THE EFFECTS OF MALEIC HYDRAZIDE ON FLOWER INITIATION

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Introduction

Since the biological effects of maleic hydrazide (MH) were first described by SCHOENE and HOFFMANN (4), a great many papers have appeared describing the effects of that compound on growth and flowering. NAYLOR (3) sprayed tobacco, maize and cocklebur with various concentrations ranging from .025% to .2% and obtained either suppression or delay of visible flowering. WHITE and KENNARD (5) delayed flowering in raspberries without any further deleterious effects on fruit set. FILLMORE (1) effectively inhibited vegetative growth and delayed flowering in Vaccinium corymbosum for two weeks. In an attempt to clarify the nature of the demonstrated inhibition of flowering by MH, the following experiments were conducted.

Experimental procedures

Plants whose flowering is sensitive to photoperiods were grown in sub-irrigated gravel beds under day lengths which prevent flower initiation. In the case of Wintex barley, a long-day variety, the plants were treated when they had developed to the point where the second leaf was mature. About one fourth of this second leaf was removed and the stump of the cut leaf immersed in a 10-milliliter vial containing an aqueous solution of the diethanolamine salt of MH. This method of treatment, as pointed out by LEOPOLD and THIMANN (2), not only insures the direct entrance of the solution into the plants, but allows more accurate control of the amount taken up by the plants. It permits use of low concentrations for a given effect; as for example, 4 mg. of MH per liter will be shown in the present study to prevent flowering entirely in Wintex barley when applied by the vial method. This concentration will not inhibit flowering to any detectable degree when sprayed on the plant.

Unless otherwise stated, short photoperiods consisted of nine hours, and long photoperiods consisted of 18 hours. Normal daylight was extended with reflector flood lamps of 150 watts furnishing between 100 and 125 foot-candles of light at the leaf surface. Each treatment was applied to 10 plants selected at the beginning of the treatment for uniformity.

In the first series of experiments barley plants were treated with the following concentrations of MH: 0, 4, 10, 40, 100, and 200 milligrams per

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The plants were treated for five days, and during treatment they were exposed to long photoperiods in order to induce flowering. The vials were then removed, and plants were returned to short photoperiods. After two weeks the plants were dissected and the number of flower primordia, fresh weights, and number of tillers recorded. Table I shows the results of a typical series of these treatments.

Maleic hydrazide in concentrations as low as 4 mg. per liter was found to prevent the formation of flower primordia in barley. Some plants after treatment with concentrations of 50 mg. per liter died, and all plants died when treated with concentrations of 100 or 200 mg. per liter. The fresh weight of the plants decreased with increasing concentrations of MH, and tillering was increased by the low concentrations of MH (table I). These results can be reproduced readily as long as plants at the same stage of development are used. Older plants are less responsive.

**TABLE I**

**EFFECT OF MALEIC HYDRAZIDE ON NUMBER OF FLOWER PRIMORDIA, FRESH WEIGHT, AND NUMBER OF TILLERS IN WINTEX BARLEY (AVERAGES OF 10 PLANTS PER TREATMENT).**

<table>
<thead>
<tr>
<th>Concentration (mg./l.)</th>
<th>Fresh weight</th>
<th>Tillers per plant</th>
<th>Flower primordia per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.8</td>
<td>0.1</td>
<td>13.0</td>
</tr>
<tr>
<td>4</td>
<td>1.14</td>
<td>2.3</td>
<td>0.0</td>
</tr>
<tr>
<td>10</td>
<td>1.10</td>
<td>1.2</td>
<td>0.0</td>
</tr>
<tr>
<td>20</td>
<td>0.95</td>
<td>1.4</td>
<td>0.0</td>
</tr>
<tr>
<td>50</td>
<td>0.67</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>100</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>200</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*Dead as result of treatment.*

It seems that here is an instance of the complete prevention of photoperiodic flower initiation by apparently nontoxic quantities of a chemical which is not a growth regulator. Under conditions reported, the treatment with 4 mg. per liter completely prevents flower initiation without causing any visible deformities or outward symptoms of toxicity.

In order to determine whether similar effective control could be shown for plants with different flowering habits, experiments were carried out with Biloxi soybean, a short-day plant. The plants were grown for four weeks under long photoperiods and then treated under short photoperiods. The youngest mature leaf (the third trifoliate leaf) was cut and immersed as described for barley. The period of treatment was extended to seven days. The plants were dissected four weeks after commencement of treatment.

As is shown in figure 1, the number of primordia appearing on the first five nodes above the treated leaf decreased as the concentration of MH was increased. However, flower initiation was less inhibited than in the case of
barley. Treatment with 4 mg. per liter resulted here in only 10% reduction in the number of flower primordia. At concentrations of 40 and 100 mg./l. the apices died. The lateral shoots had no flower primordia when dissected. Flower initiation in the apical buds was not completely inhibited by MH unless the apical bud was killed by the treatment. It seems evident from the data of this experiment and other repetitions of the same that flower

![Graph](image_url)

**Fig. 1.** The effect of maleic hydrazide on the total number of flower primordia on the first five nodes in Biloxi soybean.

initiation in soybean cannot be completely controlled with MH, as it can in barley.

In order to secure more evidence on MH effects on flowering, tests were carried out on Marketeer chrysanthemum and peppermint. Marketeer chrysanthemum is a short-day plant, and peppermint is a long-day plant.

Chrysanthemum cuttings were rooted during the month of May, transplanted into gravel beds, and grown under long photoperiods until September. They were then subjected to a foliar spray with six concentrations of MH ranging from 0 to 5000 mg./l. just prior to the commencement of short photoperiods. The sprays were applied early in September, 1950, using 18

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Flowers November 27, 1951</th>
<th>Flowers December 15, 1951</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg./l.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2.3</td>
<td>2.4</td>
</tr>
<tr>
<td>100</td>
<td>1.6</td>
<td>2.0</td>
</tr>
<tr>
<td>500</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>1000</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2500</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>5000</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
plants per treatment, after which the plants were subjected to the natural short days until harvest. The number of visible terminal flowers were recorded at intervals as shown in table II. The formation of terminal flowers was effectively inhibited with MH at concentrations of 500 mg./l. and higher. However, lateral flowers were produced on all plants which were allowed to develop lateral shoots, regardless of treatment with MH.

Peppermint plants were grown to a height of about six inches in flats of peat soil. At this stage they were given a foliar spray with 0, 500, and 2000 mg./l. of MH and exposed to 18-hour photoperiods. The apices of the shoots sprayed with MH were totally inhibited in growth and failed to resume growth even after four months. However, the lateral buds grew and produced flowers on all treatments.

The fact that chrysanthemum and peppermint produced flowers on lateral shoots even though the plants had received applications of high concentrations of MH suggests that this inhibitor may be acting against the terminal growth and not specifically against flower initiation. In an attempt to distinguish between the effects of MH on growth and on photoperiodic induction, the following experiments were conducted: After Wintex barley plants had been grown for 23 days, MH was applied at concentrations of 0, 4, 10,
and 20 mg./l. Three such sets of treatments were used. One set of plants had the apices removed with a needle immediately before beginning treat-
ment with MH; another set had the apices removed immediately after treat-
ment with MH (five days); and a third set did not have the apices removed at all. The removal of the apices was carried out in order to force the development of lateral buds or tillers. The MH was applied for five days, but the photo-induction period was extended to 12 cycles. The number of flower primordia on the apex or on the most vigorous tiller which replaced it were counted two weeks after the treatment was started.

As can be seen in figure 2, the laterals forced at the beginning of treat-
ment (curve B) were completely prevented from forming any flower pri-
mordia by 20 mg./l. of MH and the number formed was greatly reduced by lower concentrations. In contrast, the laterals forced after treatment (curve A) were very much less affected by the MH. The number of flower pri-
mordia was only reduced 44% by the highest concentration. The plants which did not have the apices removed at all (curve C) were not completely prevented from forming primordia, but the number was reduced by 71% at the highest concentration.

The same experiment was repeated on plants which were seven days younger than the above plants. The results were similar, except that on the younger plants MH was considerably more effective.

Discussion

The present experiments have shown that MH will prevent the formation of flower primordia in Wintex barley at concentrations as low as 4 mg./l. The other plants tested show a lesser inhibition of flowering by MH. When flowering is prevented in apical buds, laterals can frequently develop flowers.

If MH acts specifically against the flowering stimulus, it should be just as effective after a given period of induction as at the beginning. Thus, lateral buds forced into development after five days of induction should show no less inhibition of flowering than those forced at the beginning of treatment. If, on the other hand, MH acts only against growth of active apical meristems, then lateral buds forced into development after the MH treatment had been stopped might be expected to show less inhibition of development than those forced at the beginning of treatment. In the last experiment all plants received the same photoperiodic induction and the same duration of MH treatments. Under these conditions the flowering stimulus should be equally affected by a flowering inhibitor, regardless of time of growth. This is not the case, so MH cannot be considered to be a true flowering inhibitor.

The apparent action of MH against the formation of flower primordia seems to be through its effective inhibition of growth, rather than by any specific action against the photoperiod mechanism itself. Where terminal growth is retarded by MH, flowering in that terminal meristem is either
inhibited, reduced or delayed. However, where growth is not retarded (e.g., in lateral branches appearing after MH treatment) flower primordia are produced, even though the plant has been treated with MH.

Summary

Maleic hydrazide was found to inhibit completely the formation of flower primordia in Wintex barley, a long-day plant, at concentrations as low as $4 \times 10^{-5}$ M. The effective inhibitory concentration of maleic hydrazide was found to vary with the age and size of the plant. Photoperiodic induction of Biloxi soybean, a short-day plant, was inhibited somewhat by maleic hydrazide but the treatment did not completely suppress floral initiation. The apex died back after treatment with approximately $40 \times 10^{-5}$ M maleic hydrazide. Foliar application of maleic hydrazide on Chrysanthemum and peppermint inhibited flowering in terminal buds, but not in laterals.

Evidence was brought forth suggesting that maleic hydrazide inhibits the production of flower primordia primarily through its inhibitory effect on growth, rather than by any specific action against the photoperiodic mechanism itself.

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LITERATURE CITED