EFFECT OF HORMONE HERBICIDES ON PADDY (*ORYZA SATIVA* L.)

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ABSTRACT

The effects of four hormonal herbicides viz. amine, sodium salt and ester of 2, 4-D and M.C.P.B. in 1,000, 2,500 and 5,000 p.p.m. concentration on 'Aman' variety of paddy have been investigated. The relation between the age of the crop and the susceptibility to hormone herbicides has also been studied by giving the treatments at 'early', 'pre-flowering' and 'post-flowering' stages.

It has been found that all the chemicals produce a certain degree of adverse effect on the growth of paddy, seed-sterility and yield. Unlike wheat, paddy has been found to be more susceptible to M.C.P.B. than 2,4-D.

It has further been found that irrespective of the chemical and the stage of treatment, reduction in the rate of growth and yield and increase in the frequency of ear abnormalities is proportional to the concentration of herbicide.

It has been observed that the growth is most affected when the treatment is made at the early stage, while the yield is minimum at the pre-flowering stage of treatment. The low yield and high percentage of seed sterility has been found to coincide, and hence it is assumed that perhaps the herbicide interferes with the seed-setting in paddy.

Besides, a large number of morphological abnormalities of the ear have been recorded. Since these abnormalities occur almost exclusively when treated at the pre-flowering stage, they have been attributed largely to the formative disturbances caused by the hormone herbicides.

From the present investigations, it has been concluded that the most suitable stage for the application of the hormone herbicides for controlling weeds in paddy is the early stage of the crop growth and treatment at pre-flowering stage must always be avoided. However, in crops where there is a considerable difference in the time of flowering of weed and the crop, it has been suggested that herbicide treatment at the pre-flowering stage of the weeds is likely to exert an effective control for the next season by reducing the setting of seeds.

INTRODUCTION

It is the property of selective phytotoxicity of hormone herbicides, which makes possible the chemical control of weeds in agriculture. But, whereas the application of such chemicals either retards the growth or completely eradicates most of the broad-leaved plants, it does not leave the narrow leaved ones entirely unaffected. In monocot crops although these effects might not be very detrimental from the viewpoint of the yield, a complete knowledge of the various factors involved in chemical weed control is essential. Besides, it has been recorded that the susceptibility of the plant species varies with their age. In other words, the physiology of the plants seem to bear a direct relationship with the effect of the herbicides. Unfortunately, no work has so far been done in this line in the Indian crop plants.

It, therefore, seemed desirable to study the effect of some of the common hormone herbicides on paddy at various stages of growth of the crop, in an attempt to find out the relative toxicity of the different chemicals, the most suitable stage of growth for the application of the weedicides, as well as to study the different deleterious effects produced, their frequency and significance in relation to the yield of paddy.

Material and Method

The experiment was conducted on the field scale, at the Field Experimental Station of Bose Research Institute, at Shyamnagar (24 Parganas), on the transplanted "Aman" paddy in a suitably planned lay-out. The treatments were made at three different stages of growth. viz.,

(*i*) Early (about 6 weeks after germination)

(*ii*) Pre-flowering (about 11 weeks after germination)

(*iii*) Post-flowering or milk seed (about 12–13 weeks after germination).

Four different herbicidal products, namely, the amine salt of 2, 4-dichlorophenoxy acetic acid (amine 2, 4-D), the butyl ester of 2, 4-D (Ester 2, 4-D), the sodium salt of 2, 4-D (Na-2, 4-D) and methyl, chloro-phenoxy butyric acid(M.C.-P.B.) were used in different concentrations of 1,000, 2,500 and 5,000 p.p.m. The chemicals were sprayed in form of aqueous solutions or emulsions, using a constant pressure, high volume, Knapsack type of spraying equipment. A uniform rate of spraying at about 80 gallons of solution per acre was maintained in all the treatments. Thus on an average, the treatment given was slightly higher than the usual so as to get pronounced effects of herbicidal injury, if any.

The data with regard to growth, flowering, and sterility, etc. were taken from 10 plants selected at random from each subplot. The data of the yield were taken from each subplot separately and compared with the 'control'.

Experimental Results

Initial effects of the treatments :

The initial effects of the treatment on paddy included the wilting, yellowing and drooping of the plants. Paddy is essentially resistant to a normal dose of herbicidal chemicals at which most of the dicot weeds succumb. In the present set of treatments the initial injury varied with the concentration as well as the age of the crop. However, in none of the concentrations, the initial effect of the treatment lasted for more than 2–5 days and the plants recovered therafter. The maximum injury was recorded in case of 5,000 p.p.m. treatments. Again the initial effect of the herbicides was most pronounced when the application was made at the early stage of the growth of plants. With the increasing age of the plants, there was lesser injury and the recovery was relatively quicker.

Effect on the growth :

Although the initial effects of herbicides disappear soon, more lasting effects are produced on the physiology of plants which express in the less height of the plant and other morphological abnormalities.

The growth of the plants in each treatment was taken in terms of the maximum height attained by the plants at the mature stage. The height of ten plants selected at random from each subplot was taken and the data are included in Table I.

From the table below, it will be seen that in all the treatments there was a retardation of the growth i.e. the average height of the plants in all the treatments was lower than the control. On analysing the data with the help of Graph I, it was seen that like the initial effects, the effect of the herbicides on the growth was most pronounced at the early stage, whereas there was no significant difference between the various treatments at the pre-flowering and post-flowering stages. Even the differences between the effects of the higher concentrations were not much pronounced at the latter stages. In other words, the height of the paddy treated at a relatively mature stage with 1,000 p.p.m. almost corresponds with that of the control and the height at higher concentrations, viz., 2,500 and 5,000 p.p.m. is not very much lower.

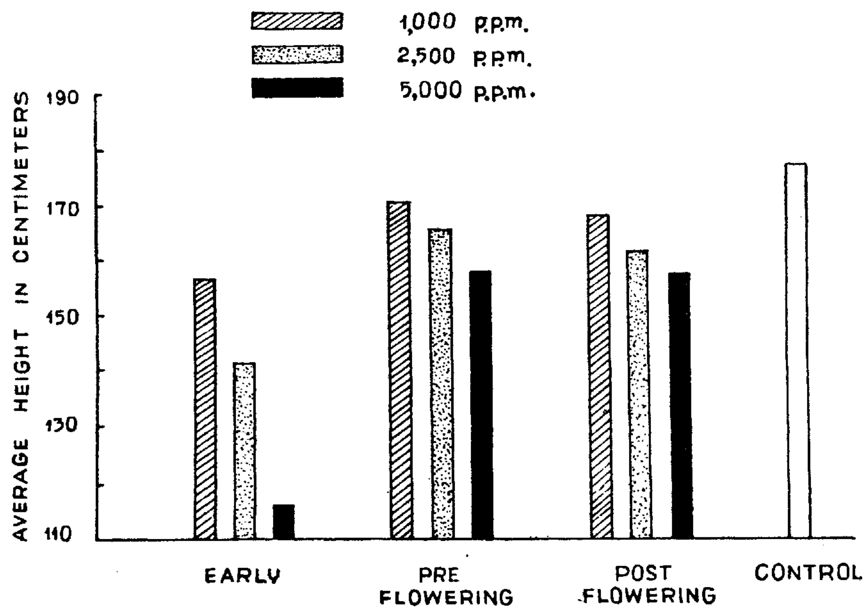
TABLE I

Max. height of plants in cm. (Average of 10 plants)

Treatment \ Stage	Early 1,000 p.p.m.	Early 2,500 p.p.m.	Early 5,000 p.p.m.	Pre-flowering 1,000 p.p.m.	Pre-flowering 2,500 p.p.m.	Pre-flowering 5,000 p.p.m.	Post-flowering 1,000 p.p.m.	Post-flowering 2,500 p.p.m.	Post-flowering 5,000 p.p.m.	Mean
Amine 2, 4-D	155.6	140.0	140.0	178.0	176.0	164.0	174.0	171.0	165.0	162.4
Ester 2, 4-D	164.0	147.0	122.4	178.0	177.0	170.0	174.0	172.0	170.0	164.6
Na-2, 4-D	153.0	127.6	86.8	161.5	156.0	140.0	160.0	151.0	140.0	141.7
M.C.P.B.	155.8	137.4	114.0	168.0	162.0	154.0	165.5	160.0	154.0	152.3
Control	—	—	—	—	—	—	—	—	—	175.0
Mean	157.1	137.75	115.8	171.4	167.75	157.0	168.37	163.5	157.25	—

There is, on the other hand, a pronounced depression of growth when the treatment was made at the early stage. Here the height is considerably lower than the control even at 1,000 p.p.m. and with the increasing concentrations, there is a steep reduction in the height of the plants; being on the average only 115.0 cm. at the 5,000 p.p.m.

GRAPH I



This shows that there exists some sort of relationship between growth and the age of the paddy as well as the strength of the chemical. The nature and the consequence of this relationship will be discussed later.

Effect on the flowering:

The date of the first flowering in the same ten plants selected at random from each subplot was taken and the duration for flowering was calculated from it. It has been found that on an average, the treatment with herbicides produced no remarkable effect on the time of flowering.

Effect on the Ears:

(a) *The length of the ear:* The length of the ears was taken from each treatment in an attempt to determine whether the depression of the vegetative activity has any corresponding influence on the reproductive activity of the plant and is included in Table II.

TABLE II

Length of the ears (av. of 10 ears in cm.)

Stage / Treatment	Early			Pre-flowering			Post-flowering			Mean
	1,000 p.p.m.	2,500 p.p.m.	5,000 p.p.m.	1,000 p.p.m.	2,500 p.p.m.	5,000 p.p.m.	1,000 p.p.m.	2,500 p.p.m.	5,000 p.p.m.	
Amine 2, 4-D	23.8	20.8	19.6	26.4	24.4	24.4	25.0	23.4	23.5	23.4
Ester 2, 4-D	22.75	22.4	17.7	25.2	23.9	22.9	26.9	26.0	25.05	23.6
Na-2, 4-D	24.3	23.1	20.05	25.5	24.15	25.1	26.6	25.8	23.4	24.2
M.C.P.B.	25.1	23.35	20.9	25.5	25.7	25.5	25.8	24.6	26.4	25.87
Control	—	—	—	—	—	—	—	—	—	26.7
Mean	23.99	22.4	19.56	25.65	24.5	24.5	26.07	24.9	24.59	—

From the table it will be seen that as in the case of growth, the length of the ears was affected to a certain degree as a result of treatment with hormone herbicides. Although the responses due to different chemicals do not show significant differences, there is a clear relationship between the age of the plants at the time of treatment and the concentration of the treatment. It was noticed that the effect of the treatments was to reduce the length of the ears to a certain extent when treated at the early stage of growth which was proportional to the concentration of the chemical used. Thus the 5,000 p.p.m. treatment has the lowest average length of the ear i.e., 19.56 cm. as against 26.7 cm. of the 'control'.

The effects of the reduction of the size of the earswill be discussed later.

(b) *Induced morphological abnormalities of the ear:* Besides the reduction in the length of the ears, a large variety of malformations of the ear were recorded in the various treated plots in course of the observations. These included—

(1) Failure of the inflorescence to emerge from the sheath. Figs. 1, 2 and 3 represent the various stages of the arrest of inflorescence. Such suppression of the ears following the herbicide treatment has been recorded by Unrau and Larter (1952) in wheat and Scragg (1952) in barley, oats and wheat. Scragg has termed

some of these as 'Bowed Ears', (2) Epinasty of the inflorescence axis : Epinasty of the inflorescence axis results in the formation of 'Screwed' and sometimes 'hooked' ears. Such ears have also been recorded in the present observation (Fig. 4). It will be noted that in such cases, the development of the ear is more or less unilateral. (3) 'Feathery Ears' : In two rare cases, the inflorescence was found to be erect and open presenting a feathery appearance, similar to certain other members of Graminae like *Saccharum* sp., *Imperata* sp., etc. Fig. 5 represents a normal ear of paddy while Fig. 6 shows the spread out 'Feathery' ear.

Effects on the ripening of the crop :

Like the flowering, the time of ripening of paddy was recorded for each subplot. It has been found that on the average, the ripening of the crop remained more or less unaffected in spite of the treatments.

Effect on the Seed sterility :

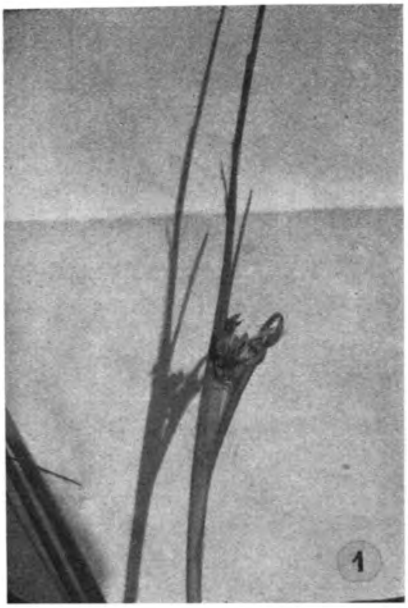
An interesting observation, in course of the present investigation was the effect of the herbicides on the seed setting. It was found that in certain treatments, a large number of seeds from each ear remained empty. Therefore, ten plants selected at random (referred to earlier) from each subplot were harvested separately. The data regarding the total number of sterile seeds in each case were collected. On the basis of this, the percentage of seed sterility has been determined and is included in Table III.

TABLE III

Percentage of seed sterility

Treatment \ Stage	Early			Pre-flowering			Post-flowering			Mean
	1,000 p.p.m.	2,500 p.p.m.	5,000 p.p.m.	1,000 p.p.m.	2,500 p.p.m.	5,000 p.p.m.	1,000 p.p.m.	2,500 p.p.m.	5,000 p.p.m.	
Amine 2, 4-D	11.32	13.49	16.20	49.70	44.30	92.56	52.68	42.26	46.15	40.96
Ester 2, 4-D	15.64	25.15	19.30	48.33	26.02	75.29	41.40	43.10	45.52	37.64
Na-2, 4-D	9.89	10.37	8.28	78.35	87.22	88.23	14.82	34.79	53.18	42.19
M.C.P.B.	19.8	14.18	20.99	19.01	61.75	72.58	19.96	43.25	50.94	35.83
Control	—	—	—	—	—	—	—	—	—	14.1
Mean	14.16	15.79	16.19	48.85	54.82	82.16	32.21	40.83	48.95	—

From the table, it will be seen that there is a marked difference in the sterility of seeds, not only at the various stages of growth but also due to different chemicals used in this experiment. In other words, the highest percentage of sterility is recorded in the application made at the pre-flowering stage (ref. Graph II), followed by the post-flowering stage. The minimum effect is produced when the application is made at the early stage.



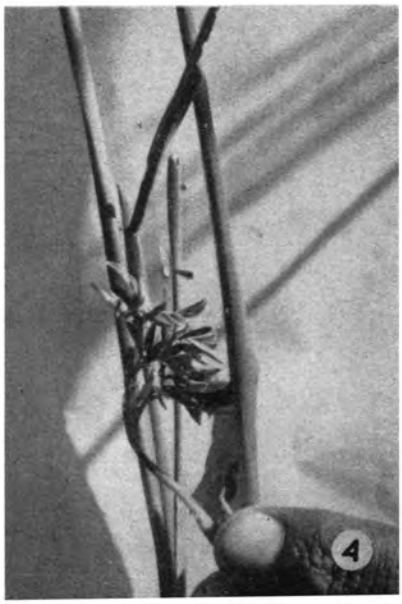


Fig. 1.—*Photograph showing* an arrested ear of paddy in a plant treated with 2,500 p.p.m. of amine 2, 4-D at the pre-flowering stage.

Fig. 2.—*Photograph showing* a partly exposed ear in 5,000 p.p.m. of amine 2, 4-D.

Fig. 3.—*Photograph showing* a short ear showing the effect of the stiffness of the 'sheath' on its development

Fig. 4.—*Photograph showing* a 'bowed' ear showing the epinasty of the inflorescence axis and few seeds.

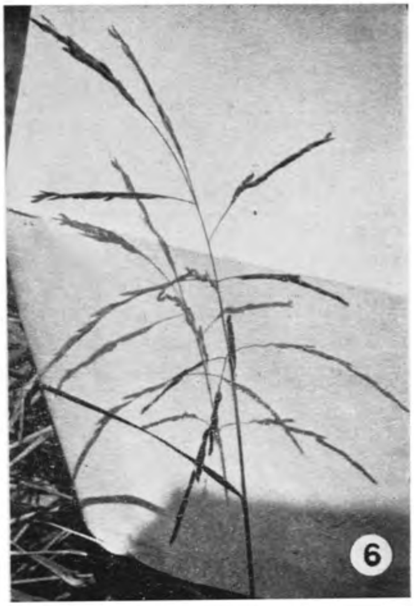
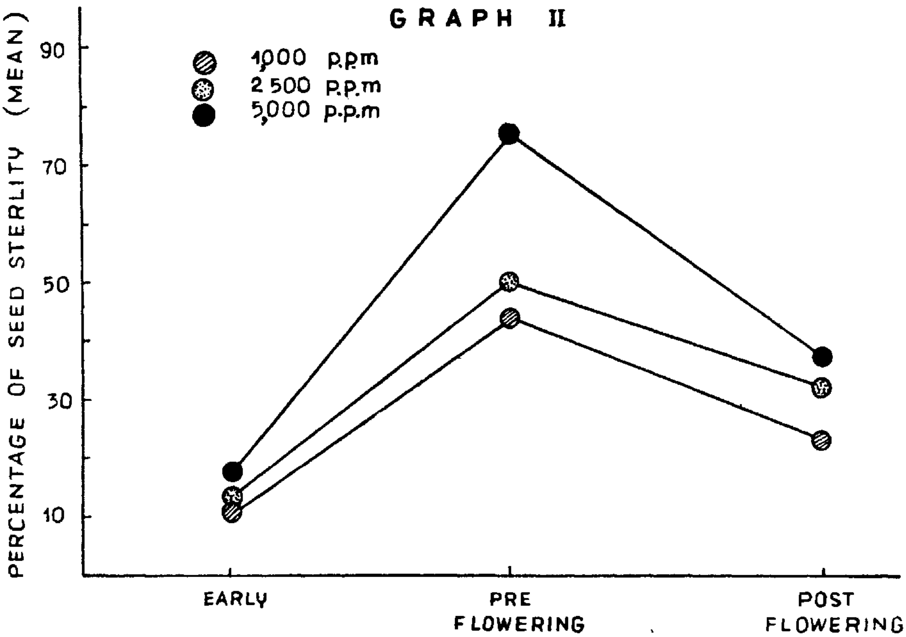
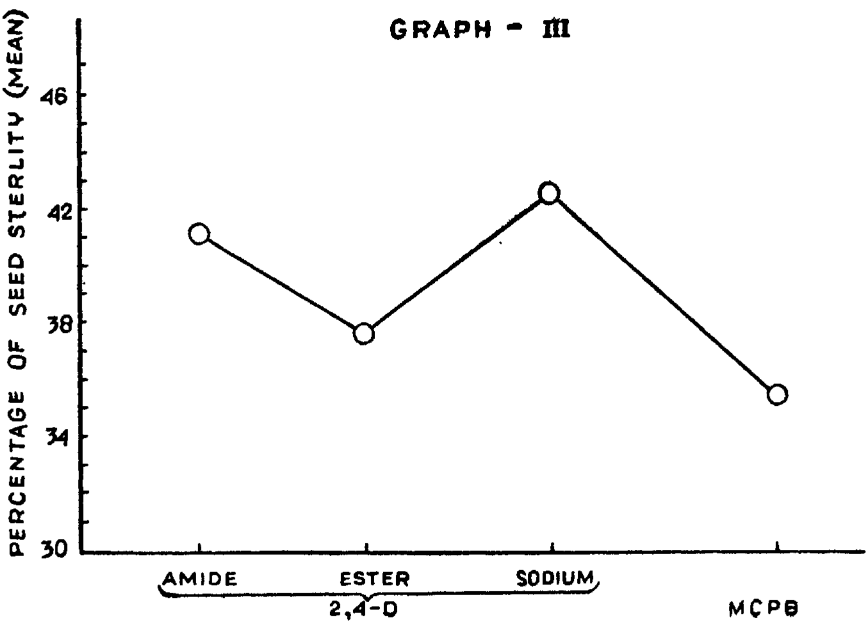


Fig. 5.—*Photograph showing* a normal ear of paddy (Control).
Fig. 6.—*Photograph showing* a "feathery" inflorescence from a plant treated with 2,500 p.p.m. of ester of 2, 4-D.



When considering the differences between the effects of the different chemicals, it has been found that the effect of 2, 4-D group of chemicals is more than the M.C.P.B. (Graph III) and that amongst the 2, 4-D derivatives the highest sterility is caused by the sodium salt and lowest by the ester formulation.



Besides, the different concentrations of the herbicides also affect the percentage of seed sterility. The following two-way table denotes the relationship between the concentration of the treatment and the age of the plant irrespective of the chemical used.

TABLE IV

Percentage of seed sterility (conc : × stage)

Stage \ Conc :	1,000 p.p.m.	2,500 p.p.m.	5.000 p.p.m.	Mean
Early	14.16	15.79	16.19	15.71
Pre-flowering	48.85	54.82	82.16	61.94
Post-flowering	32.21	40.83	48.95	40.66
Mean	31.74	37.14	49.1	—

The above data suggest that on the average there is a direct relationship between the increase in the concentration of the treatment and the percentage of sterility induced. This can also be confirmed by Graph II. However, the effect is more pronounced in case of the treatments made at the pre-flowering stage— being 48.85 per cent, 54.82 per cent and 82.16 per cent for 1,000, 2,500 and 5,000 p.p.m. respectively. When compared to the 'control' all the chemicals seem to induce a high degree of seed sterility. The causes and the consequences of such sterility will be discussed later.

Effect on the yield of Paddy :

Last but economically by far the most important effect of the treatment with hormone chemicals is on the yield of paddy. As stated earlier, the yield of paddy in the various treatments was reckoned in terms of the yield per sub-plot.

When the data were statistically analysed, it has been found that 'control' gives significantly higher yield than all other treatments but there is practically no significant variation in the yields among the four different chemicals. The stage of growth at which the treatment is made has an effect on the yield of paddy as is observed from the marginal means of the Tables Nos. V and VII. Chemicals applied at early and post-flowering stages of the growth of the plant give higher yield than those treated at the pre-flowering stage. However, the differences between the yields of early- and post-flowering stages are not significant.

Next, the strength or the concentration of the chemicals seems to have an important part to play. From Table VI, it is observed that the yield decreases with the increasing concentration of the chemical. Thus at 1,000 p.p.m. almost all the chemicals give the highest yield as compared to the two other concentrations (2,500 and 5,000 p.p.m.).

All the possible interactions between the three factors i.e. chemicals, time of application and strength, were studied and have not been found to be significant,

TABLE V

Mean yield in lb./plot
(Chemicals × Time of application)

Chemical \ Time	Early	Pre-flowering	Post-flowering	Mean
Control	—	—	—	5.50
Amine 2, 4-D	2.25	1.29	2.43	1.99
Ester 2, 4-D	2.19	0.94	2.92	2.02
Na-2, 4-D	4.04	1.65	2.25	2.65
M.C.P.B.	2.33	1.67	1.83	1.94
Mean	2.70	1.38	2.36	—

S. E. of chemical .. .. .. = 0.31
S. E. of time .. .. .. = 0.27
S. E. body of the table .. .. = 0.54

TABLE VI

Mean yield in lb./plot
(Chemical × strength)

Chemical \ Strength	1,000 p.p.m.	2,500 p.p.m.	5,000 p.p.m.	Mean
Control	—	—	—	5.50
Amine 2, 4-D	2.54	2.60	0.83	1.99
Ester 2, 4-D	2.58	1.98	1.49	2.02
Na-2, 4-D	4.00	2.88	1.06	2.65
M.C.P.B.	2.06	3.00	0.77	1.94
Mean	2.80	2.01	1.04	—

TABLE VII

Mean yield in lb./plot
(Time × strength)

Strength \ Time	Early	Pre-flowering	Post-flowering	Mean
1,000 p.p.m.	3.67	1.84	2.88	2.8
2.500 p.p.m.	3.66	1.74	2.45	2.61
5,000 p.p.m.	0.79	0.58	1.75	1.04
Mean	2.70	1.38	2.36	—

S. E. of time or strength .. .. = 0.27
S. E. of body of the table .. .. = 0.47

Discussion

The relation between age and susceptibility of paddy :

(a) *Growth :* Hormone herbicides generally produce a growth retarding effect on the plant unless used in very low concentrations. Sufficient work on this aspect as well as on the relative susceptibility of weeds has been done for the ultimate purpose of the control and eradication of such plants.

The growth inhibition recorded during the course of the present investigation has been incorporated in Table I and explained through Graph I. It has been observed that as regards growth, the inhibition of growth is one of the most outstanding features of the herbicide toxicity—a property which in its final form has given rise to the concept of chemical control of weeds.

An interesting observation during the course of present experiments is the presence of a definite relationship between the age or the stage of growth of the crop and the extent of the herbicide injury caused. As recorded earlier, irrespective of the herbicide used, the growth of paddy is markedly affected only in case of the treatments made at the early stage of growth. The maximum height attained in the other two sets of treatment viz., the pre-flowering and post-flowering stages does not vary appreciably from the 'control'. This suggests that at the early stage of growth, when the plant is in a very active state of growth, the application of hormone herbicides brings about certain irreversible physiological disbalance. This expresses itself in form of an inhibition or retardation of growth as compared with the 'control'. The disbalance itself may be caused either as a result of the destruction of the native auxins responsible for growth or due to an unhealthy competition for the active sites (on the substrates) as suggested by Foster *et al.* (1952).

In the other two stages, differentiation and reproduction rather than growth are the principal sites of enzymatic activity and hence the effect of the herbicides is not very pronounced in terms of the maximum height attained by the plants. In other words, it may be said that in the latter two sets of treatments, the plants having almost attained the maximum height, the effect of herbicide is not expressed to the same extent. The stunting of growth of the plant in turn affects the size of the ears. As will be seen from Table II, the ears are largest in the control and shortest in the plants sprayed at the early stage of growth, However, the differences in the length of the ears in the latter two treatments are not marked as compared with the 'control'.

(b) *Flowering and maturity :* The data regarding the time of flowering and maturity of crop at any stage of treatment do not vary much from the 'control'. This suggests that the treatment with hormone herbicides does not affect the photoperiodic response of paddy. The present observations are therefore not in conformity with those of Chakravarti and Pillai (1955) in *Brassica compestris* that the application of 2, 4-D and T.I.B.A. produce an earliness of flowering.

Similarly, Scragg (1952) has noted that the ripening of wheat, oats and barley is affected as a result of the treatment with selective herbicides. However, this observation also could not be confirmed by the present experiment, as the time taken for seed setting and ripening remained unaffected following the herbicide treatment.

(c) *Seed sterility :* Hormones are known to affect the fruit formation and seed-setting in plants. Thus De Tar *et al.* (1950) in pears and Osborne and Wain (1950) in apple, have reported increased fruit formation as a result of the application of 2, 4-5 trichlorophenoxypropionic acid. Increased fruit yield has also been reported in certain crops like tomato through the use of synthetic auxins. However, in most cases the increased fruit yield is not accompanied by a corresponding increase in the yield of seeds, which is explained on the basis of parthenocarpic development of the fruits. It has been suggested that the external supply of auxin affects the fruit formation in two ways. Firstly, it meets the auxin deficiency in cases where the supply of native auxin acts as the limiting factor for the fruit formation. Secondly, the external supply of auxin sometimes provides the necessary stimulus for the growth and development of fruits, even though the usual pollination and fertilisation might not have taken place (parthenocarpy).

Despite the record of certain authors that even 2, 4-D group of chemicals not only increase the fruit yield but also enhance the seed-setting, the observations during the present investigations have been to the contrary. It has been noted that when application was made at the early stage of plant growth, there was no marked increase in the percentage of seed sterility over the control. The other two stages, i.e. pre-flowering and post-flowering, responded to the spray in form of increased seed-sterility, being maximum in the former. In the highest concentration, viz., 5,000 p.p.m., seed sterility at this stage has been recorded to be as high as 80 per cent.

The observations suggest that like the growth, the effect of the herbicides on the seed-setting is linked with the age of the plants. The lower effect at the early stage in this case may be explained on the basis of the absence of the inflorescence primodia at that stage and the sufficient period of recovery allowed between the treatment and the differentiation of the inflorescence.

The greatest damage as stated earlier, was caused when the application was made on about 13 week-old paddy—i.e. the pre-flowering stage. This can be explained on the basis of—

(a) The damage caused to the differentiating inflorescence resulting in the formation of fewer flowers and developmental abnormalities in flowers already formed.

(b) The sterility may also be caused due to the upsetting of the meiosis and pre- and post-meiotic mitoses both in the mega- as well as micro-sporogenesis.

Of the two possible effects noted earlier, it may be pointed out that although there is a marked deterioration in the number of fertile seeds, the total number of flowers formed per inflorescence is not conspicuously affected. Hence, the developmental abnormalities mentioned under (a) do not seem to have much bearing on the frequency of seed-sterility.

Regarding the second cause, Srivastava (1958) has recorded a high frequency of meiotic abnormalities induced in *Crotalaria juncea* L., following the treatment of the inflorescence with hormonal herbicides. Although the meiotic abnormalities in the present material following the treatment have not been investigated, the presence of a large number of empty seeds suggests that the setting of the seeds rather than the formation of flowers has been responsible for the low yield.

In the third set of treatment, viz., at the post-flowering or milk-seed stages, there is high frequency of empty seeds as compared to the control and the plants treated at the early stage, but much lower than those treated at the pre-flowering stage. This suggests that the pollination having taken place, the further development of the seed is not affected due to the herbicidal treatment. But since all the flowers of any inflorescence are not mature at the same time, the unfertilised ovules as well as the immature flowers are affected by the treatment and contribute towards an increased percentage of seed sterility.

(d) *Yield:* The yield of paddy in lb-plot has been described earlier and the data analysed on the basis of relation between the different factors are included in Tables V, VI and VII.

As stated earlier, it has been noted that the yield in all the treatments is lower than that of the 'control'. This suggests that when applied in herbicidal concentrations (as used in the usual weed control operations in paddy) the yield of paddy is adversely affected. However, a closer scrutiny of the data reveals that there exists a definite correlation between the age of the treatment and the consequent **reduction in** the yield. The yield varies between the three stages of application.

It is highest when treated at the early stage of growth, lower at the milk-seed stage and lowest at the pre-flowering stage. The variations in the yield between the pre-flowering stage and others are significant, although the variations between the early and milk seed stage are not very pronounced. This also corresponds with the frequency of the seed sterility in all the treatments. In other words, the present observations suggest that the reduction in yield at various stages of growth is probably a function of the seed sterility caused as a result of the treatment with hormone chemicals.

Rossman and Sprague (1949) in maize, Moore (1950) in wheat and Kent *et al.* (1957) in wheat and oats have similarly recorded that the yield is reduced following the treatment with various herbicidal products of the hormone group. The present data find further support in the works of Andersen and Hermansen (1950) and Scragg (1952) in wheat, oats and barley that the lowest yield is produced when the application is made at the time of differentation of the inflorescence. The low yield also coincides with the highest frequency of morphological abnormalities of the ear, as very few have been recorded in treatments other than the pre-flowering. How far the statement of Andersen and Hermansen (1950) that the ear abnormalities do not produce any marked effect on the yield, is applicable to the present experiment could not be confirmed due to paucity of material.

Moore's suggestion (1950) that the reduction in yield was due to the tillering behaviour of the treated population could not be confirmed. His second suggestion that application at the flowering stage reduced yield due to reduction in grains per ear rather than ear/plant may now be further extended to be due to failure of seed-setting.

Again the retardation of the vegetative activity due to the application at the early stage of growth has a corresponding effect on the yield, but least as compared to the other two stages.

Considering the relationship between the age and susceptibility of paddy in general, it appears that although paddy is susceptible to the treatment with the hormone herbicides at almost all the stages of growth, the maximum deleterious effect on the yield is produced when the application is made at the pre-flowering stage. The applications made at the early and post-flowering stages do not affect the yield as much. Since the purpose of weed control, i.e., reducing the competition between the weeds and the crop plants in order to provide better conditions of growth, is hardly served if the weeds are killed after the crop has flowered, application at this stage does not seem to serve any useful purpose. It is, therefore, reasonable to assume that the most appropriate time of application of the hormone herbicides with regard to paddy is the 'early stage' of its growth i.e. about 6 week-old. Alternatively, it may be said that under all circumstances, treatment at the pre-flowering stage of the crop should be avoided.

As a corollary to the above, it may also be suggested that the highest susceptibility of plants to such treatments at the pre-flowering stage can be exploited on the weeds, in case, there exists a remarkable difference in the time of flowering of the weeds and the crop. This will lead to a low rate of seed setting in weed plants and is likely to serve as an effective measure of control of weeds for the subsequent seasons. Such treatments might be particularly useful in case of plantations like sugar-cane, banana, tea, etc.

The comparative performance of the different herbicides :

Next to the stage of treatment, the selection of a suitable herbicide for the weed control purposes in different crops is very important. The data with regard to paddy in the present observation reveal, that the vegetative growth and reproductive activity are variously affected by the different chemicals.

Thus considering the growth of paddy, it would appear that irrespective of the concentrations applied, the most deleterious effect is produced by the sodium salt of 2, 4-D and M.C.P.B. The difference between the effects of amine and ester formulations are not very striking.

Considering the effects on the reproductive activity, it has been noted that contrary to the above, there is a greater seed sterility produced by the application of amine and sodium salts of 2, 4-D. (Ref. Graph III).

But the most important aspect of the effect of these chemicals on any crop is the effect on the yield. In the present case, the highest yield has been recorded in the 'control', lower in case of Na-2, 4-D and Ester 2, 4-D and least in case of the M.C.P.B. This suggests that the toxicity of the chemicals in the final reckoning is lowest in case of Na-2, 4-D.

The present observations, therefore, are not in agreement with the observations of Templeman and Halliday (1950) in that, when used at the normal rate, the herbicides do not produce any marked effect on the yield of cereals. These observations also do not conform with the findings of Scragg (1952) that with regard to cereals 2, 4-D was a more potent herbicide than M.C.P.A. It seems that even the cereals vary in their susceptibility to different formulations. From the present observations, it is surmised that the condition of paddy is comparable to that in *Galeopsis tetrahit* and other cereals (Templeman and Wright, 1951) with regard to the susceptibility to M.C.P.B.

It may thus be concluded that as far as possible, the use of M.C.P.A. and M.C.P.B. compounds should be avoided in paddy. Likewise, the study of the comparative susceptibility of other crops to different herbicidal formulations seems necessary before large scale applications of these chemicals are made in agriculture. The necessity of the testing of other compounds on paddy itself is also indicated in order to further reduce the harmful effects of the herbicide even at the early stage of growth.

The relation between the strength of herbicides and the response :

It has been stated earlier that all the four herbicides produce adverse effects on the growth and yield of paddy. The same holds good for the three strengths (concentrations) of each chemical used in the present experiments, viz., 1,000, 2,500 and 5,000 p.p.m. It will be further noted from Graph I that the reduction in growth is directly related to the concentration. In other words, there is an increasing severity of effect with the concentrations irrespective of the chemicals used and minimum height was recorded at the 5,000 p.p.m. concentration.

Similarly, Graph II suggests that within the range of treatments, the increasing percentage of the seed sterility is the function of concentration. It is, however, interesting to point out that the increase in seed sterility does not take place in the simple ratio of the concentration. That is, the increase of sterility between 2,500 and 5,000 p.p.m. is far greater than the increase from 0 to 1,000 p.p.m. and again from 1,000 to 2,500 p.p.m.

The yield of paddy is also affected by the different concentrations, but unlike seed sterility, the reduction in the yield is proportional to the concentration of the treatment. The above observations lead to the conclusion that a great deal of caution is indicated in selecting the strength of the herbicides, so as to obtain an effective weed control without causing much damage to the crop. Perhaps better results might be obtained by spraying twice with a lower or half of the strength of the herbicide. Further investigations on this line are, therefore, indicated.

Nature and significance of the induced morphological abnormalities :

The morphological abnormalities caused by the treatment with the hormone herbicides have been described earlier. For convenience, they are being considered as follows :—

(a) *Leaves :* The usual leaf abnormalities produced by the herbicides are epinasty and the stiffness of the flag leaves. Some of the younger leaves appear curled and do not unfurl normally. However, these abnormalities were infrequent and not severe, except in very high concentrations and did not seem to affect the subsequent performance of the plants.

(b) *Ears :* A number of ear abnormalities have been recorded in the course of present observations. These included the deformities like 'bowed' and 'screwed' ears, short and compact ears and ears lying partially or wholly arrested in the sheath of the flag leaf. Such deformities of the ear have been recorded by Scragg (1952) in wheat, barley and oats. Other abnormalities like paired and whorled spikelets, big glumes and compound grains, frequently observed in herbicide treated wheat, were not found in paddy. However, in a single case (Fig. 6) a 'feathery inflorescence' or ear composed entirely of empty seeds has been recorded.

It is interesting to note that there appears to be a definite relationship between the stage of treatment and the appearance of the ear abnormalities. As a rule there were few abnormalities when the treatment was made at the early stage and none at all at the post-flowering stage. Such abnormalities, on the other hand, were abundant at the pre-flowering stage of treatment. According to Scragg (1952), these abnormalities arise due to a damage caused to the differentiating primordium of the inflorescence. In other words, the development of the ear is affected due to such a treatment. This seems to be a reasonable explanation in the present case also.

However, other abnormalities like 'bowed' and 'screwed' ears may arise only due to the excessive epinasty of the inflorescence axis, while many of other ears fail to emerge from the sheath, partly or wholly, due to the stiffness of the flag leaf, also caused due to hormone herbicide. The author is not aware of any previous record of occurrence of fertile but 'feathery' ear or inflorescence in paddy. It is therefore assumed that the occurrence of such an ear with sterile seeds may be explained on the basis of failure of seed-setting and stiffness of the axis. It is only natural that due to the emptiness of seeds, the ear gives a 'feathery' appearance.

How far the low yield at this stage of treatment is due to morphological abnormalities could not be ascertained. But taking their frequency into consideration, the ear abnormality does not seem to have much effect on the yield of paddy per plot.

(c) *Seeds :* Only two types of seeds were recorded in the present study, viz., "full" and 'empty' seeds. The full seeds were morphologically normal. The origin of the empty seeds may be two-fold :—

(*i*) due to the failure of formation of the normal gametes.

(*ii*) due to the developmental failure of the seeds following fertilization.

The former arises due to the upsetting of the nuclear divisions described earlier, while the latter may be caused due to the physiological disbalance caused by an extra supply of auxins. Which of these two causes have played the major rôle in the failure of seed-setting could not, however, be determined from the present experiment.

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