuclei				
Total		1113.21		44				
D ₀	53	25	6	17	2815	101	2916	3.46
STD ₁	296	45	17	19	3150	426	3576	11.89
STD ₂	163	22	4	12	2846	201	3047	6.60
SPD ₁	138	26	1	9	2483	174	2657	6.55
SPD ₂	134	12	4	3	2365	153	2518	6.08
STPD ₁	158	17	15	61	3406	251	3657	6.86
STPD ₂	137	18	12	9	2105	176	2281	7.72

Table 6
Table 5

Results of analysis of variance of transformed data (percentage to angular)
for meiotic chromosomal abnormalities of hexaploid wheat during 1981 - 82.
during 1982 - 83.

Item	SS	df	MS	F	P
Total	1112.21	44			
Replications	30.82	4	7.71	< 1	NS
Treatments	502.66	8			
Methods	0.25	2	0.13	< 1	NS
Doses	479.85	2	239.92	13.26	***
Methods X Doses	22.56	4	5.64	< 1	NS
Error	578.74	32	18.09		

Squash preparations of pollen mother cells of tetraploid wheat were studied during the 1982-83 season only. Again, the most common aberrations were studied during the 1982-83 season only. Again, the most common aberrations were studied during the 1982-83 season only.

Table 6

Results of analysis of variance of transformed data (percentage to arcs and angular) for meiotic chromosomal abnormalities of hexaploid wheat given in Table 7. Out of 10,048, 6,079 (60.5%) belonged to Meiosis I, whereas 3,969 (39.5%) belonged to Meiosis II. The number of cells with aberrations scored in Meiosis I stages was 542 out of a total of 527 i.e. 68.69%. The number of normal cells belonging to Meiosis I was 5,667 out of 10,048 i.e., 56.41%.

The most frequent class was Telophase, a total of 10,048 i.e. 52.9% followed by Metaphase with a total of 5,305 i.e. 26.41%; whereas 8%, the least frequent class was anaphase. The most frequent class was Telophase, a total of 10,048 i.e. 52.9% followed by Metaphase with a total of 5,305 i.e. 26.41%; whereas 8%, the least frequent class was anaphase.

Item	SS	df	MS	F	P
Total	620.95	44			
Replications	43.81	4	10.95	1.53	NS
Treatments	348.59	8			
Methods	50.66	2	25.33	5.33	*
Doses	271.89	2	135.95	19.04	***
Methods X Doses	26.04	4	6.51	0.91	NS
Error	228.35	32	7.14		

The percentage of abnormal cells found among 636 untreated (control P_0) meiocytes was 3.30, whereas, the percentage of abnormal cells in the six different treatments were 4.83 to 6.59.

The results of Analysis of variance carried out on the percentages of chromosomal aberrations in the insecticide treated tetraploid wheat is given in Table 8. In this case the Replications, Dose and Dose X Methods items were significant at 5% level.

Table 7

Summary Squash preparations of pollen mother cells of tetraploid wheat ~~loid~~ were studied during the 1981-82 season only. Again, the most common aberration observed was lagging chromosomes, followed by bridges, fragments and micronuclei. A total of 10,048 cells were scored, the details are given in Table 7. Out of 10,048, 6029 (60%) belonged to Meiosis I, whereas 4,019 (40%) belonged to Meiosis II. The number of cells with aberrations scored in Meiosis I stages was 362 out of a total of 527 i.e. 68.69%. The number of normal cells belonging to Meiosis I was 5,667 out of 10,048 i.e., 59.52%.

Meiosis I	226	87	595	32	10	13	1249	88	6.53
Meiosis II	161	121	59	19	9	6			

The most frequent stage in this study was Telophase, a total of 5,316 out of 10,048 i.e., 52.90% followed by Metaphase, a total of 3,205 out of 10,048 i.e. 31.89%; whereas, the least frequent class was Anaphase, 1527 amongst 10,048 cells i.e., only 15.20%.

Meiosis II	51	15	100	1	-	6			
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The proportion of meiocytes with chromosomal abnormalities was highest in Metaphase, 201 out of 3,205 (0.0627), followed by Telophase, 243 out of 5,316 (0.0457) and Anaphase, 83 out of 1,527 (0.0543).

The percentage of abnormal cells found among 636 untreated (control D_0) meiocytes was 3.30, whereas, the percentage of abnormal cells in the six different treatments were 4.65 to 6.59.

The results of Analysis of Variance carried out on the percentages of chromosomal aberrations in the insecticide treated tetraploid wheat is given in Table 8. In this case the Replications, Dose and Dose X Methods items were significant at 5% level.

T = Telophase.

Table 7

Summary of meiotic cells screened for chromosomal aberrations in tetraploid wheat after Carbicron treatments in 1981-82.

Results of analysis of variance of transformed data (percentages to

Treatment	Division	Cells without aberrations			Cells with aberrations			Total normal cells	Total abnormal cells	Percentage of abnormal cells
		M	A	T	M	A	T			
D ₀	Meiosis I	151	150	267	22	21	3	1582	54	3.30
	Meiosis II	136	366	512	0	4	4			
STD ₁	Meiosis I	226	87	595	32	10	13	1249	88	6.58
	Meiosis II	161	121	59	18	9	6			
STD ₂	Meiosis I	142	86	398	10	7	18	1048	60	5.42
	Meiosis II	151	83	188	13	1	11			
SPD ₁	Meiosis I	426	77	373	23	3	20	1042	53	4.84
	Meiosis II	51	15	100	1	-	6			
SPD ₂	Meiosis I	186	43	378	11	4	16	1312	64	4.65
	Meiosis II	222	94	389	7	6	20			
STPD ₁	Meiosis I	253	67	697	16	2	48	1785	102	5.41
	Meiosis II	343	77	348	14	2	20			
STPD ₂	Meiosis I	443	123	499	31	10	42	1503	106	6.59
	Meiosis II	113	55	270	3	4	16			

M = Metaphase;

A = Anaphase;

T = Telophase.

(3) Morphological Data Table 8 82 and 1982 - 83

Results of analysis of variance of transformed data (percentages to angular) for meiotic chromosomal aberrations in Carbicron treated and control tetraploid wheat during 1981 - 82.

...the control rows were scored. The morphological characters scored were plant height, number of tillers per plant, number of spikelets per ear and number of grains per ear. The data were analysed using a Replicated two-way analysis of Variance Model. The

Item	SS	df	MS	F	P
Total	446.60	44			
Replications	89.57	4	22.39	3.47	5%
Treatments	150.56	8			
Methods	11.81	2	5.91	<1.00	NS
Doses	53.04	2	26.52	4.11	5%
Methods X Doses	85.71	4	21.43	3.32	5%
Error	206.47	32	6.45		

...the first separated with 4 degrees of freedom, then the total SS was partitioned into a Treatments item with 8 degrees of freedom, and a Residual item with 32 degrees of freedom. The Treatments item was further partitioned into Replications item with 4 degrees of freedom, and a residual item with 4 degrees of freedom. The residual item was further partitioned into Methods item with 2 degrees of freedom, Doses item with 2 degrees of freedom, and Methods X Doses item with 4 degrees of freedom. The residual degrees of freedom were not fitted to a complete factorial design. This separation of Treatments item into sub-components was statistically valid. The effects of different insecticides were applied i.e., D_1 and D_2 . However, the significance of these items conclusively indicates the effect of insecticide, which is the aim of the present research project. Little importance was given to the dose effects or the effects of the different methods of application of the insecticide. A fully factorial experimental design is needed for such a study.

(1) Plant Height at Heading: The height in cm. at heading of Carbicron treated and control plants of hexaploid and tetraploid wheat grown during 1981-82 are given in Tables 9 & 10 respectively. The average plant height of hexaploid wheat for 'control' and 'Treatment' families

(3) Morphological Data of 1981 - 82 and 1982 - 83

plant height (cm) at heading of Carbicron treated and control plants of hexaploid

For collection of morphological data, ten randomly chosen plants from each of the 'Treatments' including the 'control' row were scored. The morphological characters scored were plant height, number of tillers per plant, number of spikelets per ear and number of grains per ear. The data were analysed using a Replicated Two-way Analysis of Variance Model. The Replications item was first separated with 9 degrees of freedom, then the total SS was partitioned into a Treatments item with 8 degrees of freedom, and a Residual item with 72 degrees of freedom. The Treatments item was further partitioned into Methods item with 2 degrees of freedom. Doses item was with 2 degrees of freedom and Methods X Doses item^{was} with 4 degrees of freedom. As a Factorial design can not be fitted to the complicated experimental data, this separation of Treatments item into sub-components was not strictly valid, this is because the effects of different types of application i.e., ST, SP and STP can not be separated from the effects of the different doses applied i.e., D_1 and D_2 . However, the significance of these items would conclusively indicate the effect of insecticide, which is the main aim of the present research project. Little importance was given to the dose effects or the effects of the different methods of application of the insecticide. A fully factorial experimental design is needed for such a study.

(i) Plant Height at Heading: The height in cm. at heading of Carbicron treated and control plants of hexaploid and tetraploid wheat grown during 1981-82 are given in Tables 9 & 10 respectively. The ranges of plant height of hexaploid wheat for 'control' and 'Treatment' families

Table 9

plant height (cm) at heading of Carbicron treated and control plants of hexaploid wheat during 1981-82.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP	D ₀	97	85	87	92	88	89	102	84	97	91	91.2
	D ₁	95	99	96	96	91	96	92	89	79	73	90.6
	D ₂	81	80	92	85	89	81	87	81	90	79	84.5
ST	D ₀	87	88	86	93	114	81	94	89	106	105	94.3
	D ₁	85	74	83	83	98	72	82	86	96	94	85.3
	D ₂	93	84	86	96	84	88	81	90	93	88	88.3
STP	D ₀	102	92	85	87	73	91	80	96	90	80	88.3
	D ₁	102	84	90	85	94	77	85	85	78	87	86.7
	D ₂	90	91	87	91	96	91	86	87	86	92	89.7

were 73 to 114 cm. and 72 to 102 cm. respectively; whereas that for tetraploid wheat were 82 to 109 cm. Table 10 shows the range of plant height (cm) at heading of Carbicron treated and control plants of tetraploid wheat in 1981-82.

The results of the Analysis of Variance (Tables 10 & 12) indicated significant treatment items. The differences between the means for different doses of the treatments indicated a weak trend towards higher dose reducing the height of treated plants.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP	D ₀	91	94	101	102	101	96	96	90	106	96	97.3
	D ₁	101	101	95	97	90	98	103	97	90	95	96.7
	D ₂	94	102	103	99	102	95	95	102	98	97	98.7
ST	D ₀	88	98	99	101	99	82	92	88	84	88	91.9
	D ₁	101	95	104	101	85	86	81	91	90	81	91.5
	D ₂	90	100	91	92	83	80	84	90	81	98	88.9
STP	D ₀	94	98	99	92	98	89	95	109	99	96	96.9
	D ₁	96	99	91	89	90	91	101	91	90	81	91.9
	D ₂	93	85	91	98	92	90	83	82	90	91	89.5

In both the cases of both the species the mean number of tillers was reduced in the treated plants. The results of the Analysis of Variance indicated that in both the cases the 'treatment' items were highly significant, indicating that the insecticide treatments did reduce the number of fertile tillers in both the wheat species.

(iii) Number of Spikelets per Ear of the Main Branch: The number of spikelets per ear of the main branch for hexaploid and tetraploid wheat species are given in Tables 17 & 18 respectively. In hexaploid species, the range for the 'Control' plants was 10 to 22 and for the treated families was 10 to 20; whereas, in the case of tetraploid wheat, these were 16 to 21 and 15 to 20 respectively. In all cases, the mean number

were 73 to 114 cm. and 72 to 102 cm. respectively; whereas that for tetraploid wheat were 82 to 109 cm. for control families and 80 to 104 cm. for treatment families. The mean height of treated plants of both hexaploid and tetraploid wheat were lower than that of the control plants. The results of the Analysis of Variance (Tables 10 & 12) indicated significant Treatment items. The differences between the means for different doses of the treatments indicated a weak trend towards higher dose reducing the height of treated plants.

(ii) Number of Fertile Tillers per Plant: The number of fertile tillers per plant (Tables 13 & 14) exhibited a wide range of variation both in cases of hexaploid and tetraploid wheat. In hexaploid wheat, the range in 'Control' families was 3 to 23; whereas, in treated families it was 3 to 17, in tetraploid wheat these are 6 to 18 and 2 to 18 respectively. In most of the cases of both the species the mean number of tillers was higher in the untreated (control) families than in the Carbicron treated families. The results of the Analysis of Variance (Tables 15 & 16) confirmed this, in both the cases the 'Treatment' items were highly significant, indicating that the insecticide treatments did reduce the number of fertile tillers in both the wheat species.

(iii) Number of Spikelets per Ear of the Main Branch: The number of spikelets per ear of the main branch for hexaploid and tetraploid wheat species are given in Tables 17 & 18 respectively. In hexaploid species, the range for the 'Control' plants was 10 to 22 and for the treated families was 10 to 20; whereas, in the case of tetraploid wheat, these were 16 to 21 and 15 to 20 respectively. In all cases, the mean number

Table 11

Results of analysis of variance of plant height at heading of Carbicron treated and control plants of hexaploid wheat during 1981 - 82.

Item	SS	df	MS	F	P
Total	4944.10	89			
Replications	815.21	9	90.58	1.93	NS
Treatments	757.00	8	94.63	2.02	*
Methods	17.07	2	8.08	1.00	NS
Doses	281.27	2	140.64	3.00	10 - 5%
Methods X Doses	458.66	4	114.67	2.45	NS
Error	3371.89	72	46.83		

Table 12

Results of analysis of variance of plant height of Carbicron treated and control plants of tetraploid wheat during 1981 - 82.

Item	Dose	Plants										P
		1	2	3	4	5	6	7	8	9	10	
Total		3856.90			89							
Replications	D ₀	524.23		15	11	9	5	7	9	13	12	NS
Treatments	D ₁	1092.80		9	8	6	136.50	6	14.39	3	6	**
Methods	D ₂	732.80			2		336.40		11.77			***
Doses	D ₀	140.00		14	14	12	10	16	12	23	16	NS
Methods X Doses	D ₁	219.20		4	2	5	70.00	8	2.25	3	10	NS
Error	D ₂	2240.67		10	4	11	54.80	8	1.76	11	10	NS
	D ₀			5	72	3	31.12	3	10	7	4	
	D ₁		8	13	9	8	5	4	4	7	5	
	D ₂		12	7	17	10	9	12	5	5	6	

Table 13

Number of fertile tillers per plants of Carbicron treated and control plants of hexaploid wheat during 1981 - 82.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP	D ₀	9	5	15	11	9	5	7	9	13	12	9.5
	D ₁	4	15	10	10	10	10	8	8	11	9	9.5
	D ₂	6	6	9	8	6	3	6	5	8	6	6.3
ST	D ₀	9	7	14	14	12	10	16	13	23	16	13.4
	D ₁	4	3	4	5	5	6	8	6	6	10	5.7
	D ₂	11	8	10	11	8	12	8	10	11	10	9.9
STP	D ₀	16	15	5	8	3	6	3	10	7	4	7.7
	D ₁	8	13	9	8	5	4	4	7	5	10	7.3
	D ₂	12	7	17	10	9	12	5	5	6	10	9.3

Table 14

Number of tillers (fertile) per plant of Carbicron treated and control plants of tetraploid wheat during 1981 - 82.

		Plants										Mean
Treatment	Dose	1	2	3	4	5	6	7	8	9	10	
SP Replications	D ₀	14	11	9	13	18	9	14	8	11	18	12.5
	D ₁	17	10	7	14	6	11	13	12	11	9	11.0
	D ₂	7	12	18	8	13	11	14	13	17	10	12.3
Treatments												
ST Doses	D ₀	12	15	12	13	13	5	16	10	10	9	11.5
	D ₁	8	9	12	4	4	15	6	6	9	6	7.9
	D ₂	6	11	12	11	8	5	4	7	2	5	7.1
Methods x Doses												
STP	D ₀	11	9	6	6	9	9	14	13	9	11	9.7
	D ₁	9	6	10	6	11	10	9	11	6	7	8.5
	D ₂	6	7	11	8	10	9	5	6	7	10	7.9

Table 15

Results of analysis of variance of number of tillers per plant of Carbicron treated and control plants of hexaploid wheat during 1981-82.

Item	SS	df	MS	F	P
Total	1259.60	89			
Replications	101.38	9	11.26	1.11	NS
Treatments	428.80	8	53.60	5.29	***
Methods	40.87	2	20.44	2.02	NS
Doses	111.80	2	55.90	5.52	**
Methods X Doses	276.13	4	69.03	6.81	**
Error	729.42	72	10.13		

Table 16

Results of analysis of variance of number of tillers per plant of control and Carbicron treated and control plants of tetraploid wheat during 1981 - 82.

		Plants										
Item	Test	SS	df	MS	F	P	Mean					
Total	D ₀	1103.16	89				14.6					
Replications	D ₁	26.94	9	2.91	<1.00	NS	14.9					
Treatments	D ₂	340.76	8	42.60	4.17	***	14.7					
Methods	D ₀	200.83	2	100.41	9.83	***	14.9					
Doses	D ₁	89.63	2	44.82	4.39	*	15.4					
Methods X Doses	D ₂	50.29	4	12.57	1.23	NS	15.0					
Error	D ₀	735.49	72	10.22			16.2					
	D ₁						15.3					
	D ₂						17.2					

Table 17

Number of spikelets per ear (of the main branch) of Carbicron treated and control plants of hexaploid wheat during 1981 - 82.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP	D ₀	10	14	18	12	20	15	13	19	12	13	14.6
	D ₁	15	13	15	20	13	13	18	15	15	12	14.9
	D ₂	14	12	19	15	14	14	13	11	14	11	13.7
ST	D ₀	13	20	16	12	20	15	19	13	19	12	15.9
	D ₁	19	19	20	17	12	14	18	13	11	11	15.4
	D ₂	18	19	13	13	15	14	16	10	20	12	15.0
STP	D ₀	22	21	14	20	17	16	19	21	13	19	18.2
	D ₁	15	19	14	15	14	16	14	18	15	13	15.3
	D ₂	19	18	10	19	17	18	18	17	17	18	17.2
STP	0	18	20	21	20	18	20	19	20	17	20	19.3
	1	18	20	19	18	17	17	17	18	17	19	18.0
	2	15	17	19	19	17	15	17	15	16	16	16.2

Table 18

Number of spikelets per ear (of the main branch) of Carbicron treated and control plants of tetraploid wheat during 1981-82.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP	0	18	18	18	19	18	18	19	18	18	17	18.1
	1	17	18	18	17	18	18	18	18	17	17	17.6
	2	17	19	18	16	17	16	16	19	15	20	17.3
ST	0	19	17	17	18	18	19	20	16	17	18	17.9
	1	18	19	16	17	17	17	17	16	16	17	17.0
	2	16	17	16	15	15	17	16	15	18	17	16.2
STP	0	18	20	21	20	18	20	19	20	17	20	19.3
	1	18	20	19	18	17	17	17	18	17	19	18.0
	2	15	17	19	15	17	15	17	15	16	16	16.2

of spikelets per ear of the treated families were lower than the 'Control' families. The significant 'Treatment' items (Tables 19 & 20) in both the species indicated a statistically significant negative effect of the insecticide on this trait. control plants of hexaploid wheat during 1981 - 82.

(iv) Number of Grains per Ear: The number of grains per ear of hexaploid and tetraploid wheat are given in Tables 21 & 22 respectively. This character also exhibited a wide range of variation in hexaploid wheat. The range for the 'Control' families was 30 to 69 and for the treated families was 30 to 77, whereas, in the tetraploid species these were 28 to 68 and 34 to 63 grains per ear respectively. In all cases, except ST in both the species, the 'Treatment' means were lower than the 'Control' means. The significant 'Treatment' items in both the species (Tables 23 & 24) indicate a significant negative effect of the insecticide on this important yield contributing trait.

(v) 1982-83 Morphological Data: The morphological characters were scored again from the different insecticide treated and 'Control' plants of 1982-83. The data were analysed and results similar to those during the previous year were noted. Therefore, only the results for the two characters, Number of spikelets per ear (of the main branch) and Number of grains per ear (of the main branch) for hexaploid wheat were presented in details. The mean number of spikelets per ear (Table 25) of the treated families were always smaller than the 'Controls'. The range for the control plants was 15 to 21 and for the treated families was 13 to 20. Thus, a negative effect of the insecticide treatment on number of spikelets per ear was indicated. The results of the Analysis of Variance (Table 26)

Table 19

Results of analysis of variance of number of spikelets per ear of Carbicron treated and control plants of hexaploid wheat during 1981 - 82.

Item	SS	df	MS	F	P
Total	841.96	89			
Replications	81.07	9	9.01	1.06	NS
Treatments	149.96	8	18.75	2.21	*
Methods	94.66	2	47.33	5.58	**
Doses	19.49	2	9.74	1.15	NS
Methods X Doses	35.82	4	8.95	1.05	NS
Error	619.93	72	8.49		

Table 20

Results of Analysis of Variance of number of spikelets per ear of Carbicron 118 treated and control plants of tetraploid wheat during 1981-82.

Plants												
Item	Treatment	Dose	SS	2	df	4	5	MS	7	F	9	1 P Mean
Total		D ₀	244.49	49	89	33	51	44	43	42	36	44 43.2
Replications		D ₁	21.82	33	9	69	4	2.42	56	1.19	43	NS 45.1
Treatments		D ₂	76.89	31	8	50	2	9.61	43	4.76	40	*** 46.5
Methods			10.70		2			5.35		2.65		NS
Doses		D ₀	52.30	69	2	36		26.15	5	12.95	63	*** 43.4
Methods X Doses			13.89	73	4	49	4	3.47	67	1.72	31	NS 42.6
Error		D ₂	145.78	60	72	49	5	2.02	43	40	76	41 49.3
CTP		D ₀	59	67	42	53	59	52	68	54	41	66 55.7
		D ₁	56	73	40	46	42	64	52	64	40	37 51.4
		D ₂	59	40	40	47	48	50	52	53	49	50 47.6

Table 21

Number of grains per ear of Carbicron treated and control plants of hexaploid wheat during 1981-82.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP	D ₀	30	49	60	33	51	44	43	42	36	44	43.2
	D ₁	47	39	38	69	41	39	56	43	43	36	45.1
	D ₂	42	31	47	50	28	37	43	30	40	37	38.5
ST	D ₀	32	69	42	36	60	51	53	47	63	31	48.4
	D ₁	70	73	77	45	41	48	67	41	31	33	52.6
	D ₂	54	60	39	45	50	45	43	40	76	41	49.3
STP	D ₀	55	67	42	53	59	52	68	54	41	66	55.7
	D ₁	56	73	40	46	42	64	52	64	40	37	51.4
	D ₂	59	48	40	47	48	50	52	53	49	50	49.6

Table 22

Number of grains per ear (of the main branch) of Carbicron treated and control plants of tetraploid wheat during 1981-82.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
Control	0	51	68	50	66	58	50	56	59	40	62	56.0
SP	1	55	44	55	56	62	50	49	45	49	58	52.3
STP	2	44	52	43	48	41	55	53	56	54	63	51.4
Control	0	48	63	56	47	53	42	47	48	41	28	47.3
ST	1	57	49	52	43	48	35	57	55	52	43	49.1
STP	2	56	57	61	42	60	51	46	57	42	61	48.3
Control	0	52	46	42	45	37	62	41	46	31	47	48.9
STP	1	50	40	47	51	55	38	47	48	49	50	47.5
STP	2	37	38	57	44	35	51	47	45	34	41	42.9

Table 23

Results of Analysis of Variance of number of grains per ear of Carbicron treated and control plants of hexaploid wheat during 1981-82.

Item	SS	df	MS	F	P
Total	12198.70	89			
Replications	1303.07	9	144.79	1.19	NS
Treatments	2177.60	8	272.20	2.25	*
Methods	1652.47	2	826.23	6.82	**
Doses	246.60	2	132.30	1.09	NS
Methods X Doses	260.53	4	65.13	<1	NS
Error	8718.03	72	121.08		

Table 24 25

Results of Abalysis of Variance of number of grains per ear of Carbicron 1 treated and control plants of tetraploid wheat during 1981-82.

Item	SS	df	Plant MS	F	P
Treatment	Dose 1 2 3 4 5 6 7 8 9 10 Mean				
Total	5851.79	89			
Replications	D ₀ 420.68 21 15 9 15 20 46.74 21 2 < 1 21 19 NS 19.2				
Treatments	D ₁ 1417.89 15 14 8 14 1 177.24 15 3.18 14 15 . 15.2				
Methods	D ₂ 1003.02 15 16 2 17 1 501.51 16 8.99 16 14 . 15.5				
Doses	2.82 2 1.41 < 1 NS				
Methods X Doses	412.05 16 18 4 16 1 103.01 19 1.85 16 19 NS 17.1				
Error	D ₁ 4013.22 14 1 72 15 18 55.74 20 16 17 17 16.5				
	D ₂ 15 16 16 19 16 15 16 16 18 13 16.5				
	D ₀ 15 16 18 16 15 16 18 17 16 18 16.6				
STP	D ₁ 13 16 16 15 17 15 15 17 15 17 15.6				
	D ₂ 16 17 14 17 16 18 14 14 16 14 15.6				

Table 25

Number of spikelets per ear (of the main branch) of Carbicron treated and control plants of hexaploid wheat during 1982-83.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
ST		19	21	15	15	20	18	21	20	21	19	19.2
	D ₀	16	15	14	14	17	16	15	16	14	15	15.2
	D ₁	15	15	16	17	16	14	16	16	16	14	15.5
SP		16	16	18	16	15	18	19	18	16	19	17.1
	D ₀	14	14	18	16	18	15	20	16	17	17	16.5
	D ₁	15	16	16	19	16	15	16	16	18	18	16.5
STP		15	16	18	16	16	16	18	17	16	18	16.6
	D ₀	13	16	16	15	17	15	15	17	15	17	15.6
	D ₁	16	17	14	17	16	18	14	14	16	14	15.6

confirmed this as the difference was highly significant.

Table 26

Results of Analysis of Variance of the number of spikelets per ear of Carbicron treated and control plants of hexaploid wheat during 1982-83.. for the treated

plants was 10.1 spikelets per ear. The number of spikelets per ear was lower in the treated facilities than in the control except for sp. The results of the analysis of variance for the number of spikelets per ear indicated highly significant

Item	SS	df	MS	F	P
Total	281.96	89			
Replications	17.96	9	1.99	4.1	NS
Treatments	119.16	8	14.89	7.10	***
Methods	10.82	2	5.41	2.69	NS
Doses	66.16	2	33.08	16.44	***
Methods X Doses	42.18	4	10.54	5.24	**
Error	144.84	72	2.01		

A random sample of plants of hexaploid wheat were collected at the flag leaf stage and fixed and preserved for cytological studies. No chromosomal contraction and stickiness was observed in the cells. The data collected on mitotic abnormalities were summarized in Table 29. The percentage of chromosomal abnormalities in the selfed progeny of the control plants was 3.71 and that of the selfed progeny of the treated plants ranged from 3.14 to 1.56. Complete cytological study was not carried out on tetraploid wheat due to the lack of time but random samples of 100s from 'Control' and selfed treated plants indicated no difference in the chromosomal abnormalities observed.

confirmed this as the 'Treatment' item was highly significant.

Table 27

The number of grains per ear of the treated and the control plants of hexaploid wheat exhibited a high degree of variation (Table 27). The range for the control plants was 26 to 52, whereas, that for the treated plants was 16 to 42. The mean number of grains per ear was lower in the treated families than in the 'Controls' except for Sp. The results of the Analysis of Variance for this character (Table 28) indicated highly significant 'Treatments item'.

Treatment	Dose	1	2	3	4	5	6	7	8	9	10	Mean
(4)	Performance of the Selfed Progeny of the Insecticide Treated Plants	41	40	37	34	32	26	30	30	37	31	31.8
ST	D ₁	43	39	40	27	37	25	27	38	38	38	35.7

The progeny of the selfed seeds from the Carbicron treated and control plants of 1981-82 were grown in the same field with the other experimental plants during 1982-83. No insecticides were further applied.

(A) Cytological Studies of Hexaploid Wheat: The heads from a random sample of plants of hexaploid wheat were collected at the flag leaf stage and fixed and preserved for cytological studies. No chromosomal contraction and stickiness was observed in the PMCs. The data collected on meiotic abnormalities were summarized in Table 29. The percentage of chromosomal abnormalities in the selfed progeny of the control plants was 3.71 and that of the selfed progeny of the treated plants ranged from 3.94 to 1.56. Complete cytological study was not carried out on tetraploid wheat due to the lack of time but random samples of PMCs from 'Control' and selfed treated plants indicated no difference in the chromosomal abnormalities observed.

Table 28

Number of grains per ear (of the main branch) of Carbicron treated and control plants of hexaploid wheat during 1982-83.

Treatment	Dose	1	2	3	4	5	6	7	8	9	10	Mean
Total		4279.60										
Replications	D ₀	41	40	27	24	32	26	30	30	37	31	31.8
SP	D ₁	42	35	40	27	37	35	27	38	38	38	35.7
Methods	D ₂	16	26	37	41	50	28	34	41	30	31	33.4
		302.87				251.44			7.73			
Methods x Dose	D ₀	42	34	33	33	38	36	38	34	31	46	36.5
ST	D ₁	33	25	42	40	38	37	35	42	28	38	35.8
	D ₂	33	38	37	40	34	22	36	32	23	32	32.7
	D ₀	50	52	40	50	44	42	45	52	50	42	46.7
STP	D ₁	35	42	37	39	34	36	37	40	29	33	36.2
	D ₂	37	31	33	31	28	30	33	29	36	28	31.6

Table 28

Results of Analysis of Variance of the number of grains per ear of Carbicron treated and control plants of tetraploid wheat during 1982-83.

Item	SS	df	MS	F	P
Total	4229.60	89			
Replications	203.60	9	22.62	< 1	NS
Treatments	1661.20	8	210.15	6.45	***
Methods	324.47	2	162.24	4.98	***
Doses	502.87	2	251.44	7.72	***
Methods X Doses	853.86	4	213.46	6.55	***
Error	2344.80	72	32.57		

Table 29

Summary of meiotic cells studied for chromosomal aberrations in hexaploid wheat one generation selfed after Carbicron treatments in 1981-82.

Treatment	Division	Cells without aberrations			Cells with aberrations			Total normal cells	Total abnormal cells	Percentage of abnormal cells
		M	A	T	M	A	T			
D ₀	Meiosis I	319	238	190	19	22	9	1456	54	3.71
	Meiosis II	211	187	311	0	4	0			
STD ₁	Meiosis I	405	95	616	24	3	12	1402	52	3.58
	Meiosis II	112	45	129	7	5	1			
STD ₂	Meiosis I	215	121	230	10	9	15	952	39	3.94
	Meiosis II	95	73	218	0	2	3			
SPD ₁	Meiosis I	331	87	290	7	0	8	1064	20	1.88
	Meiosis II	121	42	193	0	1	4			
SPD ₂	Meiosis I	109	210	93	4	8	0	624	16	2.56
	Meiosis II	49	43	120	0	0	4			
STPD ₁	Meiosis I	215	33	98	4	2	3	543	18	3.31
	Meiosis II	29	29	139	1	3	5			
STPD ₂	Meiosis I	205	101	39	4	0	0	512	8	1.56
	Meiosis II	21	58	88	0	2	2			

M = Metaphase;

A = Anaphase;

T = Telophase.

(B) Morphological Studies of Hexaploid Wheat: Plant height, number of fertile tillers per plant, number of spikelets per ear and number of grains per ear of the main branch were scored for both the hexaploid and tetraploid species of wheat. The performance for these characters and the results of the Analysis of Variance are discussed below:

(a) Plant Height: The performance for the selfed progeny for plant height showed no definite trend (Table 30). The range for the 'Control' plants was 68 to 101 and that for the treated plants was 71 to 101. There was no significant difference between the 'Control' means and the 'Treatment' means as indicated from the results of the Analysis of Variance (Table 31). All the Mean Squares were non-significant.

(b) Number of Tiller per Plant: The performance of the selfed families for number of tillers per plant is given in Table 32 and the results of the Analysis of Variance in Table 33. The range of the 'Control' plant was 4 to 14 and for treated plants 2 to 13. Though the 'Treatment' means were slightly smaller than the 'Control' means, this difference was found to be statistically non-significant.

(c) Number of Spikelets per Ear: The performance of the selfed families for number of spikelets per ear is given in Table 34 and the results of the Analysis of Variance in Table 35. The range for the 'Control' plants was 15 to 21 and for the treated plants 12 to 23. Here again the mean number of spikelets of the treated families were slightly lower than the 'Controls' except in STP selfed. But these differences were statistically non-significant.

Table 30

Plant height at heading (cm.) of the selfed progeny of Carbicron treated and control plants of 1981-82 hexaploid wheat grown during 1982-83.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
Total	D ₀	81	87	86	83	76	87	86	79	68	81	81.4
SP selfed	D ₁	90	88	83	81	79	101	90	81	78	71	84.2
Treatments	D ₂	76	80	81	89	71	70	71	91	81	83	79.3
Methods	D ₀	81	85	88	81	71	71	87	75	92	71	80.2
ST selfed	D ₁	71	78	79	75	81	83	74	78	80	76	77.5
STP selfed	D ₂	91	83	91	90	81	77	71	70	79	85	81.8
	D ₀	100	85	84	86	87	101	100	76	78	78	87.5
	D ₁	98	91	92	80	81	72	73	91	74	76	82.8
	D ₂	89	77	77	80	78	68	81	81	90	83	80.4

Table 31

Results of Analysis of Variance of plant height at heading of the selfed progeny of Carbicron treated and control plants of 1981-82 of hexaploid wheat grown during 1982-83.

Item	SS	df	MS	F	P
Total	5303.66	79			
Replications	576.10	9	64.01	1.14	NS
Treatments	685.36	8	85.67	1.53	NS
Methods	209.16	2	104.58	1.86	NS
Doses	97.69	2	48.85	< 1	NS
Methods X Doses	378.51	4	94.63	1.69	NS
Error	4042.20	72	56.14		

D₀

D₁

D₂

Selfed

Table 32 = 33

Number of tillers (fertile) per plant of the selfed progeny of Carbicron
treated and control plants of 1981-82 hexaploid wheat grown during 1982-83.
wheat grown during 1982-83.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
Total	D ₀	4	5	11	5	9	10	5	7	6	7	6.9
SP selfed	D ₁	11	4	7	7	5	7	6	5	5	8	6.5
	D ₂	7	7	4	8	3	6	2	7	4	3	5.1
Methods		13.07		2		9.43			1.77			
	D ₀	7	14	7	7	5	6	8	5	13	6	7.8
ST selfed	D ₁	5	8	5	9	3	7	8	11	5	7	6.8
	D ₂	13	4	8	8	7	5	7	7	5	7	7.1
	D ₀	10	6	8	5	6	10	5	5	8	6	6.9
STP selfed	D ₁	8	4	8	4	5	3	6	7	6	5	5.6
	D ₂	11	6	6	3	5	5	7	11	7	6	6.7

Table 33

Results of Analysis of Variance of number of tillers per plant of the selfed progeny of Carbicron treated and control plants of 1981-82 of hexaploid wheat grown during 1982-83.

Item		SS		df		Pla MS		F		P			
Treatment	Dose	1	2	3	4	5	6	7	8	9	10	Mean	
Total		493.60		89									
Replications	D ₀	57.82	20	19	15	6.42	7	20	1.20	16	NS	13.0	
Treatments	D ₁	51.80	14	8	13	6.48	5	16	1.21	17	NS	13.7	
Methods	D ₂	18.87	16	12	17	9.43	5	17	1.77	18	NS	16.7	
Doses		16.20		2		8.10			1.52		NS		
Methods X Doses		16.73	16	14	15	14.18	1	20	< 1	20	NS	18.5	
Error	Selfed	D ₁	383.98	13	72	19	5.33	13	15	18	15	12.5	
		D ₂	16	14	19	16	18	23	16	15	14	15	16.8
		D ₀	20	20	17	15	16	17	20	20	16	17	13.0
	Selfed	D ₁	22	18	21	13	17	17	13	13	13	13	13.0
		D ₂	19	16	14	20	17	19	20	20	18	13	18.2

Table 34, 35

Results of analysis of variance of the number of spikelets per ear of the Number of spikelets per ear (of the main branch) of the selfed progeny of Carbicron treated and control plants of 1981-82 hexaploid wheat grown during 1982-83.

Plants												
Treatment	Dose	1	2	3	4	5	6	7	8	9	10	Mean
Selfed	D ₀	20	20	17	15	18	17	20	20	16	17	18.0
SP selfed	D ₁	16	14	20	12	17	15	16	14	17	18	15.9
	D ₂	17	16	15	17	18	15	17	16	18	18	16.7
ST selfed	D ₀	20	16	19	15	18	21	20	18	20	18	18.5
	D ₁	16	18	19	19	18	18	19	18	18	15	17.5
	D ₂	16	14	19	16	18	23	18	15	14	15	16.8
STP selfed	D ₀	20	20	17	15	18	17	20	20	16	17	18.0
	D ₁	22	18	21	18	17	17	17	18	13	19	18.0
	D ₂	19	16	14	20	17	19	20	20	18	19	18.2

(a) Table 35 The performance of the selfed

Results of Analysis of Variance of the number of spikelets per ear of the selfed progeny of Carbicron treated and control plants of 1981-82 of hexaploid wheat grown during 1982-83.

The following table summarizes the results of the analysis of variance for the number of spikelets per ear of the selfed progeny of the treated plants.

Through the above performance for the number of spikelets per ear within each treatment showed no definite trend, the 'Control' seeds were inferior. The performance of the selfed and selfed seeds were of an lower than selfed for this, but the average number of spikelets in the 'Control' seeds was higher than selfed for this. The 'Control' seeds were higher than selfed for this. The 'Control' seeds were higher than selfed for this.

Item	SS	df	MS	F	P
Total	390.32	89			
Replications	44.10	9	4.90	1.23	NS
Treatments	60.02	8	7.50	1.88	NS
Methods	22.69	2	11.34	2.85	NS
Doses	17.42	2	8.71	2.19	NS
Methods X Doses	19.91	4	4.98	1.22	NS
Error	286.20	72	3.98		

indicated a significant difference in the selfed progeny of treated plants in comparison to the selfed progeny of the 'Control' plants of 1981-82. The height of the 'Control' plants exhibited a range of 88 to 105 cm., whereas, that of the treated and selfed progeny was 77 to 101.

(b) Number of Fertile Tillers per Plant: The number of fertile tillers per plant for the selfed progeny are summarized in Table 40. The range for the selfed progeny of the 'Control' plants was 4 to 19, whereas, that for the selfed progeny of the treated plants was 4 to 13. The results of the Analysis of Variance (Table 41) indicated a significant treatment effect.

(d) Number of Grains per Ear: The performance of the selfed progeny for this character is given in Table 36 and the results of the Analysis of Variance in Table 37. The range for this character was 30 to 55 for 'Control' plants and 23 to 58 for treated plants.

Though the mean performance for the number of grains per ear within each treatment showed no definite trend, the 'Treatment' means were different. The performance of the SP-selfed and STP-selfed families were often lower than ST-selfed families, but the average number of grains in the 'Control' and treated families were same (40.9 vs. 40.7). The 'Treatment' item was just significant (Table 37).

SP selfed for (C) Morphological Studies of Tetraploid Wheat: 44 40 38.1

(a) Plant Height: The performance of the selfed progeny for plant height (Table 38) and the results of Analysis of Variance (Table 39) indicated a significant reduction in plant height in the selfed progeny of treated plants in comparison to the selfed progeny of the 'Control' plants of 1981-82. The height of the 'Control' plants exhibited a range of 88 to 105 cm., whereas, that of the treated and selfed progeny was 77 to 101.

STP selfed (b) Number of Fertile Tillers per Plant: The number of fertile tillers per plant for the selfed progeny are summarized in Table 40. The range for the selfed progeny of the 'Control' plants was 4 to 19, whereas, that for the selfed progeny of the treated plants was 4 to 13. The results of the Analysis of Variance (Table 41) indicated a significant treatment effect.

Table 36

Number of grains per ear (of the main branch) of the selfed progeny of Carbicron treated and control plants of 1981-82 hexaploid wheat grown during 1982-83.

Treatment	Dose	1	2	3	4	5	6	7	8	9	10	Mean
Total		4113.56										
Replications	D ₀	43	40	42	35	39	40	33	42	38	35	38.7
SP selfed	D ₁	45	39	23	46	37	32	42	33	44	40	38.1
Methods	D ₂	48	45	40	40	42	48	36	41	37	38	41.5
Doses		130.16		2		63.08		1.58				
Methods & Dose	D ₀	44	39	54	30	49	38	55	50	39	46	44.4
ST selfed	D ₁	48	43	47	58	38	46	47	42	40	41	45.0
	D ₂	55	43	48	34	35	39	39	48	42	30	41.3
	D ₀	34	39	41	34	30	45	34	50	40	50	39.7
STP selfed	D ₁	39	49	57	37	44	52	36	36	40	44	43.4
	D ₂	42	30	39	36	31	30	39	32	28	42	34.9

Table 37

Results of Analysis of Variance of the number of grains per ear of the selfed progeny of Carbicron treated and control plants of 1981-82 of hexaploid wheat grown during 1982-83.

Item	Treatment	Dose	SS	df	MS	F	P	Mean
Total			4115.56	89				
Replications			294.89	9	32.77	4.1	NS	
Treatments			858.16	8	107.27	2.61	5%	
Methods			350.16	2	175.08	4.26	5%	
Doses			130.16	2	65.08	1.58	NS	
Methods X Doses			377.84	4	94.46	2.29	NS	
Error			2960.57	72	41.12			
STP selfed								

Table 38

Plant height at heading (cm.) of the selfed progeny of Carbicron treated and control plants of 1981-82 tetraploid wheat grown during 1982-83.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP selfed	D ₀	97	89	95	95	91	99	95	97	89	94	94.1
	D ₁	93	91	88	90	87	96	94	92	90	91	91.2
	D ₂	91	90	89	81	89	90	91	90	91	89	89.1
ST selfed	D ₀	95	93	102	88	88	89	92	93	95	95	93.0
	D ₁	98	92	89	95	93	90	85	95	90	90	91.7
	D ₂	84	79	91	86	90	81	84	81	89	81	84.6
STP selfed	D ₀	88	100	97	98	105	97	97	103	102	102	98.9
	D ₁	91	90	80	100	83	101	87	95	88	98	91.3
	D ₂	88	85	90	94	87	77	83	88	89	96	87.7

Table 39

Results of Analysis of Variance for plant height at heading of the selfed progeny of Carbicron treated and control plants of 1981-82 of tetraploid wheat grown during 1982-83.

Item	SS	df	MS	F	P
Total	2930.49	89			
Replications	91.60	9	10.10	4.1	NS
Treatments	1313.49	8	164.19	7.75	***
Methods	124.69	2	62.34	2.94	NS
Doses	1009.16	2	504.58	23.82	***
Methods X Doses	179.64	4	44.91	2.12	NS
Error	1525.40	72	21.18		

Table 40

Number of fertile tillers per plant of the selfed progeny of Carbicron f the treated and control plants of 1981-82 tetraploid wheat grown during 1982-83.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP selfed	D ₀	14	6	6	15	10	16	17	4	8	9	10.5
	D ₁	7	13	7	4	9	5	4	10	9	7	7.5
	D ₂	12	7	10	10	7	6	8	7	6	7	8.0
ST selfed	D ₀	6	8	15	6	9	7	8	10	7	8	8.4
	D ₁	7	12	6	7	11	9	6	7	5	4	7.4
	D ₂	5	11	10	6	9	6	4	7	6	10	7.4
STP selfed	D ₀	10	11	8	15	7	12	13	8	13	19	11.6
	D ₁	11	9	6	9	7	6	9	8	9	11	8.5
	D ₂	7	10	6	9	7	6	6	9	6	7	7.3

(c) Number of spikes per ear: The number of spikelets per ear of the selfed progeny was 36 to 41. The range of the selfed

Table 41

Results of Analysis of Variance for number of fertile tillers per plant of the selfed progeny of Carbicron treated and control plants of 1981-82 of tetraploid wheat grown during 1982-83.

(Table 41) indicated no significant difference among the various progeny families.

(d) Number of grains per ear: The performance of the selfed 'Control' and treated plants are shown in Table 42. The range of the selfed 'Control' plants was 36 to 41, whereas, that of the selfed treated plants was 16 to 22. The results of the Analysis of Variance (Table 42) indicated no significant differences.

Item	SS	df	MS	F	P
Total	834.49	89			
Replications	30.49	9	3.39	< 1	NS
Treatments	187.29	8	23.41	2.73	*
Methods	30.49	2	15.25	1.78	NS
Doses	124.16	2	62.08	7.25	**
Methods X Doses	32.64	4	8.16	< 1	NS
Error	616.71	72	8.56		

is because the number of spikelets and number of grains are highly correlated. The highly significant correlation observed between these two yield components (Table 46) reflected this association.

A comparison between the correlation coefficients between these two characters in untreated and treated plants was made. If insecticide treatments cause a high proportion of chromosomal aberrations and if these aberrations result in a reduction in the number of grains, the association between these two traits should be affected. However, the results in Table 46 indicate that there is no noticeable effect of insecticide treatment on the observed correlation coefficient.

(c) Number of Spikelet per Ear: The number of spikelets per ear of the selfed progeny are given in Table 42. The range of the selfed 'Control' plants was 13 to 19, whereas, that of the selfed progeny of the treated plants was 12 to 17. The results of the Analysis of Variance (Table 43) indicated no significant difference among the various progeny families.

(d) Number of Grains per Ear: The performance of the selfed 'Control' and treated plants are shown in Table 44. The range of the selfed 'Control' plants was 20 to 41, whereas, that of the selfed treated plants was 16 to 42. The results of the Analysis of Variance (Table 45) indicated no significant differences.

(5) Correlation Analysis on Grain Data for 1981-82

In cereals, the number of spikelets and number of grains are highly correlated characters. The highly significant correlation observed between these two yield components (Table 46) reflected this association.

A comparison between the correlation coefficients between these two characters in untreated and treated plants was made. If insecticide treatments cause a high proportion of chromosomal aberrations and if these aberrations result in a reduction in the number of grains, the association between these two traits should be affected. However, the results in Table 46 indicate that there is no noticeable effect of insecticide treatment on the observed correlation coefficient.

Table 42

Number of spikelets per ear (of the main branch) of the selfed progeny of Carbicron treated and control plants of 1981-82 tetraploid wheat grown in 1982-83.

Treatment	Dose	Plants										Mean
		1	2	3	4	5	6	7	8	9	10	
SP selfed	D ₀	19	18	16	15	17	15	15	14	15	16	16.0
	D ₁	15	14	15	14	17	15	14	14	16	17	15.1
	D ₂	15	15	15	15	14	15	16	14	15	16	15.0
ST selfed	D ₀	14	16	13	14	15	16	16	14	16	15	14.9
	D ₁	15	15	14	16	15	14	17	15	15	16	15.2
	D ₂	13	15	12	13	16	13	15	14	13	15	13.9
STP selfed	D ₀	15	14	16	15	16	14	14	15	15	16	15.0
	D ₁	14	14	15	14	16	15	14	14	15	14	15.5
	D ₂	16	14	14	15	15	14	14	16	15	14	14.7

Table 43

Results of Analysis of Variance for number of spikelets per ear of the selfed progeny of Carbicron treated and control plants of 1981-82 of tetraploid wheat grown in 1982-83.

Item	SS	df	MS	F	P
Treatment	Dose	1 2 3 4 5 6 7 8 9 10	Mean		
Total	214.90	89			
Replications	24.68	9	2.74	1.20	NS
Treatments	26.00	8	3.25	1.42	NS
Methods	7.40	2	3.70	1.62	NS
Doses	11.27	2	5.62	2.47	NS
Methods X Doses	7.33	4	1.83	0.81	NS
Error	164.23	72	2.28		
STP selfed					
	D ₀	31 38 28 30 23 38 39 40 34 30	31.3		
	D ₁	35 42 37 39 34 36 37 40 29 33	36.2		
	D ₂	37 31 33 31 28 30 33 29 36 28	31.6		

Table 44

Number of grains per ear (of the main branch) of the selfed progeny of Carbicron treated and control plants of 1981-82 tetraploid wheat grown in 1982-83.

Item		Plants										Mean
Treatment	Dose	1	2	3	4	5	6	7	8	9	10	
Total		2246.10										
Replications	D ₀	30	31	36	20	33	26	32	33	33	30	30.4
SP selfed	D ₁	42	35	40	27	37	35	27	38	38	38	35.7
Methods	D ₂	16	26	37	41	50	28	34	41	30	31	33.4
Doses		281.27										
Methods & Doses	D ₀	41	40	27	24	32	26	30	30	37	31	31.8
ST selfed	D ₁	33	25	42	40	38	37	35	42	28	38	35.8
Error	D ₂	33	38	37	40	34	22	36	32	23	32	32.7
	D ₀	31	38	28	30	23	38	39	40	34	32	33.3
STP selfed	D ₁	35	42	37	39	34	36	37	40	29	33	36.2
	D ₂	37	31	33	31	28	30	33	29	36	28	31.6

Table 45

Results of Analysis of Variance for the number of grains per ear of the selfed progeny of Carbicron treated and control plants of 1981-82 tetraploid wheat grown during 1982-83.

Item	SS	df	MS	F	P
Total	2966.10	89			
Replications	197.44	9	21.94	<1	NS
Treatments	341.80	8	42.73	1.27	NS
Methods	4.27	2	2.14	<1	NS
Doses	281.87	2	140.94	4.18	*
Methods X Doses	55.66	4	13.92	<1	NS
Error	2426.86	72	33.71		

Table 46

Results of correlation and regression analysis between number of spikelets per ear with number of grains per ear in untreated (D_0) and treated (D_1) plants of hexaploid wheat during 1981-82.

Species	Correlation coefficient(r) between spikelet and grains.			
	Untreated (D_0)		Treated (D_1)	
	r	P	r	P
Hexaploid	0.789	***	0.909	***

Two points emerge from the results of the cytological study:

- (a) insecticide treatment results in chromosome stickiness and contraction and (b) the Regression coefficient(b) for grains on spikelet.

	Untreated (D_0)			Treated (D_1)		
	b	t	P	b	t	P
Hexaploid	2.664	6.796	1%	4.674	11.54	1%

The percentage of ... belonging to Meiosis ... was 62.34 ... with aberrations ... Similar results were also obtained during 1982-83. These indicate that stickiness of chromosomes due to insecticide treatment might have given rise to some abnormalities. Though in majority of the cases of the treated ... the chromosomes did separate, in some cases the chromosomes due to ... failed to undergo normal course of meiotic events. What is ... were common in early stages of the cell division.

... belonging to Division I against 4% in Division II ... Moreover, the majority of abnormalities ... chromosome bridges which are often found as ... stickiness.

DISCUSSION

(I) Cytological Action of the Insecticide:

The cytological examinations made during 1981-82 on the insecticide treated materials were repeated again in 1982-83; the results obtained in both the years indicated a significant increase in the number of PMCs with meiotic abnormalities over the controls. Similar increase in chromosomal abnormalities in PMCs of the insecticide treated families was also reported by Alam et al. (1981a, 1981b) and Islam (1983) in wheat and barley and by Soliman and Al-Najjar (1980) and Al-Najjar and Soliman (1982) in wheat and two other related species.

Two points emerge from the results of the cytological study:

- (a) insecticide treatment results in chromosome stickiness and contraction
- and (b) the abnormalities were more common in early stages of meiosis.

The percentage of normal PMCs belonging to Meiosis I in 1981-82 was 62.34 but percentage of PMCs in Meiosis I with aberrations was 37.66. Similar results were also obtained during 1982-83. These indicate that stickiness of chromosomes due to insecticide treatment might have given rise to these abnormalities. Though in majority of the cases of the treated PMCs the chromosomes did separate, in some PMCs the chromosomes due to stickiness failed to undergo normal course of meiotic events. That is why abnormalities were more common in early stages of the cell division. 12.2% abnormal cells belonging to Division I against 4% in Division II were observed in 1981-82 data. Moreover, the majority of abnormalities were lagging chromosomes and chromosome bridges which are often found as a consequence of chromosome stickiness.

Studies of the cytological effects of various mutagens and antibiotics by various workers also reported the formation of different chromosomal abnormalities (Wilson et al., 1950, 1951a, 1951b; Unrau, 1953, 1954; Unrau and Larter, 1952; Wu and Grant, 1967a, 1967b; Amer, 1965). Tanaka and Sato (1952) concluded that any morphological abnormalities induced either by the action of ionizing radiations or insecticides are superficially alike and cytological disruption is the most fundamental response. As in their experiment with Tradescantia paludosa, the result of the present experiment revealed a wide range of cytological disruption, i.e., contraction of chromosomes and stickiness, fragmentation and lagging of chromosomes, bridge formation, production of micronuclei, etc.

There was little difference in the response of the tetraploid and the hexaploid wheat to the insecticide treatment. Though the percentages of abnormal PMCs were always lower in the 4x species for all treatments than the 6x species, the treatments significantly increased chromosomal aberrations as well.

Although no consistent pattern emerged between the different treatments and the frequency of chromosomal aberrations, plants with chromosomal aberrations occurred in all Carbicron - treated families indicating that the chemical interfered with the meiotic stability regardless of the type of treatment (i.e., seed treatment and/or spray).

It is especially interesting that the seeds treated before germination also showed irregularities in PMCs. Since both normal and abnormal PMCs were observed in the same flower-bud, it is likely that some chemical residue persisted in the plant tissue and caused these aberrations. Because, if the abnormalities were induced immediately after the application of the chemical, an entire inflorescence or a part of the panicle should have been

affected similarly. As this was not noticed in the present study, the insecticide apparently remained active several weeks after application and remained in the cells of the embryos, seedlings and in the germ cells — becoming active in the PMCs prior to or during meiosis. Similar effect of a herbicide, Atrazine, was reported by Liang et al. (1967) on Sorghum.

Johnson Although the mechanisms responsible for observed chromosomal abnormalities are not yet clear, chromosomal breakage could be similar to damage caused by ionizing radiation (Doxey, 1949; Unrau and Larter, 1952). Chemical application may affect genetic process of meiocytes, thus, resulting in various aberrations. Numerous biochemical process occurring in a cell may be inhibited, enhanced or altered by a nasty chemical like Carbicron, thus, upset the cell division cycle. Wu and Grant (1966) suggested that these changes may be alteration in the activities of genes or gene products rather than gene mutations.

(II) Morphological Effects of the Insecticide: effects of the insecticide treatments on the quantitative characters were

observed In a large number of the experiments carried out on mutagenic action of chemicals on plants, cytological disruption were accompanied by an induction of gene mutation. The array of the cytological disruptions observed in the present study suggested that the insecticide used had enough potential to induce the rearrangements of genes. Therefore, it seems more likely that changes in the morphological characters would result as a consequence of the treatment. insecticide phytotoxicity, the standard dose

should be The four morphological characters plant height, number of tillers, number of spikelets and number of grains studied all indicated a negative effect of the insecticide. These characters in wheat and barley are known

to be controlled by polygenes (Fonseca and Patterson, 1968; Cannell, 1969; Grafius and Okoli, 1974; Rasmusson and Cannell, 1970). Many workers have reported yield reduction and crop injury from misapplication of herbicides (Bingham and Porter, 1961; Drake et al., 1963; Everson and Arle, 1956; Holstun and Bingham, 1960; Porter et al., 1959; Wiese et al., 1964). Johnson (1961) showed that dicryl N - (3, 4-dichlorophenyl)-methyl - acrylamilide delayed maturity in cotton, which could influence fibre quality. Everson and Arle (1956) found that pre-emergence application of Monuron 3-(P-chlorophenyl)-1, 1-dimethylurea at high doses reduced ball weight, fibre length, and fibre coarseness. Scifres and Santelmann (1966) also found that Paraquat (1, 1-dimethyl-4, 4 - dipyridinum cation) did have influence on cotton fibre quality. Santelmann et al. (1966) also detected effect of two herbicides, Prometryne (2, 4-bis(isopropyl amino) - 6 - methyl mercapto - S - triazine) and DSMA (Disodium Methane Arsonate) on fibre strength of cotton; both of these reduced fibre strength during one year but not in the following year. In the present study, however, the negative effects of the insecticide treatments on the quantitative characters were observed for both 1981-82 and 1982-83. This suggests a significant influence of the insecticide on these characters.

The significant decrease in the three yield components i.e., number of fertile tillers, number of spikelets per ear and number of grains per ear, due to the insecticide treatment is important. This reduction in the mean performance was more spectacular in Dose 2 than in Dose 1. In presence of this insecticide phytotoxicity, the standard dose should be determined in the light of the observed results.

(III) Persistence of the Effects of the Insecticide to the Next Generation;

Transmittable changes in plants induced by chemical insecticides may be caused by an alteration of genetic material. It has already been mentioned in the introduction that effect of certain chemical herbicides could be transmitted via seeds (Dunlap, 1951). Plant abnormalities induced by another chemical, Dalapon, were found in several generations after the herbicides was applied in barley (Suneson, 1960). However, Liang et al. (1967) suggested that the chemical residue in soil from previous treatments might have caused crop injury in certain of these cases.

The selfed seeds of the insecticide treated families were sown in different field in 1982-83. However, no significant difference was observed between the selfed progeny of the treated and the non-treated families in respect to the chromosomal aberration in PMCs. Statistical analysis of the morphological and yield characters indicated that the selfed progeny of the treated families did not differ from the control groups for both 6x and 4x wheat. Similar results were obtained by Liang et al. (1967) in Sorghum.

It is questionable whether tetrads or meiocytes containing chromosomal aberrations are actually transmitted to subsequent generations. A large number of second generation plants from seeds of the insecticide treated plants were screened but no significant difference for chromosome abnormalities or other morphological characters were found. Non-viability of the pollen grains containing chromosomal aberrations can be put forward to explain the non-transmission of the abnormalities. Even if, the pollen grains with small aberrations would be viable, these would be less competitive than the normal pollen tubes during fertilization.

Though the quantitative characters were affected by Carbicron treatment, these effects were not inherited in the next generation plant. This was also perhaps due to non-viability or non-competative pollen grains containing the aberrations.

Experimental evidence and information concerning the response of the crop plants to insecticides is required to ensure their safe and economic use. Data presented here indicate that before the plants response to the chemicals can be fully determined, information must be obtained concerning the cytogenetic action of the chemicals and their persistent effect in plants.

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