EFFECT OF HERBICIDES ON CELL DIVISION STERILITY AND YIELD IN RICE

By

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THESIS
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DECLARATION

I hereby declare that this thesis entitled "Effect of herbicides on cell division, sterility and yield in rice", is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
9-2-1981.

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CERTIFICATE

Certified that this thesis, entitled "Effect of herbicides on cell division, sterility and yield in rice" is a record of research work done independently by Shri. K. KISHORE KUMAR, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Rice is one of the most important crops in the world today. The total area under the crop exceeds 100 million hectares, of which over 90 per cent is grown in Asia. Thus it forms the staple food of millions of Asians, whose number is increasing rapidly. Yet the demand for rice in Asia exceeds the present world supplies. So stepping up of rice production is one of the major concerns of world agriculture.

The importance of rice in Indian agriculture needs no special emphasis. Every concerted effort is focused in improving its yield and production. Scientific methods of rice culture have been an answer to it. But keeping pace with it are a number of bottlenecks, among which weeds, pests and diseases stand out. It is estimated that loss in rice yield due to noxious weeds is between ten and seventy per cent (Duara, 1955). Annual loss in India has been worked out to be a staggering figure of over 2.5 million tonnes (Tiwary, 1953). Present day agriculture with its specialised methods, its rapid mechanisation and efficient handling of fungi and insect pests demand adequate weed control.

Ever since the discovery of chemicals as useful tools for weed control in the early twentieth century, the demand for more and more herbicides has been on the increase. It is needless to say that chemical weed control gave a great boost to agricultural production.

Rice fields are particularly suited for the development and spread of both aquatic and semi-aquatic weeds of different kinds and this poses the most serious problem in rice production. This has necessitated the formulation of a variety of rice herbicides. Many of them are hormonal and selective in action. They act as growth retardants. There are many reports of such chemicals causing physiological, cytological and mutagenic changes in living tissues, both in plants and animals. Now the time has come for scientists to look carefully and critically into the possible toxic hazards to non-target organisms and to the ecosystem by the indiscriminate use of herbicides.

As early as 1948, Ryland has reported that phenoxy compounds, which are potential herbicides, cause inhibition of cell division. He observed that colchicine like effects of mitotic irregularities were simulated by them. Since then many investigators have worked in these lines. From time to time many workers have reported on the mutagenic effects of a wide range of herbicides, fungicides and insecticides when used in plants (Liang and Liang, 1972; Wuu and Grant, 1966, 1967). In recent studies by Ehrenberg (1979) on genetic effects of chlorophenoxy compounds, the data have indicated that though the genetic risk of using such chemicals is low at the time of application, the latent potentiality of these in causing genetic deterioration cannot be completely ruled out.

Hence it is needless to say that certain chemicals have deleterious effects on crop plants and investigations to evaluate the cytogenetic and physiological effects on crops caused by herbicides will be useful. Repeated use of chemicals can even cause damages which may lead to loss of desirable genetic attributes. So a better understanding of the cytogenetic responce of plants to herbicides would ultimately help in the formulation of effective and safe chemical weed control.

The present study is an attempt to investigate whether certain commonly used herbicides are having any effect on cell division, sterility and yield in rice when applied at normal doses. Also it will help in understanding the extent of weed control possible by different chemicals and cultural methods.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A review of literature pertaining to the effect of herbicides on the morphology, cytology, sterility and yield in plants are given below.

Effect on height of plants.

Guh and Kuon (1975) in their studies on the response of rice cultivars to herbicides reported that in five varieties of rice, high rate of application of butachlor, nitrofen and P.A.M. consistently reduced plant height, culm length, leaf number and dry weight of foliage.

A reduction in plant height was also observed by Sotnik (1977) in his studies on the introduction of male sterility in winter wheat. Chemicals like 2, Chloroetheno-phosphonic acid had growth inhibiting effects, reducing plant height to some extent.

Tiller characteristics.

Among several herbicides tried in rice, Sridhar and co-workers (1974) have observed that in benthiocarb treated rice fields the number of tillers and productive tillers were highest. This they attributed to be due to better weed control and least phytotoxicity.

Experiments in rice by Sankaran et al. (1974) gave conclusive evidence that although propanil decreased weed population and dry weight of weeds, yield components like productive tillers were not influenced.

Ramamurthi et al. (1974) in their studies on the effect of propanil on weed growth and yield of I.R.20, reported that hand weeding was significantly superior to double application of propanil. Unweeded plots had the most dense weed count and significantly lower number of effective tillers.

Shibayama and Noda (1977) studied the morphological response of rice plants to phenoxy herbicide M.C.P.A. and reported that M.C.P.A. induced reduced tillering by bud inhibition.

Panicle characteristics.

Studies conducted on the effect of granular herbicides in control of weeds in rice by Sridhar et al. (1974) showed that the maximum number of panicles was observed in hand weeded plots. The lowest number of panicles was observed in unweeded plots indicating the effect of weed competition in reducing panicle density. It was also evident that panicle number can be increased by reducing weed competition.

Pereiro and Pena (1976) in studies on the phytotoxicity of 2,4-D amine at different stages of development of rice showed that best yields were obtained when sprayed 10, 20 and 30 days after germination. There was no significant difference in panicle length consequent to chemical treatment.

1000 grain weight.

Ramamurthi et al. (1974) in herbicide trials on the effect of propanil on weed growth and yield reported that

1000 grain weight was not significantly altered by sowing or weeding methods.

Nair and Sadanandan (1976) in studies on the comparative performance of granular herbicides on rice found that granular herbicides butachlor, 2,4-D and nitrofen had no effect on 1000 grain weight and panicle length.

Yield.

Studies on the effectiveness of granular herbicides in rice by Sridhar et al. (1974) showed that among the several herbicides tried the maximum yield was obtained from hand weeded plots and benthiocarb applied plots.

Clarete and Mabbayad (1975) in studies on the effect of fertilizer application, row spacing and weed control on the yield of upland rice reported that pre-emergence application of butachlor 2 kg ai/ha followed by hand weeding was comparable to three hand weedings with regard to grain yield and weed count.

Rola (1975) in studies on the response of wheat varieties to 15 herbicides elucidated the following results. Grain yield was found to be reduced in all the varieties when the herbicides were applied during the vegetative phase.

Effect on weeds.

Verma and Mani (1967) observed that propanil was a very effective herbicide for post-emergence spray in controlling most of the weeds in rice. Good control of a large weed flora comprising of grasses, sedges and broad leaved weeds was possible with the herbicides.

Chang (1969) in experiments to evaluate the performance of granular herbicides concluded that granular formulation of nitrofen at 2 kg + 2,4-D 0.8 kg/ha three to four days after transplanting gave the best overall control. But it was found to be a very toxic treatment. However, injuries disappeared by panicle initiation time.

Herbicides like benthiocarb, propanil, M.C.P.A. and nitrofen gave efficient weed control in rice comparable to hand weeding (C.R.R.I. Annual Report, 1971).

In a study on the effect of chemical and cultural methods in weed control in rice Rangiah et al. (1974) observed that machete and Stam F.34 were very efficient in controlling weeds. *Cyperus* species was not effectively controlled by any herbicide. A complete control of barnyard grass (*Echinochloa crusgalli*) was also not possible with Stam F.34. In their results strong negative correlation (r = -0.96) was obtained in the case of yield and weed dry weight at harvest. Similar negative correlations were reported by Verma and Mani as early as 1967.

Singh and Kothari (1974) in studies on the relationship between growth of weed and wheat crop, reported that chlorophenoxy herbicides significantly reduced uptake of nitrogen and dry matter production. The uptake of nitrogen by weeds and weed dry matter were negatively correlated with the uptake of nitrogen by the crop and grain yield. Herbicides which failed to check the weed growth failed to reduce loss of nitrogen due to uptake by weeds and this affected grain production. The correlation coefficient between dry matter production and grain yield was positive (r = 0.92), weed dry matter production was negatively correlated with uptake of nitrogen by crop and crop yield also.

Le Clair (1977) could get excellent control of barnyard grass by the application of benthiocarb in rice fields. Little or no phytotoxicity was observed.

Crop injury by herbicides

Srivastava (1958) in studies on the effect of hormone herbicides on rice has reported on the morphological abnormalities caused by the treatment with such herbicides. Usual leaf abnormalities produced by toxic chemicals were epinasty and stiffness of flag leaf leading to drying of the leaves. Some of the younger leaves appear curled and do not unfurl properly. However such abnormalities were reported to be in-frequent and not severe at normal doses.

Smith (1969) in experiments to compare different herbicides for weed control in rice reported that nitrofen applied at 3 kg/ha to rice either with molinate or propanil injured rice plants. Burning of leaf margins and curling of leaf tips were observed.

Lozano and Cardinas (1970) studied the phytotoxic symptoms produced by herbicides on crops. They found that typical injury symptoms like leaf burning and curling were observed in cotton, rice, sesamum, sorghum and soyabean when treated with 2,4-D, atrazine, diuron, trifluralin and picloram.

El-Kalla in 1975 studied the influence of three common herbicides on spring barley and winter barley for three years. He found that winter barley was killed by the herbicides at 3 leaf stage. In all the cases herbicide application resulted in retardation of growth, but the reduction in shoot formation was counteracted by improved development of remaining tillers.

Kataoka et al. (1977) reported that nitrofen 2 to 3 kg/ha injured rice when applied soon after transplanting. The herbicide thiobencarb at doses 3.1 to 4.7 kg/ha also caused slight injury.

Chromosomal abnormalities.

Templeman and Sexton (1945) were able to show that herbicide prophan inhibited the growth of both monocotyledenous and dicotyledenous plants. The inhibition depended mainly on the cessation of cell division in shoot and root meristems. In shoots and roots of barley and oats this compound induced an abnormal cytological behaviour viz., an interrupted mitotic cycle, blocked metaphase, multinucleate cells, giant nuclei and increased number of partially contracted chromosomes.

Ryland (1948) reported that 2,4-D caused a general inhibition of cell division in *Allium cepa* which simulated irregular mitosis induced by colchicine. Nygren (1949) observed stickiness, micronuclei, irregular spindles and anaphase bridges induced by the application of 2,4-D.

2,4,5-Trichlorophenoxy acetic acid and monochlorophenoxy acetic acid.

Doxey and Rhodes (1949) treated roots of Allium cepa for 22 hours in M.C.P.A. Longitudinal contraction and transverse swelling of chromosomes occurred at 100 ppm, sticky bridges and sticky chromosomes at 500 ppm and chromosomes fused in irregular picnotic masses at 2500 ppm when all the cell division ceased.

Unrau and Larter (1952) in their studies on the cytogenetic response of cereals to 2,4-D observed aberrations resembling those induced by x-rays or mutagenic chemicals. Mutagenic agents generally cause chromosomal abnormalities in the form of aberrations observed during various stages of meiotic and mitotic cell division. Such effects were simulated by 2,4-D on cereals.

Sawamura (1965) reported the effect of five hormonal herbicides viz.,2,4-D, 2,4,5-T, 2,5-D, M.C.P.A, and S.E.S., on plant cells. They caused chromosome bridges, stickiness and retardation of chromosome movement during anaphase. The effect of these herbicides on mitotic cells revealed close connection with herbicidal activity on weeds and with malformation in cultivated plants. Further in 1965 he also found that non-hormonal herbicides such as pentachlorophenol and 3-Cl.I.P.C. suppressed spindle formation. 3-Cl.I.P.C. produced disturbed mitosis as caused by colchicine.

Amer and Saheir (1965) in their studies on the cytological effects of some carbamate pesticides found that total mitotic arrest in root tip cells occurred. Similar results were observed by Hamm and William (1966). They tried rapid action carbamate herbicides and found that treatment of young seedlings arrested growth and caused mitotic inhibition.

Wuu and Grant (1966, 1967) studied the cytological effects of fifteen pesticides in barley. Formation of long chromatin threads, nuclear coalescence, clumping of chromosomes, chromosome fragments, bridges, univalents, polyploid cells, micro nuclei etc. were observed in the pollen mother cells.

Amer and Ali (1968) reported the meiotic effects of phenolic pesticides. They concluded that phenols did not cause much variation in the type of abnormalities in the pollen mother cells of Vicia faba. The more common meiotic abnormalities were stickiness, laggards and anaphase bridges. P-nitrophenol was the most toxic since it produced the highest percentage of abnormal pollen mother cells.

Treatment of bajra seeds in 0.1 per cent solution of herbicides like atrazine, simazine, 2,4-D, propanil and nitrofen reduced germination and seedling growth. Chromosomal abnormalities were also noted in the pollen mother cells (Rao *et al.*, 1971).

Liang and Liang (1972) studied the effect of herbicides on chromosomal behaviour in two varieties of sorghum.

Chromosomal abnormalities were found in the microsporocytes at meiosis. The aberrant cells contained extra pair of chromosomes.

Nakeem and Shehab (1972) reported the cytological effects of herbicide simazine on Vicia faba. Simazine applied to root tips induced stickiness of chromosomes, laggards, bridges, fragmentation and spindle distortion. When applied during flowering stage chromosome stickiness and bridges were mainly induced. But the percentage of abnormality was more when soil treatment was done.

Mohandes and Grant (1972) did cytological investigations on the effect of 2,4-D and amitrole in twelve species of different crop plants. Chromosome bridges, fragments, laggards and chromatin bodies were observed. The herbicide 2,4-D also induced chromosome contraction and C-mitosis like effects.

Bale and Hart (1973) evaluated the cytogenetic effects of sodium fluoride and hydrofluoric acid on barley. The chemicals were reported to be inducing chromosomal aberrations and mitosis was found to be inhibited by each of the three different concentrations of both chemicals. Treatment produced binucleate cells, micro-nuclei etc.

Nakeem and Shehab (1973) in their studies on the cytological effect of herbicides 2,4-D, Dalapon and Paraquat reported that both mitosis and meiosis were affected. Induced abnormalities including chromosome stickiness, laggards, fragments, polyploidy, spindle disturbance and multi-nucleate pollen mother cells were observed. Herbicide 2,4-D induced the highest percentage of abnormalities.

Soheir and Farah (1974) investigated the cytological effect of pesticide rogor in the root tips of <u>Vicia faba</u> and <u>Gossypium barbadense</u>. A great reduction in mitotic index when compared to control was observed. Disturbed prophase, metaphase and anaphase stages were the most dominant abnormalities. Chromosome contraction was noticed in cotton, chromosome stickiness, fragmentation, anaphase bridges and multipolar anaphases were seen in <u>Vicia faba</u>.

Studies by Prasad and Das (1977) on the effect of 2,4-D, I.A.A. and G.A. on root-tip mitosis of <u>Vicia faba</u> revealed various chromosomal aberrations like bridges, fragments, breakages, micronuclei, stickiness, chromosome condensation etc.

Significant increase in structural rearrangements of chromosome was reported in <u>Crepis capillaris</u> cells by Tashikhodzhaev <u>et al.</u> (1977) when herbicide trifluralin and isofenophos were applied.

Logvinenko and Morgun (1978) studied the mutagenic effects of some pesticides on spring durum wheat. When growing plants were treated with 2,4-D and its sodium and amine salts increased frequency of chromosomal aberrations was noted in root-tip cells.

Pollen sterility.

Koul (1971) investigated the causes of sterility in gametocide induced male sterile *Vicia faba*. He noticed that meiosis was completely normal in untreated plants and only 70 per cent normal in treated ones. In the remaining pollen mother cells varying degrees of chromosome stickiness were noted causing multiple chromosome associations and in extreme cases clumping of entire chromosome complement at prophase and metaphase. Disjunction of chromosomes in such cells was characterised by bridges and laggards, multipolar cells were observed at both divisions of meiosis.

Amer and Ali (1968 & 1977) studied the cytological effects of four pesticides 2,4-D, 2,4,5-T, 2,4 dichlorophenol and 2,4 trichlorophenol. They were tested for their effect on meiosis pollen viability and yield. Plants were sprayed at two developmental stages. A significant percentage of sterile pollen grains was obtained.

Rivas and Mizani (1974) reported the gameticidal effect of herbicide dalapon on sesamum. Acoitova variety was the least affected among the three varieties tested for reduction of height, leaf and branching modifications, unopened flowers, malformation of pollen etc. In varieties Maipoval and Serrano many of the alterations were enhanced by higher doses. A considerable amount of sterility was also observed.

Shiryaeva (1975) reported that several herbicides had effects on microsporogenesis and gametogenesis in sugarbeet.

Varying degrees of pollen sterility was observed in diploids.

In their studies on the effect of herbicide treatments on carrot and onion seed production, Anderson and Campbell (1977) found that male fertile inbreds of onion were more sensitive to herbicide linuron and napropamide than male sterile ones. Many bulbs failed to produce inflorescences. Linuron caused reduction in number of flowers per umbel.

Khokhlova (1977) studied the changes in pollen fertility and emergence of panicle in barley, treated with 2,4-D. An increase of pollen sterility confined to the lower spikelets of the earheads in plants of three varieties studied was noticed when the chemical was applied at tillering stage.

Wells and Gilmour (1977) observed sterility in rice cultivars caused by the herbicide Methan sodium mono arsenate. The herbicide applied to plots induced sterility and symptoms of straight head disease.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken in the Department of Agricultural Botany, College of Agriculture, Vellayani during the year 1979 in order to assess the effect of certain herbicides on cell division, sterility and yield in rice.

Materials

Experimental site

A rice field with facilities for controlled irrigation and drainage was selected in the Instructional Farm, College of Agriculture, Vellayani. The experimental area was under a bulk crop of paddy during the previous season.

Season and climatology

The experiment was conducted during the third crop season locally known as punja. The period of the experiment was from January 1979 to April 1979.

Crop

Rice variety Triveni was used for the experiment. It is a high yielding variety of short duration popularly cultivated in Kerala. Its duration ranges from 95 to 105 days. Pure seeds of the variety were obtained from the Model Agronomic Research Station, Karamana, Trivandrum, of the Kerala Agricultural University.

Herbicides

Five herbicides were chosen for the present study. The details are given below:

Sl. No.	Common name	Active ingredient	Proprietory name	Formulation
1.	Benthiocarb	S-(4-chlorobenzyl)-N-N-diethyl thiocarbamate.	Saturn	50% E.C.
2.	Butachlor	2,chloro-2,6-diethyl N-(butoxy methyl) acetanilide.	Machete	50% E.C.
3.	Nitrofen	2,4.dichloro-phenyl 4-nitro-phenyl ether.	Tok-E 25	25% E.C.
4.	2,4-D sodium salt	Sodium salt of 2,4-dichloro-phenoxy acetic acid.	Fernoxone	80% W.P.
5.	Propanil	N-(3,4-dichloro-phenyl) propionanilide.	Stam-F.34	35% E.C.

Methods

The details of the field experiment are furnished below:

Design	:	R.B.D.
Replication	:	4
Number of treatments	:	7
Total number of plots	:	28
Gross plot size	:	3 x 3 m
Net plot size	:	2.6 x 2.4 m
Total number of hills/plot	:	600
Number of plants/hill	:	2

The lay out is presented in Fig.1.

Treatments		Date of application
T_1	Benthiocarb @ 2 kg ai/ha	18th D.A.T.
T_2	Butachlor @ 1 kg ai/ha	18th D.A.T.
T_3	Nitrofen @ 1.5 kg ai/ha	18th D.A.T.
T_4	2,4-D sodium salt @ 1 kg ai/ha	18th D.A.T.
T_5	Propanil @ 1.75 kg ai/ha	18th D.A.T.
T_6	Hand weeding, local practice on 20th and 40th day of transplanting	
T_7	No weeding	

Nursery

An area of six square metres adjoining to the experimental plot was thoroughly ploughed. Two raised beds of size 2 x 6 m were made and germinated rice seeds were sown. Sowing was done on 3rd February, 1979.

FIG. 1. LAY OUT PLAN - RANDOMISED BLOCK DESIGN.

Periodical water management and a 5 per cent urea spray were given in the nursery for the healthy growth and development of the seedlings.

Main field

Land preparation

The experimental area was ploughed three times. Four blocks were laid out each with seven plots of size 3 x 3 m. The plots were separated with bunds of 60 cm with a channel of 30 cm in between. Irrigation-cum-drainage channels were provided between the blocks and all around the blocks. The general plan of the lay out is presented in Fig.1.

Fertilizer application

Cattle manure at the rate of 5 tonnes per hectare was applied to each plot at the time of preparatory cultivation. Urea, superphosphate and muriate of potash were applied to each plot so as to supply nutrients at the rate of 70 kg N, 35 kg P_2O_5 and 35 kg K_2O per hectare respectively (Package of Practices, 1978).

Two third of N and full dose of P and K were applied as basal dressing at the time of transplanting and the remaining dose of N was given at the panicle initiation stage. Lime was also applied at the rate of 600 kg/ha as per Package of Practices, 1978.

Transplanting

The 21 day old seedlings were transplanted to the main field from the nursery. Seedlings were planted with a spacing of 15 x 10 cm. Two seedlings were planted per hill.

Irrigation and drainage

After transplanting controlled irrigation and drainage were given as and when required.

Weed control

Herbicides benthiocarb, butachlor, nitrofen, propanil and 2,4-D were applied eighteen days after transplanting. Hand weeding was done twice, the first after twenty days of transplanting and the second forty days after transplanting. A polythene spray drift screen of four feet height was erected around each plot to avoid the spray drift fall in the adjoining plots.

Observations

A. Field studies

1. Height of plants

The height of plants was measured on the 5th, 20th, 35th and 50th day of transplanting and also at harvest.

2. Total tillers

Total number of tillers was counted at the maximum tillering stage and their means recorded.

3. <u>Productive tillers</u>

Number of productive tillers was counted at the time of harvest and their means recorded.

4. <u>Filled panicles</u>

Number of filled panicles (as mean values) was recorded at the time of harvest.

5. <u>Length of panicles</u>

The lengths of individual panicles from each observation plant were measured and their means compared.

6. <u>Grain weight per plant</u>

The grain yield from the observation plants was weighed and the mean recorded.

7. <u>Grain-chaff ratio</u>

The grain number and chaff number from the observation plants were counted and their ratio worked out.

8. <u>Grain yield</u>

Total grain yield from the observation plants was recorded.

9. <u>1000 grain weight</u>

Random samples of grains were drawn, three from each plot and 1000 grains were counted and weighed. The mean of the three random samples was taken which represented 1000 grain weight of each treatment.

10. <u>Weed observations</u>

(a) <u>Weed flora</u>

Identified the major weed species of the rice fields in the area and their names were recorded.

(b) Weed count

Periodical weed count was taken from all the plots till harvest. A wooden frame of 1 sq.metre size was used for taking the weed count. It was randomly placed at two places in each plot and the weed count was taken and their means recorded.

(c) Weed index

Weed index was calculated using the following formula.

$$W.I. = \frac{X-Y}{X} \times 100$$

W.I. = Weed Index

X = Yield from weed free plot or the treatment which recorded minimum weeds.

Y = Yield from the treatment for which weed index is to be worked out.

(This is a method of reporting weed control trials elucidated by Gill and Vijayakumar (1969)).

(d) Percentage of weed control

Percentage of weed control was calculated using the formula

$$\frac{\text{Total weed count} \times 100}{\text{Total weed count in unweeded plot}}.$$

(e) Weed dry weight

One observation was taken at the time of harvest. Weeds from one metre square area were collected, oven-dried and their weights were recorded.

B. Cytological studies

(i) Cell division and chromosomal aberration

The pollen mother cells were studied with a view to ascertain the meiotic behaviour of different treated plants. Preliminary studies showed that the best time of fixing rice flower buds under Vellayani condition was between 9.30 and 10.00 a.m. on bright sunny days. Panicles of appropriate size were fixed in acetic alcohol (1:3) saturated with ferric acetate. Four panicles from main tillers were randomly collected from each plot for fixing. The fixed inflorescences were kept in room temperature for 12 to 24 hours. The panicles were then washed and preserved in 70 per cent ethyl alcohol and stored in a refrigerator.

Meiosis was studied from temporary acetocarmine smears of pollen mother cells. The anthers were teased on the slide with a fine stainless steel needle in a drop of two per cent acetocarmine. The anthers were then gently pressed to facilitate the release of the pollen mother cells, the debris removed, warmed and the slide was pressed between the folds of blotting paper and sealed with paraffin.

For scoring chromosomal abnormalities spikelets from five plants from each replication were randomly selected. An Olympus binocular research microscope was used throughout the study.

Photomicrographs of abnormal cells were taken with an Olympus camera (35 mm) with an eye piece of 15x in conjunction with an oil immersion objective 100/1.30.

(ii) Estimation of pollen sterility

Pollen grains from naturally opened spikelets were mounted in a drop of glycerine aceto-carmine (1:1). For estimation of pollen sterility the pollen counts were taken after two hours of staining. Three spikelets from three plants selected at random from each plot were used for study.

Well-filled and uniformly stained grains were taken as fertile and the rest as sterile. Both fertile and sterile grains were counted from each microscopic field and thirty such readings were taken from each plot. Sterility percentage was computed from the data.

An Olympus monocular microscope with A10x eye piece and objective 40/0.65 was used for sterility estimation.

RESULTS

RESULTS

A. Field studies

1. Height of plants

Height measurements were taken at five stages after transplanting. The mean heights of plants are recorded in table 1.

Height observations on the fifth and twentieth day after transplanting did not show any significant difference, while the observation on the 35th day of transplanting showed significant difference between treatments. Plants in treatment hand weeding (T_6) showed maximum height followed by 2,4-D (T_4), propanil (T_5) and butachlor (T_2) applied plots. They did not differ significantly among themselves. Hand weeded plots (T_6) had significantly taller plants when compared to those with no weeding (T_7) and benthiocarb (T_1). Plants in the nitrofen-applied plots (T_3) showed symptoms of phytotoxicity like burning of leaf margins and curling of leaf tips which persisted for two weeks. But later these symptoms vanished.

Significant height differences were observed in all the subsequent observations also. On 50th day of transplanting, treatments hand weeding, propanil, 2,4-D and butachlor did not differ significantly. But they all had

Table 1. Mean height of plants (cm) at various intervals after transplanting.

Treatments	Days after transplanting 5	20	35	50	At harvest
T_1	11.20	16.73	28.70	61.23	74.43
T_2	12.20	18.00	30.30	64.15	76.35
T_3	12.13	17.43	27.63	56.19	68.63
T_4	12.30	19.28	31.15	65.40	78.50
T_5	11.93	19.10	30.38	66.25	79.30
T_6	12.80	18.13	31.40	66.43	79.68
T_7	12.18	17.15	28.90	59.85	73.05
C.D.	0.704	1.260	2.460	4.580	6.010

significantly taller plants than nitrofen. Hand weeding, propanil and 2,4-D had significantly taller plants than all other treatments except butachlor. Treatments butachlor, benthiocarb and 2,4-D did not differ significantly among themselves.

At harvest, hand weeding and propanil treated plots were found to have significantly taller plants compared to no weeding and nitrofen. Nitrofen, benthiocarb and no weeding did not differ significantly. Similarly benthiocarb, no weeding, butachlor and 2,4-D did not differ significantly.

2. Total tillers

The data relating to total tillers are presented in table 2. Tiller production in treatments butachlor, benthiocarb and hand weeding were significantly higher compared to treatments propanil, 2,4-D and no weeding. Treatments nitrofen, propanil, 2,4-D and no weeding did not differ significantly.

3. Productive tillers

The mean values of productive tillers are given in table 2. Hand weeded plots produced significantly more number of productive tillers compared to all other treatments. The least number of productive tillers was found in unweeded plots and nitrofen-applied plots which were more or less on par. No weeding had significantly lesser number of productive tillers compared to hand weeding, butachlor, 2,4-D, benthiocarb and propanil. Treatments benthiocarb, propanil and nitrofen did not differ significantly.

In the correlation analysis significant negative correlation was obtained between weed count and productive tillers (r = -0.55).

4. Filled panicles

The data for filled panicles are presented in table 2. Hand weeded plots produced maximum number of filled panicles which was significantly more than all other treatments. Unweeded plots produced significantly lesser number of filled panicles when compared to hand weeding, 2,4-D and propanil. Panicle number in no weeding, nitrofen, benthiocarb and butachlor did not differ significantly.

5. Panicle length

Mean panicle length is given in table 2. Observations on panicle length indicated that there was no significant difference among treatments with regard to this character.

6. Grain weight per plant

The mean values of grain weight per plant are presented in table 3. Significantly higher grain weight was obtained in hand weeded treatment compared to all others.

Table 2. Measurements of total tillers, productive tillers, filled panicles and panicle length (as mean values).

Treatments	Total tillers	Productive tillers	Filled panicles	Panicle length (cm)
T_1	8.00	4.60	3.85	22.56
T_2	8.05	4.85	3.93	22.51
T_3	7.10	4.00	3.38	22.23
T_4	6.88	4.78	4.48	21.97
T_5	6.90	4.48	3.95	22.62
T_6	7.88	6.15	5.68	22.67
T_7	6.60	3.68	3.14	21.83
C.D.	0.818	0.752	0.753	1.083

The lowest grain weight was obtained from unweeded treatment which was on par with nitrofen.

7. Grain chaff ratio

Grain number and chaff number from the observation plants were counted and their ratio was worked out. The data is presented in table 3. This gave an index of the percentage of spikelet sterility.

Significantly high spikelet sterility was obtained in case of treatments 2,4-D and nitrofen compared to all other treatments. Treatments propanil, hand weeding, no weeding and benthiocarb did not show any significant difference in spikelet sterility among themselves.

Correlation analysis of characters spikelet sterility with yield indicated a negative value (r = 0.25).

8. Grain yield

When the yield from each treatment was compared, significantly higher yield was obtained from hand weeded treatment (table 3). Yield was significantly low in case of unweeded treatment and nitrofen compared to all others. Butachlor, 2,4-D, propanil and benthiocarb did not differ significantly in yield.

Correlation studies between yield and characters like height and productive tillers showed positive correlation.

Table 3. 1000 grain weight, grain weight per plant, grain chaff ratio and bulk yield.

Treatments	1000 grain weight (g)	Grain weight per plant (g)	Grain chaff ratio	Bulk yield (g)
T_1	20.841	5.91	1.35	2051.75
T_2	21.500	5.98	1.18	1960.00
T_3	20.850	4.91	1.07	1590.00
T_4	21.090	6.42	1.00	1985.00
T_5	21.220	5.14	1.31	1991.25
T_6	21.320	8.76	1.33	3165.75
T_7	21.050	4.60	1.34	1447.50
C.D.	0.364	0.168	1.37	427.44

Significant negative correlations were obtained in case of weed dry weight, weed count, pollen sterility, spikelet sterility and chromosomal abnormalities when compared with yield.

9. <u>1000 grain weight</u>

The mean values of 1000-grain weight (g) are given in table 3. Nitrofen (T_3) showed the lowest value while butachlor (T_2) the highest.

<u>Weed observations</u>

(a) <u>Weed flora</u>

The experimental site was found to be predominantly infested with the following weeds:

1. *Echinochloa crusgalli*
2. *Echinochloa colona*
3. *Fimbristylis miliaceae*
4. *Marsilia quadrifoliata*
5. *Panicum repens*
6. *Cyperus rotundus*
7. *Cyperus iria*
8. *Salvinia* spp.
9. *Monochoria vaginalis*

(b) <u>Weed count</u>

The weed density and treatment effects on weed population at various stages of growth are graphically represented in Fig.2 and data of periodical weed counts are given in table 4.

On the first weed count after treatments the lowest weed intensity was noticed in hand weeded plot. Treatments propanil and nitrofen gave significantly better control of weeds compared to 2,4-D and butachlor. Propanil, nitrofen and benthiocarb did not significantly differ among themselves. Also 2,4-D, butachlor and benthiocarb did not differ significantly.

In all the subsequent weed observations also the best weed control was effected by the hand weeded treatment and the least by no weeding. As per the second weed count after treatment the best control of weed effected by chemical was by propanil followed by benthiocarb, nitrofen, butachlor and 2,4-D.

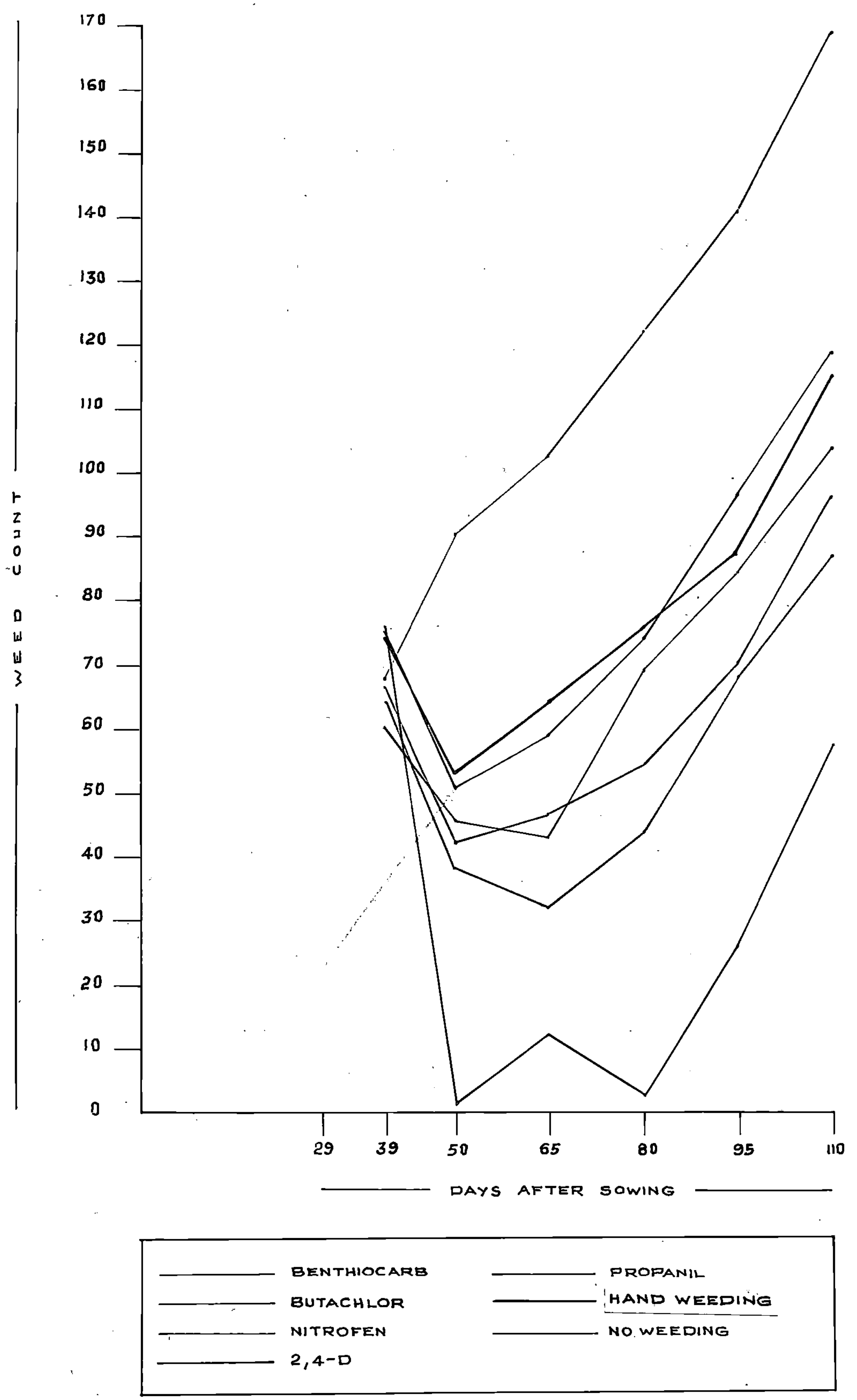
Almost same results were obtained for the subsequent weed counts also. Among the herbicides better weed control was given by propanil and nitrofen since they had significantly lower weed population at this stage compared to no weeding, 2,4-D, butachlor and benthiocarb.

As per the observation on weed counts at various stages of growth of the crop the best weed control has been achieved by hand weeding. Among the herbicides, nitrofen was found to give better control all throughout followed by benthiocarb and propanil.

Table 4. Periodical weed count.

Treatments	Weed count before treat-ment	Weed count after treatment (15 days interval)				
		I	II	III	IV	Harvest
T_1	8.28	6.76	6.55	8.35	9.20	10.17
T_2	8.74	7.17	7.78	8.69	9.90	10.94
T_3	8.40	6.56	6.79	7.42	8.37	9.77
T_4	8.61	7.34	8.08	8.71	9.35	10.85
T_5	8.03	6.25	5.65	6.65	8.22	9.41
T_6	8.77	1.10	3.59	1.77	5.16	7.65
T_7	8.27	9.59	10.18	11.09	11.89	13.04
C.D.	0.795	0.690	1.105	0.960	1.163	1.194

FIG. 2. EFFECT OF TREATMENTS ON WEED COUNT AT DIFFERENT STAGES OF GROWTH



Correlation analysis of first weed count at 30 days after transplanting which is the critical period as it coincided with panicle initiation time and at harvest were studied in relation to yield, sterility, productive tillers, filled panicle and height.

A significant negative correlation was obtained in the case of weed count with yield (r = -0.69), productive tillers (r = -0.55) and filled panicles (r = -0.53). Eventhough a positive correlation was obtained with sterility and weed count (r = 0.23) it was not significant.

(c) Weed index

The values relating to the weed index are presented in table 5. Maximum weed index of 54.25 was obtained in the case of unweeded treatment. Minimum weed index was obtained in the case of benthiocarb with 35.15. Butachlor, 2,4-D and propanil had weed indices which were more or less on par. The data are represented graphically in Fig.3.

(d) Percentage of weed control

The data are presented in table 5. The highest mean percentage of weed control all throughout the growing period of the crop was achieved by hand weeding with 86.6%. A weed control percentage of 58.42% was achieved with nitrofen. Benthiocarb and propanil gave 45.70% and 45.45% control respectively. 37.30% control was achieved by each of the herbicide treatments butachlor and 2,4-D. The percentages of weed control by the treatments have been graphically presented

FIG. 3. WEED INDEX IN COMPARISON TO HAND WEEDED CONTROL.

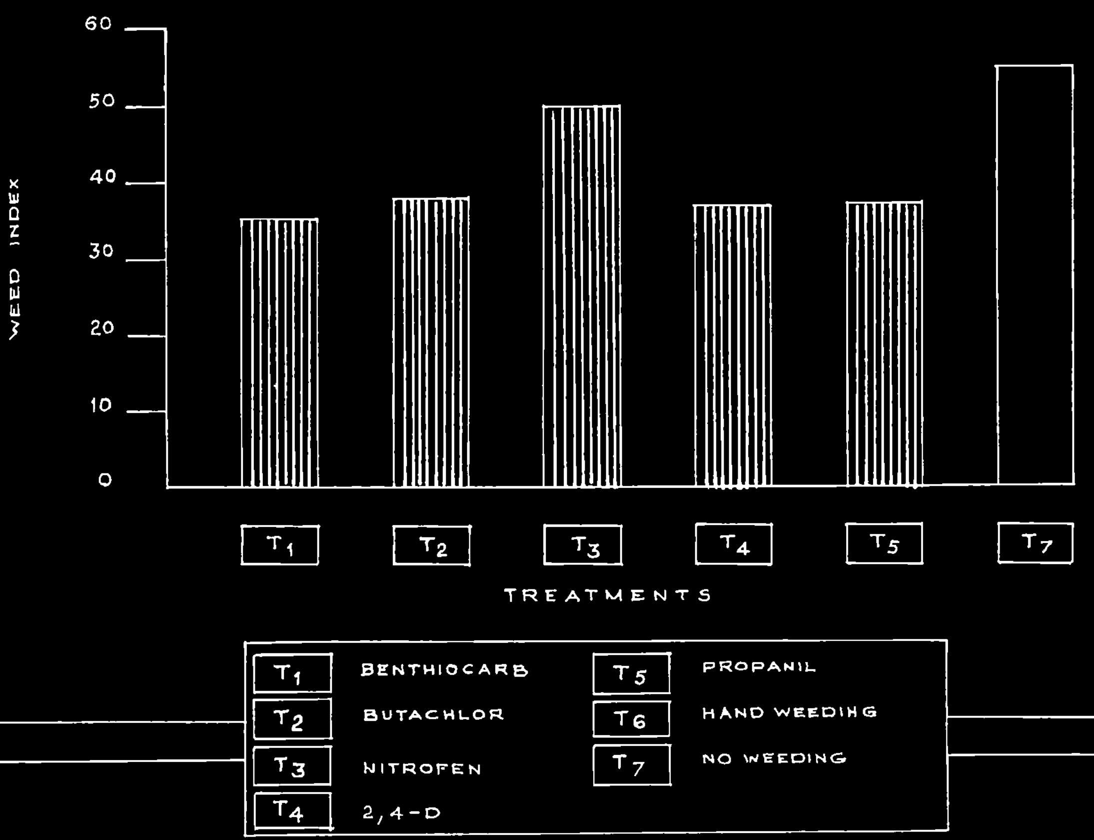


FIG. 4. PERCENTAGE OF WEED CONTROL IN COMPARISON WITH NO WEEDING

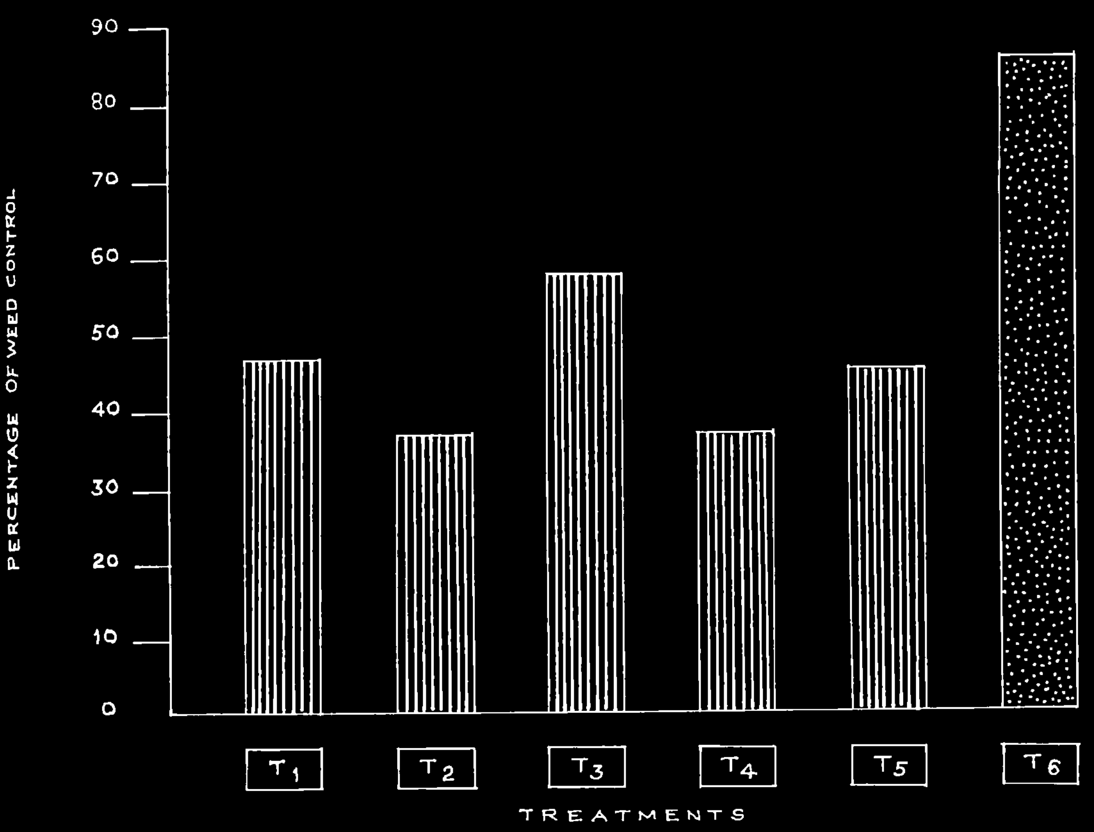


Table 5. Weed dry weight at harvest, weed index and percentage of weed control.

Treatments	Weed dry weight	Weed index	Percentage of weed control
T_1	61.27	35.15	45.70
T_2	74.30	37.73	37.30
T_3	69.86	49.74	58.42
T_4	53.25	37.26	37.30
T_5	66.91	37.07	45.45
T_6	32.67	-	86.60
T_7	97.24	54.25	-

C.D. for weed dry weight = 15.95

in Fig. 4.

(c) Weed dry weight

The weight of the uniformly sun dried weeds obtained from the plots at harvest were statistically analysed and compared. The figures are given in table 5.

It was observed that dry weight of weeds in hand weeded plot was significantly lower than all other treatments. Significantly high weed dry weight was obtained in the case of unweeded plots. Treatments 2,4-D, benthiocarb and propanil did not differ significantly among themselves.

Herbicide 2,4-D, benthiocarb and propanil gave the best results among chemicals in reducing weed dry matter (Fig. 5).

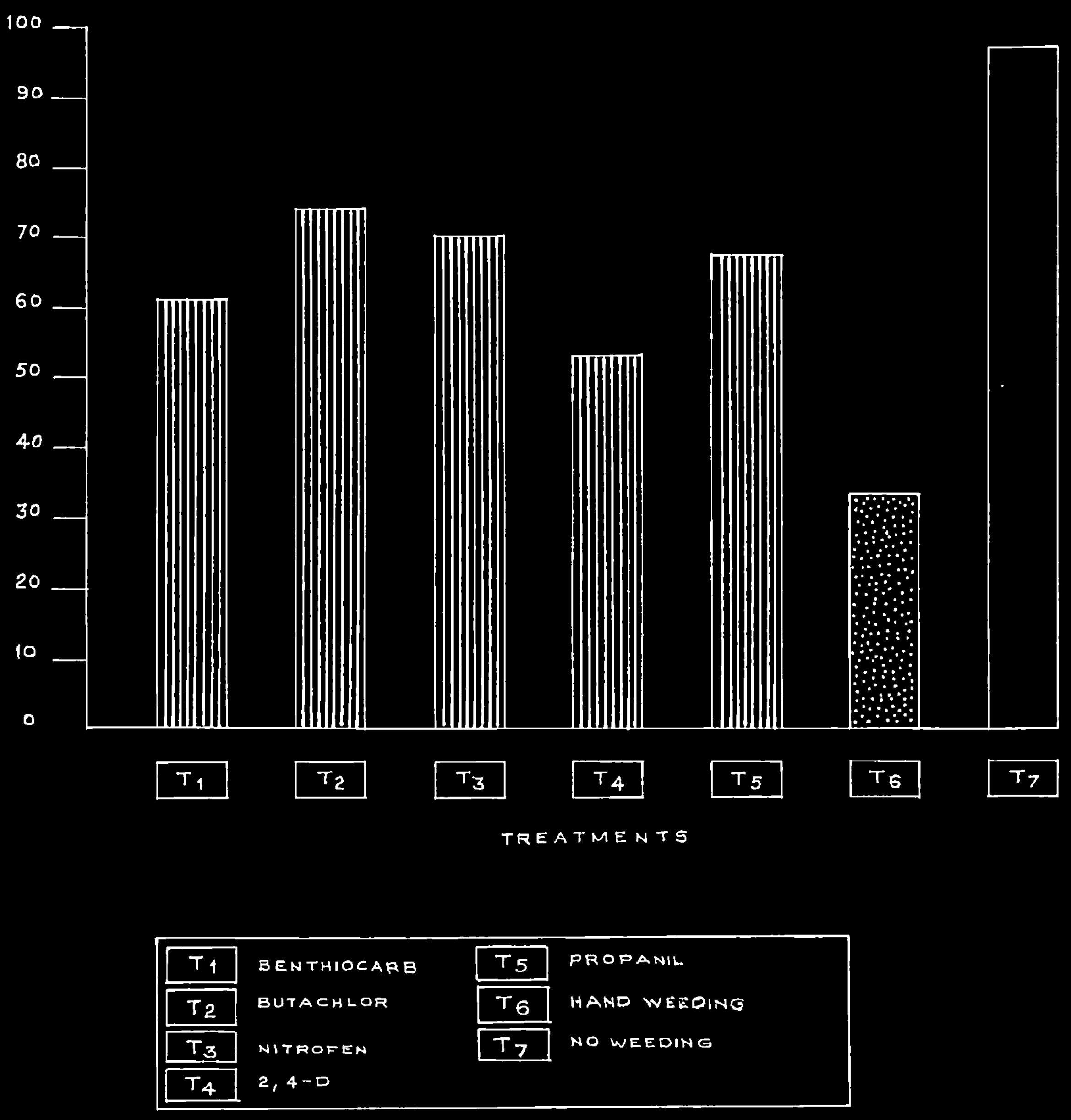
Correlation studies of yield with weed dry weight showed a significant negative relationship.

B. Cytological studies

1. Cell division

In the pollen mother cell studies, the maximum percentage of dividing cells was found in propanil treatment followed by nitrofen and butachlor. It was significantly more than the percentage of division observed in hand weeding. The percentages of cell division in no weeding, 2,4-D and benthiocarb did not differ significantly among themselves.

FIG. 5. WEED DRY WEIGHT AT HARVEST.



2. Scoring for abnormalities

Several chromosomal abnormalities were observed in all the treatments. Abnormalities like chromosome breakages, late congression of bivalents and stickiness of chromosome at metaphase I and bridges, laggards, fragments, unequal distribution etc. at anaphase were observed. The frequency of their appearance varied in different treatments.

Highest percentage of abnormalities was observed in 2,4-D and nitrofen. They had significantly more abnormal cells compared to all other treatments. The lowest number of aberrant cells was observed in benthiocarb and propanil treatments. Butachlor, hand weeding and no weeding had significantly more aberrant cells compared to propanil and benthiocarb.

A larger number of cells with chromosome clumping and stickiness at metaphase I were observed in the case of 2,4-D and nitrofen treatments. Besides it had a high frequency of bridges and fragments in early anaphase I. Nitrofen showed the highest frequency of laggards, and unequal distribution in the early and late anaphases (table 6). The maximum frequency of fragments was observed in treatment with butachlor.

Photomicrographs of chromosome abnormalities and pollen sterility are given in Plate I. Camera lucida diagrams of pollen mother cell abnormalities are given

Table 6. Chromosomal aberrations in the pollen mother cells.

Treatments	Number of anaphase cells observed	Type of abnormality					
		Stickiness	Fragments	Unequal distribution	Chromosome clumping	Bridges and/or fragments	Laggards
		1	2	3	4	5	6
T_1	114	4	3	2	2	0	2
T_2	75	2	4	2	1	1	0
T_3	122	6	2	6	3	5	2
T_4	105	7	3	2	5	3	2
T_5	67	2	2	3	3	1	1
T_6	89	3	2	2	2	3	0
T_7	80	1	2	4	1	2	0

PLATE I

1. Pollen in butachlor treatment.

2. Chromosome clumping at metaphase in 2,4-D treated plot.

3. Pollen in Stam-F-34 treated plot.

4. Laggards in late metaphase of 2,4-D applied plot.

5. A chromosome bridge observed during anaphase I in nitrofen treatment.

6. Fragments observed in 2,4-D treatment during anaphase separations.

7. Pollen of handweeded plot.

8. Pollen of unweeded plot.

9. Pollen sterility observed in 2,4-D applied plot.

10. A persistent bridge in 2,4-D treatment.

11. Pollen sterility in nitrofen applied plot.

12. Laggards and unequal separation at anaphase in 2,4-D treatment.

13. Pollen of benthiocarb treatment.

14. Sticky chromosomes in nitrofen treatment.

PLATE I. PHOTOMICROGRAPHS OF CHROMOSOMAL ABNORMALITIES IN POLLEN MOTHER CELLS AND POLLEN STERILITY.

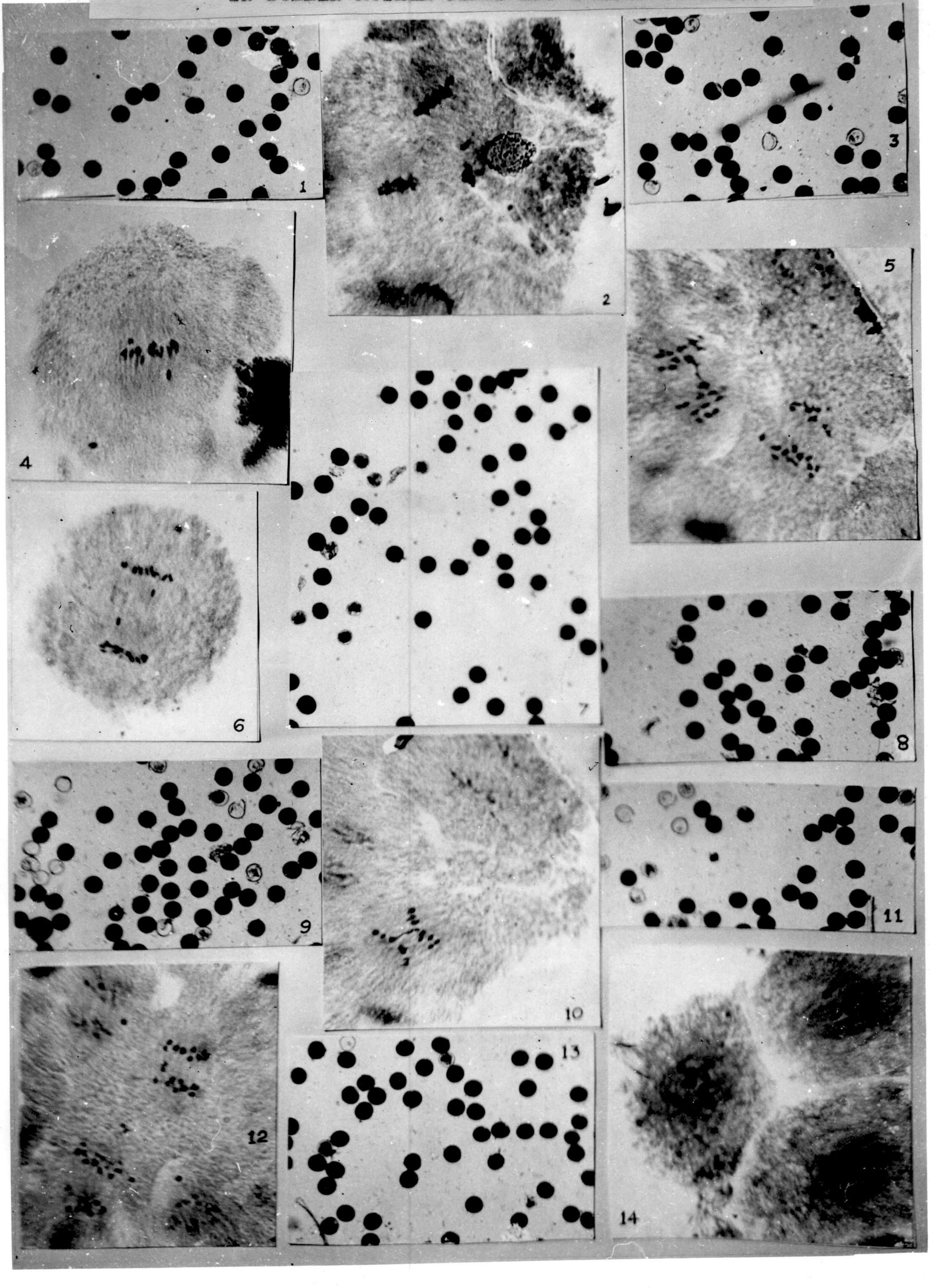


PLATE II

1. A normal anaphase separation observed in hand weeding.

2. Laggard in 2,4-D treatment.

3. A chromosome bridge during anaphase I in nitrofen.

4. A persisting bridge observed in late anaphase of 2,4-D treatment.

5. Chromosome clumping in 2,4-D treatment.

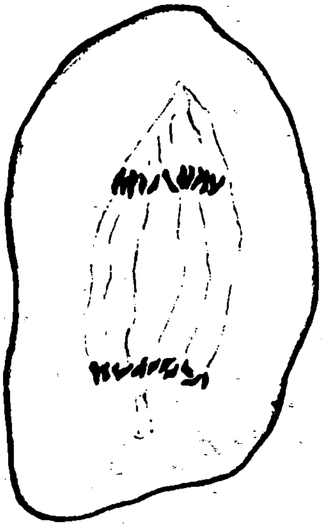
6. Remnants of a bridge seen in 2,4-D.

7. A normal cell - No weeding

8. A tripolar spindle formation in 2,4-D.

9. Unequal distribution of chromosome during anaphase in nitrofen treatment.

PLATE II. CAMERA LUCIDA DRAWINGS OF CHROMOSOMAL ABNORMALITIES IN POLLEN MOTHER CELLS.



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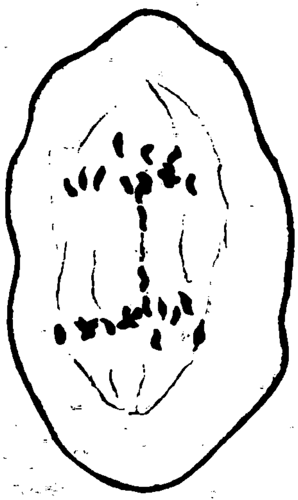

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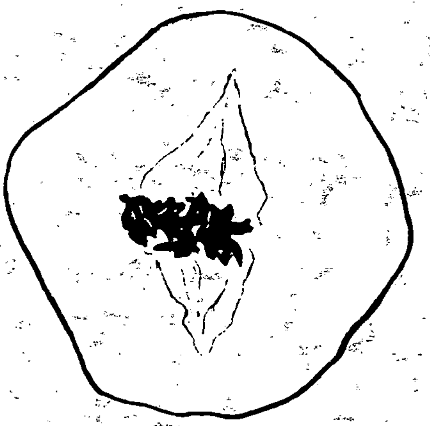

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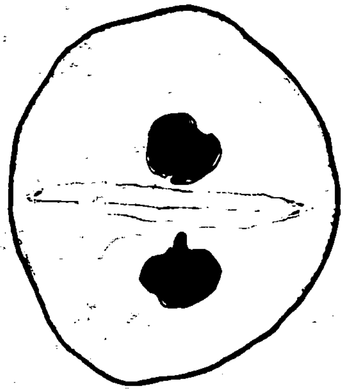

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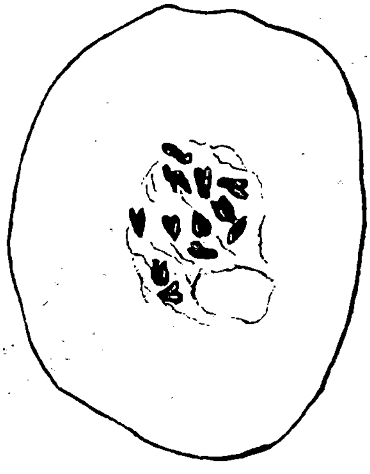

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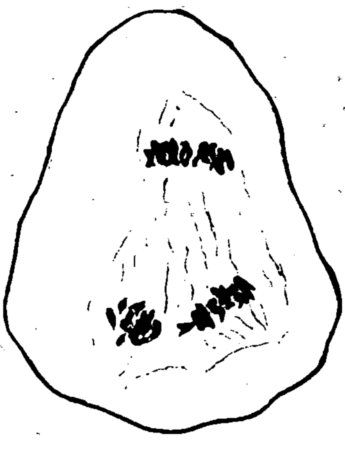

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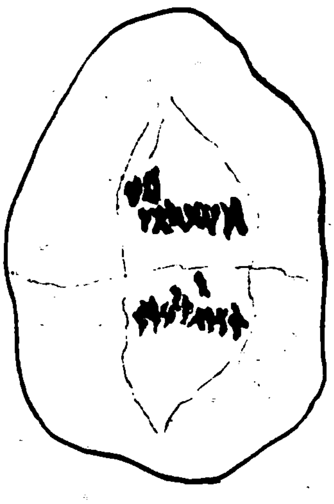

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in Plate II. The mean percentages of dividing cells and abnormal cells are given in table 7.

3. Pollen sterility

Observations on pollen sterility (Plate I) gave the following results.

Treatment 2,4-D had the highest percentage of pollen sterility which was significantly more when compared to all other treatments except nitrofen, butachlor and no weeding (Fig.6).

The lowest pollen sterility was obtained in benthiocarb and hand weeded treatments. They had significantly less sterile pollen than 2,4-D and nitrofen. But sterility in hand weeding and benthiocarb was comparable with butachlor, no weeding and propanil (table 7).

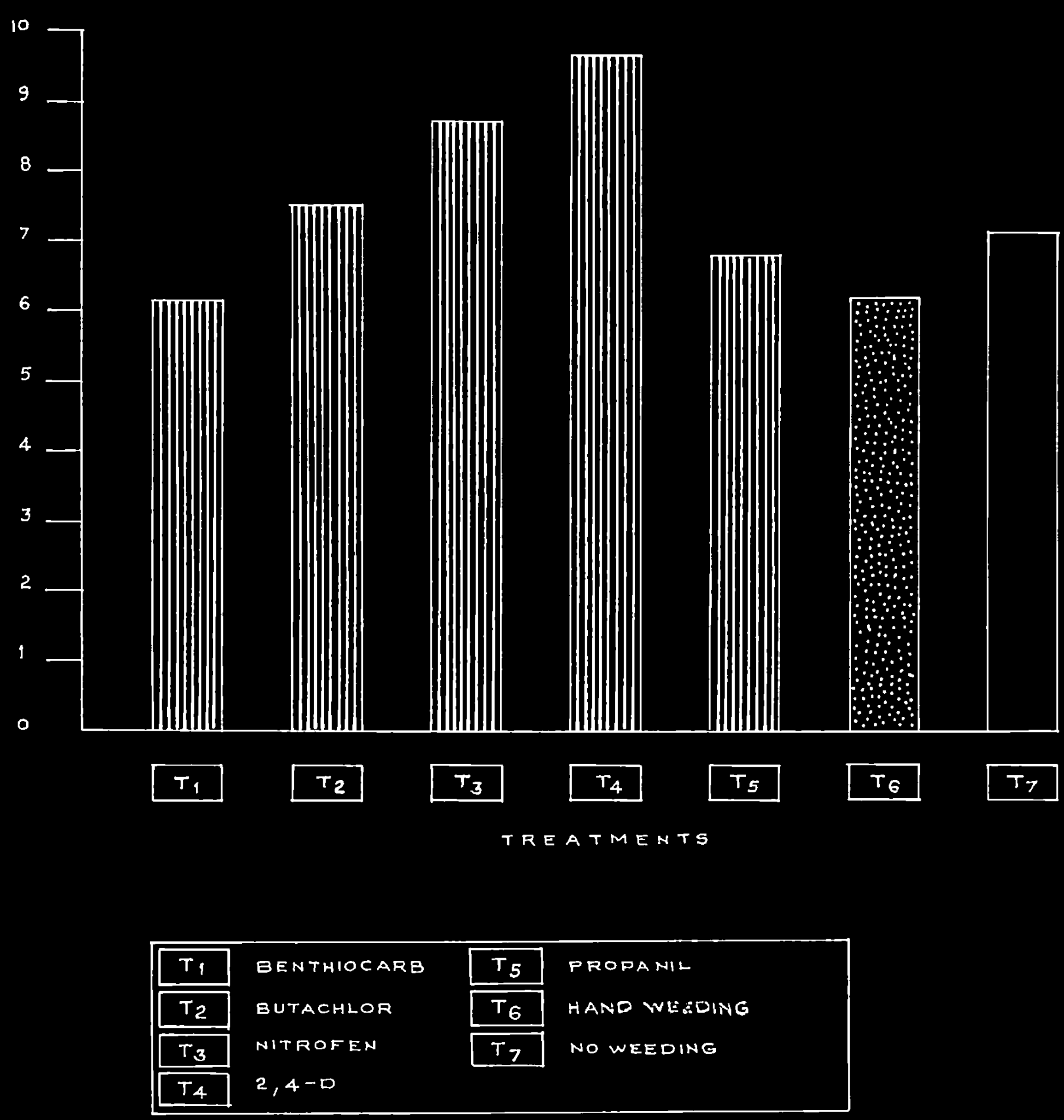
The correlation analysis of pollen sterility, percentage of abnormality, spikelet sterility, weed counts, productive tillers and yield gave the following results.

Eventhough positive correlation was observed with regard to sterility and weed count it was not significant. But yield and sterility showed significant negative correlation. Similarly significant negative correlation for yield was also obtained with chromosome abnormality and pollen sterility.

Table 7. Mean percentage of dividing cells, abnormal cells and pollen sterility.

Treatment	Percentage of dividing cells	Percentage of abnormal cells	Pollen sterility
T_1	30.32	15.94	14.26
T_2	31.72	17.91	15.64
T_3	32.10	23.24	17.09
T_4	30.10	23.65	18.05
T_5	33.26	16.06	14.99
T_6	28.46	17.21	14.43
T_7	30.75	17.75	15.34
C.D.	2.00	1.66	2.75

FIG. 6. EFFECT OF TREATMENTS ON POLLEN STERILITY.



DISCUSSION

DISCUSSION

The property of selective phytotoxicity of herbicides helps in the chemical control of weeds in agriculture. Though the application of certain chemicals either retards the growth or completely eradicates most of the broad leaved plants, they do not leave the narrow leaved ones entirely unaffected. In monocot crops although these effects may not be very detrimental from the view point of yield, a complete knowledge of the various factors involved in chemical weed control is essential. The physiology of the plants also bears a direct relationship to the effect of the herbicides.

In the present study the effect of five selective herbicides on the cytology, sterility and yield in rice was studied. The different weed flora and their relative population density with respect to herbicidal treatments were also recorded. Height of plants showed significant variation in all observations after treatment. It shows that this yield parameter has been greatly influenced by herbicidal treatments and weed intensity. In all herbicide treatments there was a retardation of growth as expressed by lower mean heights in comparison to the hand weeded treatment. Likewise in the unweeded treatment also a lower plant height was observed indicating the influnence of weed in reducing plant height.

As per observations on 35th day of transplanting the height of plants in treatments nitrofen (T_3), benthiocarb (T_1) and unweeded plots (T_7) were low when compared to other treatments. Height of plants was observed to be the minimum in nitrofen applied plots and this was significantly lower than hand-weeding, 2,4-D, propanil and butachlor. Plants in this treatment showed typical phytotoxicity symptoms of burned leaf margins and curled leaf tips. Subsequently in such affected plants, failure of the inflorescence to emergences from the sheath was also noted. Similar observations have been reported by Unrau and Larter in barley, oats and wheat (1952). These phytotoxicity symptoms may be due to the dose effect of the chemical. The reduction of height may be attributed to the reduction of photosynthetic efficiency and mitotic cell division induced by nitrofen. In treatments with benthiocarb and no weeding even though the height of plants was lesser, those treatments did not differ significantly from all other treatments except hand weeding which had significantly taller plants. The taller plants in hand weeded plots may well be attributed to the complete weed control effected by hand weeding which in turn eliminated weed competition with crop.

In the subsequent observations also the trend of growth followed a similar pattern. Contrary to the observation on 35th day, the height of plants on the 50th day and at harvest indicated that treatment propanil had taller plants compared to 2,4-D even though the difference was not significant. This can be attributed to a faster growth induced by propanil in the later stages of the crop. During this period 2,4-D however has acted as a growth retardant.

Likewise benthiocarb treatment showed an increased height measurement on the 50th day after transplanting and at harvest over plants with no weeding. This may be due to the higher intensity of crop weed competition in the vegetative and later stages in the no-weeding treatment as compared to the chemical applied plots where weed competition was lower than unweeded plots.

Such detrimental effects on height by herbicides and other chemicals have been reported by Guh and Kwon (1975) who found that repeated application of chemicals like nitrofen, butachlor etc. substantially reduced plant height, culm length, leaf number and dry weight of foliage. It is clear from the present study that the inhibition of growth is a prominent feature of herbicide toxicity. This is also in conformity with the work of Sotnik (1977) who has found that chemicals had growth inhibiting action and reduced plant height to a certain extent.

There was significant difference between treatments in the case of total number of tillers. Tiller production was found to be low in case of treatments no weeding, 2,4-D, propanil and nitrofen. Tiller production in treatments butachlor, benthiocarb and hand weeding was high. The occurrence of high tiller production in these treatments may be attributed to the toxic effects of these herbicides on the weed growth resulting in a reduction of weed competition and the lesser phytotoxicity of chemical on the crop.

Higher number of tillers was observed in butachlor and benthiocarb applied plots than in other treatments. This is in confirmity with the work by Sridhar et al. (1974) where they observed that in benthiocarb treated rice fields the number of tillers and productive tillers were the highest and this they attributed to the better weed control and lesser phytotoxicity of the chemical. Contrary to the reports by Sankaran et al. (1974) they also found that herbicide propanil has an effect in reducing total number of tillers. This observation is in confirmity with the present study also.

The result that unweeded plots have a lower number of tillers agrees with the work done by Ramamurthy et al. (1974). They found that unweeded plots had the most dense weed population and a significantly lower number of productive tillers. The observation that 2,4-D reduces tillering is confirmed by work done by Shibayama and Noda (1977) in which they found that another phenoxy herbicide M.C.P.A. caused a reduction in number of tillers.

With regard to productive tillers the maximum number of productive tillers was found in the case of hand weeded control with about 77.8 per cent of total tillers being productive. For 2,4-D it was 69.5 per cent, propanil 64.9 per cent, butachlor 60.0 per cent and nitrofen 56.3 per cent (Table 2). The highest number of productive tillers in the case of hand weeding may be attributed to be due to an absence of weed competition and non-influence of any chemicals. At the same time the lowest number of productive tillers in the case of no weeding is obviously due to the heavy weed competition. In the other treatments the variation can be attributed to the effect of chemicals on the crop and also due to the varying degrees of weed competition caused by their differential degrees of weed control.

In the correlation analysis significant negative correlation was obtained between weed count and productive tillers indicating that weeds play a significant role in reducing the number of productive tillers.

There was no significant difference in the case of panicle length with regard to any of the treatments. This result is in conformity with the result of the work done by Nair and Sadanandan (1978) wherein a study of comparative performance of granular herbicides like butachlor, 2,4-D and nitrofen, they found that the chemicals had no effect on panicle length.

Pereira and Pena (1976) have also reported that 2,4-D, amine sprayed at different stages of growth of rice had no effect on the length of the panicle. So, neither weed competition nor the action of various herbicides have any effect on panicle length or 1000 grain weight.

However significantly high spikelet sterility was obtained in the case of 2,4-D and nitrofen. In the case of 2,4-D it may be attributed to the high degree of chromosomal abnormalities induced by this chemical by upsetting the meiosis and post-meiotic mitoses, both in the microsporogenesis and megasporogenesis resulting in pollen and ovule sterility. This is in conformity with the finding of Amer and Ali (1974) who found that chlorophenoxy herbicides caused significantly high pollen sterility. In the case of nitrofen treatment this may be due to its phytotoxic effect on the plant which might have disrupted the cell metabolism and cell division, leading to sterility in plants.

With regard to yield of grains significantly high yield was obtained in hand weeded treatment while in all other treatments yield is lower. This suggests that even in recommended doses, herbicide application adversely affects the yield of paddy. The retardation of vegetative activity by the application of herbicides at the early stages of growth as evidenced by growth reduction has a corresponding effect in the yield as per the observations in the present study. Lowest yield was obtained in the case of treatments no weeding and nitrofen. All others gave moderate yield. The reduced yield in nitrofen inspite of the fact that comparatively good weed control was effected, may be attributed to the phytotoxicity caused by the herbicide and its possible residual effects. However the reduced yield in unweeded plots is due to the high density of weed population. Among the other herbicides the highest yield was obtained in the case of treatment with benthiocarb. A low weed index value has also been obtained in case of benthiocarb (table 5). These observations confirm the results of Sridhar et al. (1974). They, in a weed control experiment, observed that benthiocarb applied plots had the highest yield compared to other herbicides.

Observations on 1000 grain weight indicated that there was no significant difference between treatments as far as this character was concerned. This finding is in agreement with the finding of Ramamurthy et al. (1974) who has reported that 1000 grain weight was not influenced by herbicide application. In another report Nair and Sadanandan (1978) also have observed that granular herbicides like nitrofen, 2,4-D and butachlor have no effect on 1000 grain weight of rice.

Correlation studies for yield with plant height and number of filled panicles showed significant positive correlations. However significant negative correlations were obtained for yield with weed count, weed dry weight, pollen sterility, spikelet sterility and chromosomal abnormalities. This shows that all these characters had negative influence on yield.

Rola (1975) in his studies on the response of wheat varieties to several herbicides elucidated that the yield in herbicide applied plots was lower when the herbicides were applied during the vegetative phase. This is in conformity with the results obtained in the present experiment where the total yield is significantly lower in all treatments when the herbicides were applied during the vegetative phase of growth.

With regard to weed control, hand weeding was the best. Among the herbicides, nitrofen treatment gave the best weed control followed by benthiocarb and propanil.

Correlation of weed counts at the critical period of the crop i.e. panicle initiation time in relation to plant height, productive tillers, number of filled panicles, sterility and yield showed that there was significant negative correlation between yield and weed count. This indicated that weed population had negative influence on yield. Similar negative correlations for yield were obtained with productive tillers and filled panicles too. This showed that weed population had a significant influence in reducing the number of total and productive tillers and final yield.

The maximum effect in reducing weed dry weight in treatments was observed in the case of 2,4-D followed by benthiocarb (table 5). The maximum weed dry weight was observed in unweeded plots.

The low weed dry weight in 2,4-D applied plots inspite of the lower mean weed control percentage may be attributed to the fact that 2,4-D was effective in controlling the heavy broad leaved weeds compared to the other herbicides which were lower in efficiency in controlling broad leaved weeds than 2,4-D (table 5).

Correlation studies of yield with weed dry weight showed significant negative correlation. This indicated that higher the weed dry matter lower the yield. This result is in conformity with the work of Verma and Mani (1967) and Rangiah et al. (1974). They got strong negative correlation between yield and weed dry weight at harvest.

Singh and Kothari (1974) in their studies on the relationship between growth of weeds and wheat crop showed that uptake of nitrogen by weeds and weed dry weight were negatively correlated with uptake of nitrogen by crop and grain yield. This may be the reason for the reduced yield in the unweeded plots of the present study.

The usual leaf abnormalities produced by toxic chemicals are epinasty and stiffness of flag leaf leading to drying of the leaves. Some of the younger leaves curl upwards and do not unfurl normally (Srivastava, 1958). In the present investigation, with regard to injury to rice plants by the application of herbicides, the highest phytotoxicity was observed with nitrofen. Typical symptoms like burned leaf margins and curled leaf tips were observed. Similar phytotoxicity symptoms were observed by Smith (1969); Lozano and Cardinas (1970) when herbicides were applied to crop plants. Katoska et al. (1977) has observed that nitrofen when applied soon after transplanting injured rice plants and the symptoms were identical to those observed in this experiment also.

These observations lead to the conclusion that a great deal of caution is indicated in deciding the strength of herbicides and the stage of the crop so as to obtain an effective weed control without causing much damage to the crop.

The pollen mother cell studies revealed that maximum percentage of dividing cells was observed in propanil treated plots (table 7). At the same time highest percentages of abnormal cells were observed in 2,4-D and nitrofen applied plots (Plate I). Among the treatments the lowest percentage of abnormalities was observed in benthiocarb followed by propanil.

Chromosomal aberrations like stickiness of chromosomes at metaphase, chromosome breakages and fragments were mostly observed in case of 2,4-D and nitrofen applied plots (Plate I & II). Stickiness of chromosome is a pathological condition apparently brought about as a result of the chemical treatments. The chromosomes in such cases are clumped together in compact masses in one or more groups. But sometimes the chromosome might be sticky at the end only resulting in the obstruction to the normal anaphasic separation. Such abnormalities have been reported earlier by several workers like Ryland (1948), Doxey and Rhodes (1949), Unrau and Larter (1952), Sawamura (1964) etc.

Aberrations like stickiness, fragments and laggards have been reported by Hakeem and Shehab (1972) for herbicide simazine. Abnormalities like bridges and fragments were observed by Mohandas and Grant (1972) when they sprayed 2,4-D and amitrole on twelve species of crop plants. The present observations also confirm that such abnormalities are induced by herbicide 2,4-D in the dividing cells of rice.

Lagging chromosomes on the spindle were frequent in 2,4-D and nitrofen. These seem to arise perhaps due to the insufficient contraction of the spindle fibres. Typical anaphase bridges were observed in treatments with 2,4-D in this investigation (Plate I & II). Unequal separation of chromosomes was also noted in 2,4-D treatments during anaphase. High frequency of fragments were observed in butachlor treatment.

Depending on the observation of frequency of dividing cells and abnormal cells it is clear that herbicidal chemicals have effect in delaying cell division and in inducing abnormalities which lead to inhibition of growth, pollen sterility, seed sterility and consequently the reduction in yield.

Significantly high pollen sterility was caused by the herbicides 2,4-D and nitrofen (table 7). Herbicide induced sterility has been reported earlier by many workers. High pollen sterility was observed by Amer and Ali (1974) as due to the effect of phenoxy acetic acid and phenols. When plants were sprayed at two developmental stages a significant pollen grain sterility was noted. Also Khokhilova (1977) reported 2,4-D induced pollen sterility in barley when the chemical was applied in the late tillering stage.

The observations in the present study regarding 2,4-D are all in conformity with the above findings. The high amount of pollen sterility observed in the case of nitrofen treatment may be attributed to the phytotoxicity caused by the treatment and the resultant physiological imbalance which might have disrupted meiosis during the formation of the panicle. This might have lead to the formation of sterile pollen. So the high frequency of chromosomal abnormalities seen in the case of 2,4-D and nitrofen has been reflected in the formation of higher percentage of sterile pollen.

However no significant correlation was observed with regard to pollen sterility and weed number indicating that pollen sterility was not induced by weed population. But yield and pollen sterility showed significant negative correlation indicating the negative effect on yield by high pollen sterility. Chromosomal abnormalities also had negative influence on yield in rice.

The highest percentage of chromosomal anomalies recorded by 2,4-D is reflected in the highest grain-chaff ratio shown by the same treatment. These two parameters are significantly and positively correlated with each other in the case of 2,4-D followed by treatment nitrofen. However the significantly high grain chaff ratio in 2,4-D treatment does not affect the final yield in this study as it is almost on par with highest yield obtained from benthiocarb treatment.

To sum up, from an overall assessment of results of this experiment, it is quite obvious that the best method of weed control is by hand weeding and highest yield was also recorded in this treatment. Also the percentage of chromosomal abnormalities in the pollen mother cells and sterility in this treatment were very low. The lowest yield observed in unweeded plots clearly indicate that high weed competition can substantially reduce the yield of a crop. Though the highest frequency of chromosomal aberrations was recorded in 2,4-D, this has not been reflected on its yield. This may be attributed to the fact that 2,4-D can more effectively kill the broad leaved weeds and this might have contributed to a better yield. A still lower dose of 2,4-D may be expected to reduce the chromosomal abnormalities and pollen sterility which may still enhance the yield.

Among the herbicides, nitrofen effected the best weed control followed by benthiocarb and propanil. But pollen sterility was the lowest in benthiocarb followed by propanil and butachlor. Benthiocarb gave the highest yield followed closely by propanil and 2,4-D.

SUMMARY

SUMMARY

Chemical weed control is becoming a common practice in rice cultivation. In this experiment five commonly used herbicides have been tried to assess their possible effects on the cytology, sterility and yield in rice. Observations were taken on height of plants, tiller and panicle characteristics, weed flora, chromosomal aberrations, sterility and yield and the data were analysed statistically to understand the possible relations between these characters and herbicide treatments.

Significant reduction in plant height was observed in the case of treatments nitrofen and no weeding. Hand weeding and propanil treatments had the least effect on height. Phytotoxicity symptoms were observed in the case of nitrofen treatment.

Total tillers were found to be maximum in treatments with butachlor, benthiocarb and hand weeding. However lowest number of tillers was found in unweeded treatment. The number of productive tillers was found maximum in the case of hand weeding and the minimum in no weeding and nitrofen treatments. Statistical analysis indicated that significant negative correlation existed between weed count and the number of productive tillers.

Subsequent observations on the number of filled panicles showed that maximum number of filled panicles was found in the case of handweeding plots and lowest in no weeding and nitrofen treatment. But panicle length and 1000 grain weight did not differ significantly among the treatments.

With regard to grain-chaff ratio the treatments differed significantly. Grain-chaff ratio reflected the extent of spikelet sterility. High spikelet sterility was observed in the case of nitrofen and 2,4-D treatments. Benthiocarb, propanil and handweeding showed the least amount of spikelet sterility. Correlation studies of spikelet sterility with grain yield showed negative relationship.

With regard to yield, significantly higher yield was obtained in the case of hand weeded plots and the lowest yield in unweeded plots. With regard to herbicide treatments, benthiocarb had the maximum yield followed by propanil and 2,4-D.

Yield showed significant positive correlation with filled panicles and productive tillers, but had negative correlation with weed dry weight, pollen sterility, weed count and spikelet sterility.

Observations on weed count at different stages of growth indicated that maximum control of weeds was effected by hand weeding. A mean control of 86.6 per cent was achieved by it all throughout the growth and development of the crop. However among the herbicide treatments, mean weed control was the best with nitrofen followed by benthiocarb and propanil.

Weed dry weight at harvest was found to be the least in hand weeded treatment when compared to all other treatments. Among the herbicides the best result was obtained with benthiocarb followed by propanil for weed index.

With regard to percentage of cell division of pollen mother cells maximum percentage of cell division was observed in the case of propanil followed by nitrofen and butachlor. The percentages of cell division in hand weeding, 2,4-D and benthiocarb were lower.

Several chromosomal abnormalities were observed in 2,4-D and nitrofen treatments. Lower percentage of abnormalities was observed in butachlor, followed by hand weeding and no weeding.

2,4-D and nitrofen treatments had a high frequency of chromosomal clumping, stickiness, bridges and fragments at metaphase and early and late anaphases.

A high percentage of pollen sterility was observed in the case of 2,4-D and nitrofen treatments. Pollen sterility in benthiocarb was the lowest, followed by hand weeded treatment.

The highest percentage of chromosomal abnormalities recorded in 2,4-D and nitrofen was reflected in the high pollen sterility and grain-chaff ratio in these treatments. This indicates a significant positive correlation between these parameters.

Sterility and weed count eventhough were positively correlated, the relationship was not statistically significant. However sterility and yield showed significant negative correlation. A similar trend was also obtained for yield when correlated to chromosome abnormality and pollen sterility.

To sum up, this study showed that the maximum weed control and highest yield was obtained in plots which had two hand weedings as per recommended normal practice. This treatment was superior to all the chemical herbicide treatments tried suggesting that even in recommended doses, herbicide adversely affect the yield of paddy. Among the herbicides nitrofen effected the best weed control followed by benthiocarb and propanil. However the highest yield was obtained in the benthiocarb applied plots which also showed the lowest percentage of pollen sterility.

2,4-D treatment gave a good yield performance almost on par with benthiocarb and propanil inspite of the fact that the treatment also had the highest percentages of chromosomal aberrations and pollen sterility. This may be attributed to the fact that 2,4-D can more effectively kill the broad leaved weeds thus reducing competition between the crop and the large sized weeds which might have contributed to a better yield.

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APPENDICES

APPENDIX I

Abstract of ANOVA

		Mean square				
		Height of plants (days after transplanting)				
Source	df	5	20	35	50	Harvest
Block	3	1.520	2.067	5.995	33.677*	30.898
Treatment	6	0.925	3.685	7.700**	59.130**	63.818*
Error	18	2.245	7.178	2.751	9.485	16.375
	df	Total tillers	Effective tillers	Filled panicles	Panicle length	Grain weight
Block	3	0.030	5.356	4.527	1.544	1.817
Treatment	6	1.494*	2.418**	2.799**	1.050	7.264**
Error	18	0.305	0.256	0.278	0.531	0.851

*Significant at 0.05 level

**Significant at 0.01 level

APPENDIX II

Abstract of ANOVA

Source	df	Mean square						Mean square of weed dry weight
		Weed count		At definite intervals				
		Before treatment	I weed count	II	III	IV	V (Harvest)	
Block	3	0.754	0.749*	0.308	0.371	0.262	0.948	77.250
Treatment	6	7.917**	26.570**	17.050**	33.340**	16.636**	10.946**	1566.560**
Error	18	0.504	0.216	0.553	0.418	0.634	0.646	114.950

*Significant at 0.05 level

**Significant at 0.01 level

Note: The weed counts were analysed after $\sqrt{x+1}$ transformation

ABSTRACT

Herbicides have become a very important tool for weed control and research in this line has been progressing ever since their invention. Studies on the possible damages which herbicides cause at the chromosomal level have been undertaken under laboratory conditions by many workers. But only a few studies have been done on this aspect under field conditions. This study was done with the aim of finding the extent of chromosomal aberrations and consequent deterioration of yield attributes in rice caused by the application of five selective herbicides. Observations on the herbicidal influence on weed population have also been taken.

From this study it has been found that herbicides do cause chromosomal changes during cell division. Pollen mother cell studies revealed that highest number of chromosomal abnormalities occur in 2,4-D and nitrofen treatments when applied at a dose of 1 kg and 1.5 kg a.i. per hectare, eighteen days after transplanting. Such abnormalities caused pollen sterility and consequent spikelet sterility leading to reduction in yield. These parameters showed significant positive correlation.

The highest yield and best weed control was effected with handweeding. Among the herbicides highest yield was

obtained from benthiocarb. Nitrofen showed the maximum percentage of weed control among herbicides followed by benthiocarb and propanil. Pollen sterility was the lowest in benthiocarb treatment.

Inspite of its high percentage of weed control, the yield was low in nitrofen treatment. At the same time a comparatively high yield was obtained in 2,4-D treatment which showed the highest percentage of chromosomal aberrations and pollen sterility. This may be due to the fact that this herbicide can effectively kill the large broad leaved weeds thus reducing competition between the crop and weed flora which might have contributed to a better yield.