CHEMICAL STIMULATION OF SEEDSTALK DEVELOPMENT IN CRUCIFERAE

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CHAPTER I

INTRODUCTION

Vegetables are a most important natural source of vitamins A and C, and rank high as sources of vitamins B_1 and B_2. They are also excellent sources of carbohydrates, proteins and the most important sources of minerals including calcium, phosphorus and iron (7).

Cabbage (Brassica oleracea var. capitata L.), cauliflower (Brassica oleracea var. botrytis L.), and broccoli (Brassica oleracea var. italica Plenk) belong to the Cruciferae--"mustard" family (51). They are important food crops which have a high vitamin, mineral, carbohydrate, and protein content. They are hardy and thrive best in cool weather, being grown in many regions of the world during the winter.

Most of the cultivated cole crops are biennials, however, if they are grown at a temperature of between 40° and 50° F., practically all of them will produce flowers and seeds the first year and, therefore, become annuals (7).

The study was to observe the use of chemicals substituted for the vernalization treatment required by these crops.

The objectives of this study were:

A. to observe the effect of gibberellic acid on the growth and flower initiation of three subspecies of B. oleracea;

B. to observe the effect of 3-indoleacetic acid (IAA), an auxin, when applied in conjunction with gibberellic acid (GA), a growth regula-

tor, on the growth and flower initiation of three subspecies of B. oleracea;

C. to observe the effect of 2-chloroethanephosphonic acid (Ethrel), a growth regulator, on the growth and flower initiation of three subspecies of B. oleracea;

D. to observe the effect of spray applications of 2-chloroethanephosphonic acid (Ethrel) and gibberellic acid (GA), when the applications were separate, on the growth and flower initiation of three subspecies of B. oleracea;

E. to observe the effect of spray applications of Alar and gibberellic acid (GA), when the applications were separate, on the growth and flower initiation of three subspecies of B. oleracea.

CHAPTER II

REVIEW OF LITERATURE

Several studies conducted to determine the effect of gibberellic acid on plant growth and flower bud initiation have been described in review articles by Boodley and Mastalerz (6), Wittwer and Bukovac (55, 56, 57), and Harrington (22). Burg and Burg (8) studied the role of auxin and ethylene on plant growth. Cooke and Randall (15) studied the effect of ethylene for the induction of flowering in pineapples. Zee Vaart and Jan (60) and Asakit (4) studied the effect of Alar on plant growth and flower formation. It is the purpose of this literature review to consider in some detail only those studies dealing with the effects of these chemicals on plant growth and flower bud initiation.

Effects of Gibberellins

Prior to 1956 no detailed reports appeared relative to the effects of gibberellin on the flowering of plants (49). Previous work showed that one of the effects of gibberellin was the acceleration of flowering in long day annuals grown under short photoperiods (29, 55, 57). In 1956 Lang (30) reported that gibberellic acid also was found to replace the cold requirement but not the long day requirement, for flowering of Hyoscaymus niger. Boodley and Mastalerz (6) successfully substituted gibberellic acid (1,000 to 5,000 ppm) for the cold treatment normally required for azaleas.

Many vegetable crops respond to gibberellin by an increased rate of stem elongation or by earlier flowering (56). Wittwer and Bukovac (55) found that several long-day annuals, including leaf and head lettuce (Lactuca dentata and L. sativa), radish (Raphanus sativus), spinach (Spinacia oleracea), mustard (Brassica juncea), endive (Cichorium endiva), and dill (Anethum graveolens), flowered and produced seed under short-day conditions when treated with gibberellic acid.

In 1957 Wittwer and colleagues (57) demonstrated that gibberellic acid induced fruit setting in tomato but growth was inferior to that produce either by the indole auxins, the phenoxy acids, or the naphthoxy acids, or normal pollination. Further test confirmed these results, Wittwer and Tolbert (58) also found that addition of chloroethyl trimethylammonium chloride to the gibberellic acid and 3-indoleacetic acid resulted in growth of tomato ovaries significantly greater than that produced either by gibberellic acid or by 3-indoleacetic acid alone or in combination.

In 1960 Harrington (22) used the seedstalk-promotion tendency of gibberellin to prevent heading, induce bolting and increase seed yield of tight head lettuce plants. Applications of 3 and 10 ppm were applied to plants at the 4 and 8 leaf stage of growth. The seed crop matured about two weeks earlier and the yield was significantly increased over that of the controls.

Effects of Auxins

Indoleacetic acid (IAA) is one of the growth promoting chemicals that regulates the growth of plants. In 1950 Bonner (5) stated that indoleacetic acid is known to occur widely in tissues of higher plants,

where it is physiologically active in the promotion of cell elongation. The study reported by Leopold and Guernsey (31) in 1953, indicated that it also is active in increasing the number of flower primodia of the plants. Another effect of indoleacetic acid is in the development of new roots, reported by Warmke (52). In 1949 Skoog (47) reported that in many species the change in the apical meristem from vegetative to reproductive growth is characterized by a broadening and thickening of the cells at the expense of elongation, indicating, the existence of specific reproductive stimuli or flowering hormones.

Many morphological effects influenced by auxins, such as callus growth, new root growth, epinasty, etc., have been observed and reported by many workers. In 1942, Skoog, Schneider, and Molan (48) reported that tissues such as shoots and roots or adjacent tissue layers in the stem, may have different auxin concentration requirement for growth. These requirement will vary for each organ in successive stages of development. High concentrations of auxins also lead to growth inhibition because of the effective blocking of one molecule by another from simultaneous contact with both enzyme and substrate. Thimann and Bonner (50) indicated that small amount of auxin brought about growth promotion by combining with special substrates, while 2, 3, 5-triiodobenzoic acid apparently acts as an auxin synergist. In 1949 Loomis (32) reported that the application of high concentrations of auxin to young tissues causes swelling, a reaction that may entail both cellular enlargement and division.

Effects of Ethylene

The effects of ethylene have been investigated intensively and re-

ported by many worker (12, 14, 18). It is now known that ethylene induces physiological changes such as fruit ripening, abscission of parts, proliferation of tissue, breaking of dormancy, inhibition of growth and variation in cellular metabolism. In 1964 Abeles and Rubinstein (1) considered that if the internal auxin level is increased by indoleacetic acid applications or sprays of gibberellic acid, the production of ethylene is likewise increased. Burg and Burg (8) also considered that IAA induces ethylene formation in a variety of stem sections. The ethylene in turn causes the swelling and inhibition of growth in sunflower sections, which has been attributed directly to a high concentration of auxin. Morgan and Gausman, (37) working with cotton and cowpea found that incubation of either pieces of tissue or intact plants in atmospheres containing ethylene reduced the degree of polar auxin transport. Further work by Burg (9) on pea tissue also showed a reduction of polar as well as lateral transport.

Since ethrel (2-chloroethanephosphonic acid), an ethylene-releasing compound (15), is available in liquid form, the uses of this material in direct field studies is possible. Numerous reports in the literature indicate that application of 2-chloroethanephosphonic acid (ethephon)[1] (3) to plants may induce various growth responses. These include changes in the initiation of female flowers of cucurbits (16, 25, 26, 33, 36, 40, 41, 43, 46) and accelerated ripening of many fruits (11, 19, 20, 23, 24, 28, 42, 44, 45). The action of ethrel as a plant growth regulator has been attributed to a decomposition product, ethylene (3, 11, 20, 34, 43,

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[1]Ethephon is the approved common name for 2-chloroethanephosphonic acid. Ethrel is the registered trade mark of Amchem Products, Inc., for plant growth regulator formulation, the principal active ingredient of which is ethephon.

53, 59). Ethrel was also reported to reduce internode length (27), and to affect flowering of pineapple and have other growth regulator properties (2).

Effects of Alar

Numerous investigations on the effects of succinic acid 2, 2-dimethyl hydrazide (Alar)[2] have been conducted since its growth retarding effects were first reported in 1962 (39).

Several investigations of the effect of Alar on the morphology and anatomy of different plant species have been reported (17, 21, 35, 54). Crittendon and Kiplinger (17) found that a foliar spray of 5,000 ppm Alar on poinsettia resulted in significantly smaller leaves. Thicker leaves with longer palisade cells and a looser arrangement of the spongy parenchyma cells were reported by Halfacre and Barden (21). After 1 year old 'Golden Delicious' and 'York Imperial' apple trees were sprayed with Alar they observed a cultivar difference.

Wilde and Edgerton (54) reported that foliar sprays of Alar decreased the number of mitotic figures in the outer 8 layers of the stem apices of apple seedlings. McConnell and Struckmeyer (35) found inhibited cell division and elongation with extensive disruption of the meristematic initials in root apices of zinnia seedlings when seeds were germinated in aqueous solutions of Alar.

Alar has not only been used to reduce internode length but also for initiation and breaking of lateral buds as well as influence on the

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[2]Alar is N-dimethylamino succinamic acid and more recently named succinic acid 2, 2-dimethyl hydrazide.

flowering of certain plant species (10, 13, 38, 60). Previous work, comparing Alar with other growth retarding chemicals, indicated that it had a greater retarding effect on leaf lettuce seedstalk initiation even when the temperatures were relatively high (70° to 80°F.) (4).

CHAPTER III

MATERIALS AND METHODS

Seedlings of three vegetables, cabbage (B. oleracea var. capitata), cauliflower (B. oleracea var. botrytis), broccoli (B. oleracea var. italica), were treated with ethrel (2-chloroethyl phosphonic acid), GA (gibberellic acid), and combinations of gibberellic acid and 3-indole-acetic acid (IAA), to determine their effect on growth and flowering.

Experiments, using chemical as a substitute for the cold treatment normally required to induce flowering of certain members of the cruciferae family, were conducted. Experimental procedures are described below.

Experiment I: The first experiment was started June 20, 1972, and terminated September 14. Seeds of cabbage and broccoli were planted in vermiculite on June 20. Seedlings were transplanted into a soil mix of one part sandy soil, one part peat, and one part perlite, placed in "Jiffy" pots June 26. Seeds of cauliflower were planted in the same way June 25 and seedlings transplanted June 30.

Four plants of each variety per treatment were randomly chosen and sprayed July 21. Cabbage and broccoli plants had 4-6 true leaves and cauliflower plants had 3-4 true leaves. The treatments consisted of: (1) check; (2) GA at 10, 100, 1,000, 2,000, and 3,000 ppm; (3) combinations of GA at 10, 100, 1,000, 2,000, and 3,000 ppm with equal volumes of IAA 100 ppm; (4) ethrel at 5, 10, 25, 50, and 100 ppm. The spray

was applied by means of a hand atomizer until the leaves and stems were thoroughly wetted. "Tween-20", at the rate of 3 drops per liter of spray solution, was used as a surfactant. Distilled water with the same volume of "Tween-20" was sprayed on the control plants. Treated plants were transplanted into a pad-and-fan cooled greenhouse (House 6). All plants of one treatment were planted in a row spaced 1' x 2'. Observations were made daily and the data collected as follows:

1. Plant height
2. Number of leaves
3. Diameter of heads and/or curds
4. Date of first bolting

Experiment II: The second experiment was started June 20, 1972, and terminated January 29, 1973. The procedures and methods for cabbage and broccoli were the same as in Experiment I. Seeds of cauliflower were planted June 25, and handled as in Experiment I. The size and position of plants, number of replicates per treatment and date and method of spraying were the same as in Experiment I. The treatments consisted of: (1) check; and (2) ethrel at 5, 10, 25, 50, and 100 ppm. The treated plants were planted in a pad-and-fan cooled greenhouse (House 6). The second application of the same concentrations was made August 25 and the plants transplanted August 30. All plants of a treatment were planted in one row spaced 1' x 2½'. Observations were made daily and the data collected as follows:

1. Plant height
2. Number of leaves
3. Diameter of heads and/or curds
4. Date of first bolting

5. Date of first flowering

6. Duration from first bolting to first flowering

7. Number of flower branches

Experiment III: The third experiment was started September 8, 1972, and terminated February 19, 1973. Seeds of cabbage, cauliflower, and broccoli were planted September 8 and seedling transplanted September 13. Three plants of each variety per treatment were randomly chosen and treatment applied October 24, when they had 4-6 true leaves. Treatments consisted of: (1) check; (2) ethrel at 100, 200, 500, and 1,000 ppm; (3) Alar at 2,500, 5,000, and 7,500 ppm. The spray was applied to all plants as described in Experiment I. The treated plants were set October 25 in a 6 x 7 inch tin can in a soil mixture consisting of one part sandy soil, one part peat, one part perlite and placed in the greenhouse (House 6). Gibberellic Acid at 1,000 ppm was applied to all plants January 15, 1973, except the control. Plants of each treatment were set in one row spaced 2' x 2'. Observations were made and data collected as follows:

1. Plant height

2. Number of leaves

3. Date of first bolting

4. Date of first flowering

5. Number of flower branches

CHAPTER IV

RESULTS

Experiment I

The Effect of Gibberellic Acid, Alone and in Combination With 3-indoleacetic Acid, and Ethrel, on Plant Growth of Cabbage

Data in Table I shows the effect of spraying cabbage plants with various concentrations of GA, alone and in combination with 100 ppm IAA on plant height and head size. Increasing concentrations of GA, alone and in combination with IAA cause an increase in plant height over the controls. Increasing concentrations of GA and GA plus IAA also increase head size, however, when the concentration was increased to 2,000 ppm there was a decrease in head size but still larger than those of the control.

The effect of spray applications of Ethrel (Table I) at various concentrations on cabbage plants. The first effect on the plants, following treatment, was stunting which lasted about two weeks. The degree of stunting was correlated with concentrations of the chemical with treated plants being shorter than those of the control. Following the two weeks, the treated plants elongated and were taller than the controls. Head size of plants treated with 50 and 100 ppm of Ethrel was larger than the nontreated plants. Treated plants matured the head more rapidly than did the control. Maturation of the head was indicated by the expansion and cracking of the head. Leaves of Ethrel treated cabbage

TABLE I

THE EFFECT OF SPRAY APPLICATIONS OF GIBBERELLIC ACID, ALONE AND IN COMBINATION WITH 3-INDOLEACETIC ACID, AND ETHREL AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT AND HEAD SIZE OF CABBAGE*

Treatment (ppm)	Plant Height** in Inches	Size of Head (Dia.)** in Inches
Check	9.1	3.6
GA 10	10.2	3.6
GA 100	12.1	3.7
GA 1,000	13.5	4.7
GA 2,000	15.0	4.6
GA 3,000	15.6	4.1
GA 10 + IAA 100	10.1	4.1
GA 100 + IAA 100	11.0	4.3
GA 1,000 + IAA 100	13.2	4.4
GA 2,000 + IAA 100	15.1	4.2
GA 3,000 + IAA 100	15.5	4.3
Ethrel 5	9.5	3.7
Ethrel 10	10.0	3.6
Ethrel 25	10.1	4.0
Ethrel 50	10.5	4.4
Ethrel 100	11.1	5.1

*Average of 4 plants.

**Data collected 9/5/72.

plants were larger than those of GA treatments both alone and in combination with IAA as well as those of the controls.

The Effect of Gibberellic Acid, Alone and in Combination With 3-indoleacetic Acid, and Ethrel, on Plant Growth, Number of Leaves, and Date of First Bolting of Broccoli

Data in Table II shows that average height of the treated plants of all concentrations of GA, alone and in combination with 100 ppm IAA was greater than those of the control plants. Increasing concentrations of GA alone and in combination with 100 ppm IAA did not cause a difference in number of leaves. All GA, alone and in combination with IAA-treated plants tended to bolt earlier than did those of the controls. Plants sprayed with gibberellic acid (1,000 to 3,000 ppm) and/or gibberellic acid 1,000 to 3,000 ppm plus 100 ppm IAA tended to bolt more quickly than did plants of any other treatment.

The effect of various concentrations of Ethrel sprayed on broccoli plants are given in Table II. Treated plants were stunted for about 2 weeks and then became elongated, and were taller than those of the control. Increasing the concentrations of the chemical treatment tended to increase plant height. Increasing concentrations of Ethrel did not cause any variation in average number of leaves per plant. Increasing concentration of the chemicals from 5 to 100 ppm caused earlier bolting. Plants treated with Ethrel at 100 ppm were delayed in bolting when compared to plants treated with 5 to 50 ppm.

The Effect of Spray Application of Gibberellic Acid, Alone and in Combination With 3-indoleacetic Acid, and Ethrel at Various Concentrations on Plant Growth and Number of Leaves of Cauliflower

TABLE II

THE EFFECT OF SPRAY APPLICATIONS OF GIBBERELLIC ACID, ALONE AND IN COMBINATION WITH 3-INDOLEACETIC ACID, AND ETHREL AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT, NUMBER OF LEAVES*, AND DATE OF FIRST BOLTING OF BROCCOLI

Treatment (ppm)	Plant Height** in Inches	Number of** Leaves	Date of First Bolting
Check	22.1	29.00	9/11/73
GA 10	24.1	28.75	9/03/72
GA 100	26.5	29.75	9/02/72
GA 1,000	26.2	31.25	8/29/72
GA 2,000	27.1	27.00	8/27/72
GA 3,000	27.2	30.50	8/27/72
GA 10 + IAA 100	24.2	26.25	9/01/72
GA 100 + IAA 100	26.1	32.50	9/06/72
GA 1,000 + IAA 100	27.5	28.75	8/31/72
GA 2,000 + IAA 100	27.2	29.50	8/31/72
GA 3,000 + IAA 100	27.3	31.25	9/01/72
Ethrel 5	23.1	25.00	8/31/72
Ethrel 10	23.5	28.25	9/01/72
Ethrel 25	24.1	30.75	9/02/72
Ethrel 50	26.5	29.50	8/31/72
Ethrel 100	27.0	32.75	9/08/72

*Average of 4 plants.

**Data collected 9/5/72.

TABLE III

THE EFFECT OF SPRAY APPLICATIONS OF GIBBERELLIC ACID, ALONE AND IN COMBINATION WITH 3-INDOLEACETIC ACID, AND ETHREL AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT AND NUMBER OF LEAVES OF CAULIFLOWER*

Treatment (ppm)	Plant Height** in Inches	Number of** Leaves
Check	11.2	48.75
GA 10	12.2	51.50
GA 100	13.3	47.00
GA 1,000	15.1	50.25
GA 2,000	16.0	48.50
GA 3,000	17.2	53.25
GA 10 + IAA 100	12.1	49.00
GA 100 + IAA 100	13.1	52.00
GA 1,000 + IAA 100	14.3	44.50
GA 2,000 + IAA 100	15.5	47.25
GA 3,000 + IAA 100	16.2	50.75
Ethrel 5	11.1	52.00
Ethrel 10	11.2	56.25
Ethrel 25	11.7	58.25
Ethrel 50	12.2	57.00
Ethrel 100	12.3	61.50

*Average of 4 plants.

**Data collected 9/5/72.

Data in Table III show the effect of spraying cauliflower plants with various concentrations of GA, alone and in combination with 100 ppm IAA on plant height and number of leaves. The average height of all treated plants was greater than those of the control. There appeared to be a relationship between plant height and concentrations of chemical. Higher concentrations of the chemical caused plants to develop an increased stemlength. Increasing the concentrations of the chemicals of the treatments did not affect leaf number.

Plants treated with Ethrel were slightly elongated within a few weeks after treatment. Stem elongation was similar to that of broccoli. Increasing the concentration of Ethrel from 5 to 50 ppm had little effect on the number of leaves, whereas when the concentration of Ethrel was increased to 100 ppm there was an increase in leaf number over those of the control (48.75 to 61.50).

Experiment II

The Effect of Spraying Cabbage With Various Concentrations of Ethrel on Plant Growth

Data in Table IV shows the effect of spraying cabbage plants with various concentrations of Ethrel on plant height and head size. Increasing the concentrations of the chemical treatment caused an increase in plant height over that of the control, on all but the 10 ppm application. Stem elongation of cabbage plants was similar to cabbage in Experiment I. Increasing the concentrations of Ethrel from 5 to 100 ppm caused an increase in head size of cabbage over those of the control.

TABLE IV

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL ON PLANT HEIGHT AND HEAD SIZE OF CABBAGE*

Treatment (ppm)	Plant Height** in Inches	Head Size (Diameter)** in Inches
Check	10.3	4.8
Ethrel 5	10.4	5.3
Ethrel 10	10.3	5.1
Ethrel 25	11.4	5.6
Ethrel 50	12.4	5.4
Ethrel 100	12.1	5.6

*Applications were made 7/21/72 and 8/25/72.

**Average of 4 plants, it was recorded 11/2/72.

The Effect of Spraying Broccoli With Ethrel at Various Concentrations on Plant Height, Number of Leaves, Size of Curd, Date of First Bolting, Date of First Flowring, Duration From Bolting to Flowering, and Number of Terminal and Laternal Flower Branches

Data in Table V shows that the average height of all treated plants of all concentrations of Ethrel was greater than those of the control plants, however, when the concentration of Ethrel was increased to 25 ppm there was an increase in plant height over that of the control and the other treatments. After each application of Ethrel, treated plants were stunted for a few weeks and then became elongated, and were taller than the control. Increasing concentrations of Ethrel from 5 to 100 ppm tended to increase the number of leaves from 5 to 10. Increasing the concentrations of Ethrel did cause an increase in size of curd over that of the control, however, when the concentrations of the chemical

TABLE V

THE EFFECT OF SPRAYING BROCCOLI WITH ETHREL AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT, NUMBER OF LEAVES, SIZE OF CURD, DATE OF FIRST BOLTING, DATE OF FIRST FLOWERING, DURATION FROM BOLTING TO FLOWERING, AND NUMBER OF FLOWER BRANCHES*

Treatment (ppm)	Plant Height in Inches (a)	No. of Leaves	Size of Curd (dia.) in Inches (b)	Date of First Bolting	Date of First Flowering	Duration From Bolting to Flowering	No. of Flower Branches (c)		
							T	L	Total
Check	21.7	51.75	5.1	10/12/72	11/17/72	36	23.50	8.75	32.25
Ehtrel 5	26.8	55.75	6.0	10/02/72	11/03/72	32	28.75	12.75	41.50
Ethrel 10	26.5	59.75	6.6	9/25/72	10/27/72	32	29.75	9.50	39.25
Ethrel 25	32.0	59.50	5.2	10/05/72	11/02/72	28	24.25	13.25	34.25
Ethrel 50	29.6	61.25	5.4	10/05/72	11/02/72	28	26.75	12.50	39.25
Ethrel 100	29.2	61.75	5.6	10/07/72	11/06/72	30	27.25	11.00	38.25

*Average of 4 plants.

(a) 11/26/72.

(b) 11/05/72.

(c) 1/29/73.

T: Terminal flower branches.

L: Lateral flower branches.

was 5 and 10 ppm, there was a marked increase in size of curds. Plants sprayed with Ethrel tended to bolt earlier than that of the control, however, when the concentration of the chemical was 10 ppm, bolting was earlier than in the other treatments. The date of first bolting of the plants treated with Ethrel 100 ppm tended to be delayed slightly in comparison with that of the other treated plants. The date of first flowering of treated plants was earlier than that of the control. Plants treated with 10 ppm flowered earliest. The time span from first bolting to first flowering of the treated plants was 4 to 8 days less than the control. Increasing the concentrations of Ethrel tended to increase the number of terminal and lateral flower branches of broccoli plants over that of untreated plants. The difference being 32.25 to 41.25 branches per plant.

The Effect of Spraying Cauliflower With Ethrel at Various Concentrations on Plant Height, Number of Leaves, Size of Curd, Date of First Flowering, and Number of Terminal and Lateral Flower Branches

Data in Table VI shows that the average height of all treated plants were greater than that of the control, excepted the plants that treated with Ethrel 5 ppm. When the concentration of Ethrel was increased to 100 ppm there was an increase in plant height over that of the control from 14.1 to 16.0 inches. Increasing the concentration of the chemical treatment tended to increase the number of leaves. Increasing the concentration of Ethrel had a little effect on size of curds. Plants treated with 5 to 50 ppm Ethrel appeared to flower earlier than those of the control and 100 ppm Ethrel. Number of flower branches of the plants treated with 10 and 100 ppm Ethrel was greater than from the other treatments, however, the size of the flower branches of all the treated plants

TABLE VI

THE EFFECT OF SPRAYING CAULIFLOWER WITH ETHREL AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT, NUMBER OF LEAVES, SIZE OF CURD, DATE OF FIRST FLOWERING, AND NUMBER OF FLOWER BRANCHES*

Treatment (ppm)	Plant Height in Inches (a)	No. of Leaves (c)	Size of Curd (dia.) in Inches (b)	Date of First Flowering	No. of Flower Branches (c)	
					Terminal	Lateral
Check	14.1	51.75	6.2	1/26/73	82.50	--
Ethrel 5	14.1	55.75	6.5	1/23/73	76.25	--
Ethrel 10	14.3	59.75	6.6	1/21/73	84.75	--
Ethrel 25	14.4	59.50	6.2	1/23/73	71.25	--
Ethrel 50	14.5	61.25	6.3	1/24/73	81.75	--
Ethrel 100	16.0	61.75	6.7	1/26/73	85.50	--

*Average of 4 plants.

(a) 11/2/72.

(b) 12/05/72.

(c) 1/29/73.

was larger than those of the control.

Experiment III

The Effect of Spray Applications of Ethrel and Alar at Various Concentrations on the Growth of Cabbage Plants

Data in Table VII shows the effect of spraying cabbage plants with various concentrations of Ethrel and Alar on plant height. The average plant height of each Ethrel treatment was slightly greater than the control. The effect on the treated plants was similar to those in Experiment I, however, when the concentration of the chemical increased from 200 to 1,000 ppm, epinasty was observed on 4-6 of the lower leaves. Leaves of the plants treated with 1,000 ppm Ethrel, were decidedly misshapen and abnormal.

Plants treated with 2,500 to 7,500 ppm Alar were stunted when compared to the controls. The plants treated with 7,500 ppm, were taller than those treated with either 2,500 or 5,000 ppm.

The Effect of Spray Applications of Ethrel and Alar at Various Concentrations on Plant Height, Number of Leaves, and First Bolting of Broccoli

Data in Table VIII shows that average plant height of the plants treated with 100 to 500 ppm of Ethrel tended to be greater than those of the control. The effect on the treated plant was similar to that on cabbage. Increasing the concentration of Ethrel tended to delay bolting of the plants. Plants treated with 100 ppm Ethrel appeared to bolt two days earlier than those of the control.

Average plant height of broccoli was shorter on plants treated with

TABLE VII

THE EFFECT OF SPRAYING CABBAGE WITH ETHREL AND ALAR AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT*

Treatment (ppm)	Plant Height** in Inches
Check	4.0
Ethrel 100	4.2
Ethrel 200	4.1
Ethrel 500	4.2
Ethrel 1,000	4.3
Alar 2,500	2.4
Alar 5,000	2.4
Alar 7,500	3.2

*Average of 3 plants.
**1/15/73.

TABLE VIII

THE EFFECT OF SPRAYING BROCCOLI WITH ETHREL AND ALAR AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT, DATE OF FIRST BOLTING*

Treatment (ppm)	Plant Height in Inches***	Date of First Bolting
Check	13.2	12/22/72
Ethrel 100	15.6	12/20/72
Ethrel 200	14.1	**
Ethrel 500	13.7	12/24/72
Ethrel 1,000	10.3	**
Alar 2,500	7.5	12/20/72
Alar 5,000	5.1	12/30/72
Alar 7,500	5.6	12/29/72

*Average of 3 plants.

**The treated plants did not bolt by 1/15/73.

***1/15/73.

Alar than were those of the control. The date of first bolting of plants treated with 5,000 to 7,500 ppm Alar was delayed slightly over both the control and the 2,500 ppm treated plants.

The Effect of Spray Applications of Ethrel and Alar at Various Concentrations on Plant Height and Bolting of Cauliflower

Data in Table IX shows that the average plant height of the plants treated with 100 to 500 ppm Ethrel tended to be greater than those of the control. The effect of the treatments was similar to those in Experiments I and II, however, when the concentration of the chemical was increased to 1,000 ppm it caused injury to the terminal and lateral buds of the plants. Bolting of the treated plants was delayed when compared to the control.

Plants treated with 2,500 to 7,500 ppm Alar were more stunted. The average height of the plants treated with 2,500 and 7,500 ppm Alar tended to be greater than the plants treated with 5,000 ppm Alar. Cauliflower plants treated with 2,500 ppm Alar tended to bolt earlier than those of the control, however, when the concentration of the chemical was increased from 5,000 to 7,500 ppm there was a delay in bolting.

The Effect of Various Concentrations of Ethrel, Alar, and GA, on Plant Height of Cabbage When Applied Separately

Data in Table X shows that the average height of all treated plants was greater than those of the control. Stems of the treated plants were elongated. The plants did not form solid heads, but tended to be loose when compared to control plants. Neither bolting nor flowering of the plants were observed by the end of the experiment.

TABLE IX

THE EFFECT OF SPRAY APPLICATIONS OF ETHREL AND ALAR AT VARIOUS CONCENTRATIONS ON PLANT HEIGHT AND DATE OF FIRST BOLTING OF CAULIFLOWER*

Treatment (ppm)	Plant Height in Inches (a)	Date of First Bolting
Check	3.7	12/18/72
Ethrel 100	4.3	12/19/72
Ethrel 200	4.0	12/28/72
Ethrel 500	4.1	**
Ethrel 1,000	***	***
Alar 2,500	3.4	12/10/72
Alar 5,000	2.7	12/26/72
Alar 7,500	3.4	12/19/72

*Average of 3 plants.

**Bolting was delayed.

***Plants were damaged and dead.

(a) 1/15/73.

TABLE X

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL**, ALAR**, AND GA***, ON PLANT HEIGHT OF CABBAGE WHEN APPLIED SEPARATELY*

Treatment (ppm)	Plant Height in Inches (a)
Check	5.6
Ethrel 100; GA 1,000	8.5
Ethrel 200; GA 1,000	7.6
Ethrel 500; GA 1,000	8.3
Ethrel 1,000; GA 1,000	7.5
Alar 2,500; GA 1,000	5.7
Alar 5,000; GA 1,000	6.3
Alar 7,500; GA 1,000	6.7

*Average of 3 plants.
**10/24/72.
***1/15/73.
(a)2/19/73.

The Effect of Various Concentrations of Ethrel, Alar, and GA on Plant Height, Number of Leaves, First Flowering, and Number of Flower Branches of Broccoli When Applied Separately

Data in Table XI shows that the average height of the plants treated with Ethrel and gibberellic acid was in most instances slightly greater than the control, whereas, plants treated with 200 ppm Ethrel and 1,000 ppm gibberellic acid were smaller than the control. This might be due to the delay in flowering. Numbers of leaves on the treated plants were greater than those of the control. Earlier flowering was observed when the plants were treated with 100 ppm Ethrel and 1,000 ppm GA. Other treatments delayed flowering when compared to untreated plants. Lateral flower branch development of treated plants was greater than with untreated plants. This was reflected in a greater total of flower branches.

Average plant height of all treatments of Alar and GA was less than that of the control. Height of the treated plants tended to increase with increasing concentrations of the chemical. Number of leaves on all treated plants was greater than on untreated plants (26 to 31.33). Flowering in all treatments was delayed in comparison with that of the control. The number of both terminal and lateral flower branches was greater than for the control.

The Effect of Various Concentrations of Ethrel, Alar, and GA, on Number of Leaves and Number of Flower Branches of Cauliflower When Applied Separately

Data in Table XII shows that plants treated with 200 and 500 ppm

TABLE XI

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL**, ALAR**, AND GA***, ON PLANT HEIGHT, NUMBER OF LEAVES, DATE OF FIRST FLOWERING, AND NUMBER OF FLOWER BRANCHES OF BROCCOLI, WHEN APPLIED SEPARATELY*

Treatment (ppm)	Plant Height in Inches (a)	No. of Leaves (a)	Date of First Flowering	(a) No. of Flower Branches		
				T	L	Total
Check	34.0	26.00	1/25/73	12.33	8.67	21.00
Ethrel 100; GA 1,000	36.3	28.33	1/21/73	15.67	13.00	28.00
Ethrel 200; GA 1,000	28.3	29.67	****	16.67	14.00	30.67
Ethrel 500; GA 1,000	36.7	30.67	1/28/73	13.33	16.67	30.00
Ethrel 1,000; GA 1,000	34.7	38.00	****	13.00	13.67	26.67
Alar 2,500; GA 1,000	23.7	31.00	1/27/73	16.00	18.67	34.67
Alar 5,000; GA 1,000	26.8	31.00	2/06/73	14.67	20.67	35.34
Alar 7,500; GA 1,000	30.1	31.33	1/31/73	12.67	22.00	34.67

*Average of 3 plants.

**10/24/72.

***1/15/73.

****Delay flowering.

(a) 2/19/73.

T: Terminal flower branches.

L: Lateral flower branches.

TABLE XII

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL**, ALAR**, AND GA***, ON PLANT HEIGHT, NUMBER OF LEAVES, AND NUMBER OF FLOWER BRANCHES OF CAULIFLOWER, WHEN APPLIED SEPARATELY*

Treatment (ppm)	Plant Height in Inches (a)	No. of Leaves (a)	No. of Flower Branches (a)	
			Terminal	Lateral
Check	6.6	31.67	50.33	---
Ethrel 100; GA 1,000	12.7	34.33	55.00	---
Ethrel 200; GA 1,000	****	38.00	****	---
Ethrel 500; GA 1,000	****	40.67	****	---
Ethrel 1,000; GA 1,000	*****	*****	*****	---
Alar 2,500; GA 1,000	15.6	32.67	66.67	---
Alar 5,000; GA 1,000	7.0	38.00	59.00	---
Alar 7,500; GA 1,000	5.7	35.33	65.33	---

*Average of 3 plants.

**10/24/72.

***1/15/73.

****The curd were attacked by slime mold (fungi).

*****Plants were damaged and dead.

(a)2/19/73.

Ethrel and 1,000 ppm GA were attacked by slime mold. Average plant height of those treated with 100 ppm Ethrel and 1,000 ppm GA was greater than were the controls. Increasing the concentration of treatments tended to increase the number of leaves on treated plants. The number of flower branches of the plants treated with 100 ppm Ethrel and 1,000 ppm GA was greater than the control. No lateral flower branches were observed.

Average height of plants treated with 2,500 ppm Alar and 1,000 ppm GA was much greater than the control while the other treatments were similar to the untreated plants. Number of leaves per plant of all chemical treatments was greater than the untreated plants. Number of terminal flower branches of all chemical treatments was greater than that of the control.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Under greenhouse conditions certain of gibberellic acid, alone and in combination with 100 ppm IAA, treatments caused a definite acceleration in plant growth development. In the study reported herein, the treatments of cabbage plants with spray applications of gibberellic acid, alone or in combination with 100 ppm IAA, caused an increase in plant height as well as in head size, however, when the concentration was increased there was a decrease in head size.

The immediate effect of Ethrel treatments from 5 to 1,000 ppm was stunting. This situation proceeded for a few weeks and then the plants became slightly elongated when compared to untreated plants. Treated plants matured head more rapidly than did the control, as indicated by the expansion and cracking of the heads. Leaves of treated cabbage plants were also larger than the control. On the basis of the results it is believed that one application of these chemicals can not be substituted for the cold treatment normally required by cabbage. Further research must however be done to determine the frequency of spray applications with various concentrations of the chemicals to use and to enable cabbage to bolt and flower as an annual plant. All plants treated with Alar were stunted, and it appeared that when the concentrations were increased plant height tended to increase.

The application of 1,000 ppm GA to the plants treated with 100 to

1,000 ppm Ethrel and 2,500 to 7,500 ppm Alar appeared to increase stem elongation as compared to the untreated plants. Treated plants did not form heads as well as the control plants. However, further research must be done to determine the appropriate time of applications and the concentrations of these chemicals to initiate flower bud formation and development in cabbage.

The treatments of broccoli plants with one spray application of various concentrations of gibberellic acid, alone or in combination with 100 ppm IAA, and one or two spray applications of 5 to 100 ppm Ethrel caused acceleration in flower bud initiation over that of the control plants. On the basis of these tests it is believed that these chemicals can be successfully substituted for cold treatment normally required for this plant. A spray application of 200 to 1,000 ppm Ethrel tended to delay bolting and flowering of broccoli. One or two applications of 5 to 100 ppm Ethrel and one application of 200 to 1,000 ppm Ethrel resulted in an increase in leaf number on broccoli. Two applications of 5 to 100 ppm Ethrel caused an increase in size of inflorescence of broccoli over the control. The number of flower branches was also greater.

It should be noted that Ethrel causes an increase in leaf number, curd size, and flower branches of broccoli, however, when the concentration of the chemical was increased to 1,000 ppm, it caused a decrease in the number of flower branches over those of the other treated plants. It might be due to high concentrations of Ethrel forced the lateral shoots to develop so that the number of flower branches was decreased and delayed bolting and flowering of broccoli. Plants became slightly elongated a few weeks after treatments with 5 to 1,000 ppm Ethrel. Stem elongation of broccoli was similar to that of cabbage. Epinasty was

observed on a few of the lower leaves of plants treated with 200 to 1,000 ppm Ethrel. The translocation of this chemical within the plants was very slow.

When 1,000 ppm GA was applied to the plants treated with 100 to 1,000 ppm or 2,500 to 7,500 ppm Alar there was an increase in leaf number over those of the control. Applications of GA to the plants treated with either Ethrel and Alar caused an increase in plant height and flower branches. Further research must however be done to determine more precisely what concentrations of these chemicals to use and at what stage of plant growth the treatments might be the most effective.

Spray applications of various concentrations of gibberellic acid, alone or in combination with 100 ppm IAA, and 5 to 100 ppm Ethrel influenced plant height of cauliflower plants similar in effect to that of cabbage and broccoli. Plants treated with Ethrel caused an increase in number of leaves. Epinasty was observed on leaves of plants treated with 200 to 1,000 ppm Ethrel, however, when the treatment concentration was increased to 1,000 ppm both terminal and lateral buds were injured. Plants treated either once or twice with 5 to 50 ppm Ethrel tended to bolt and to flower earlier than did the controls, however, when the concentrations were increased from 100 to 1,000 ppm bolting of cauliflower plants was delayed. Both the stems and flower branches elongated when 1,000 ppm GA was applied to the plants treated with 200 to 500 ppm Ethrel. Application of GA was effective when applied to the mature curds of cauliflower, whereas applications caused injury to the immature curds. Leaf number and flower branches of treated plants were greater than those of the control.

Increasing the concentrations of Alar caused treated plants to be

stunted. When 1,000 ppm GA was applied to the plants treated with 2,500 to 7,500 ppm Alar both the stems and flower branches of treated plants were increased. Earlier bolting was observed when the plants were treated with 2,500 ppm Alar. Treating plants with 2,500 ppm Alar caused flower bud initiation of cauliflower.

From these results it may be concluded that one spray applications of 10 to 3,000 ppm GA, alone or in combination with 100 ppm IAA and one or two applications of 5 to 100 ppm Ethrel, appeared to promote flower bud initiation of broccoli. Two spray applications of 5 to 50 ppm Ethrel were also observed to promote flower bud initiation and development of cauliflower. The results obtained in this study raise doubt that one application of GA, alone or in combination with 100 ppm IAA and one or two applications of Ethrel, have any appreciable effect on flower bud initiation of cabbage.

CHAPTER VI

SUMMARY

The study reported herein relate to the effects of gibberellic acid, alone and in combination with 3-indoleacetic acid, Ethrel as well as Ethrel, Alar, and gibberellic acid applied separately at certain stages of growth and development of three subspecies of B. oleracea.

Cabbage, broccoli, and cauliflower plants grown in the greenhouse, and sprayed with various concentrations of gibberellic acid (10 to 3,000 ppm), alone and in combination with 100 ppm IAA caused an increase in plant height of these plants over those of the control. Increasing the concentration of the chemicals had no apparent effect on number of leaves of cauliflower and broccoli. Head size of cabbage plants treated with chemicals was greater than the control. Earlier bolting was observed on broccoli plants treated with these chemicals.

Three subspecies of B. oleracea were sprayed once or twice with 5 to 100 ppm Ethrel. The first effect of chemical treatment on plants was stunting. The degree of stunting was correlated with the concentration of the chemical. Stems of plants treated with Ethrel were slightly elongated a few weeks after application when compared to the control. Effect on the three subspecies of B. oleracea was similar when treated with 200 to 1,000 ppm Ethrel, except cauliflower. When the concentration of Ethrel was increased to 1,000 ppm, plants were killed within a few weeks of treatment.

Cabbage plants which were sprayed either once or twice with 5 to 100 ppm Ethrel tended to produce larger heads and mature earlier than the controls. When 1,000 GA was applied to the cabbage plants treated with 100 to 1,000 ppm Ethrel and 2,500 to 7,500 ppm Alar, the treated plants increased in height and the leaves were elongated but the heads were loose. None of the chemical treatments of cabbage resulted in bolting or flowering.

Broccoli plants were sprayed twice with 5 to 100 ppm Ethrel. The diameter of the curd in all treatments was larger than the control. Number of leaves and number of flower branches of plants treated with Ethrel or Alar increased over that of the control. Earlier bolting and flowering was observed on broccoli plants receiving one or two applications of 5 to 100 ppm Ethrel. On the other hand concentrations of 200 to 1,000 ppm Ethrel tended to delay bolting and flowering. Earlier bolting was also observed on the plants treated with 2,500 ppm Alar, but this treatment delayed flowering. Higher concentrations of Alar tended to delay bolting and flowering of broccoli.

Cauliflower plants sprayed with 200 to 500 ppm Ethrel, 2,500 to 7,500 ppm Alar, and once or twice with 5 to 100 ppm Ethrel resulted in an increase in leaf number over that of the control. Earlier bolting was observed when cauliflower plants were treated with 2,500 ppm Alar. Earlier flowering was also observed when two applications of 5 to 50 ppm Ethrel were made. Higher concentrations of chemicals tended to delay bolting and flowering of cauliflower.

No treatments resulted in any marked difference in size of curd or number of flower branches but the treatments of 2,500 to 7,500 ppm Alar tended to increase the number of flower branches over the control.

When 1,000 ppm GA was applied to the plants treated with 100 to 1,000 ppm Ethrel and 2,500 to 7,500 ppm Alar, the stems and flower branches elongated more than those of the control plants.

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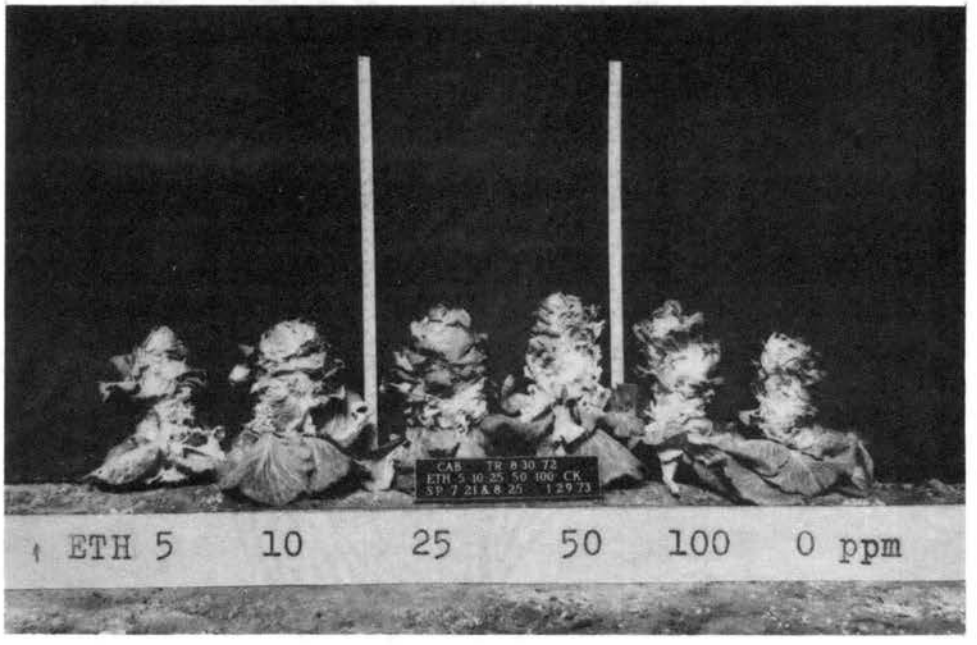
A P P E N D I X E S

APPENDIX A

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL ON PLANT HEIGHT OF CABBAGE

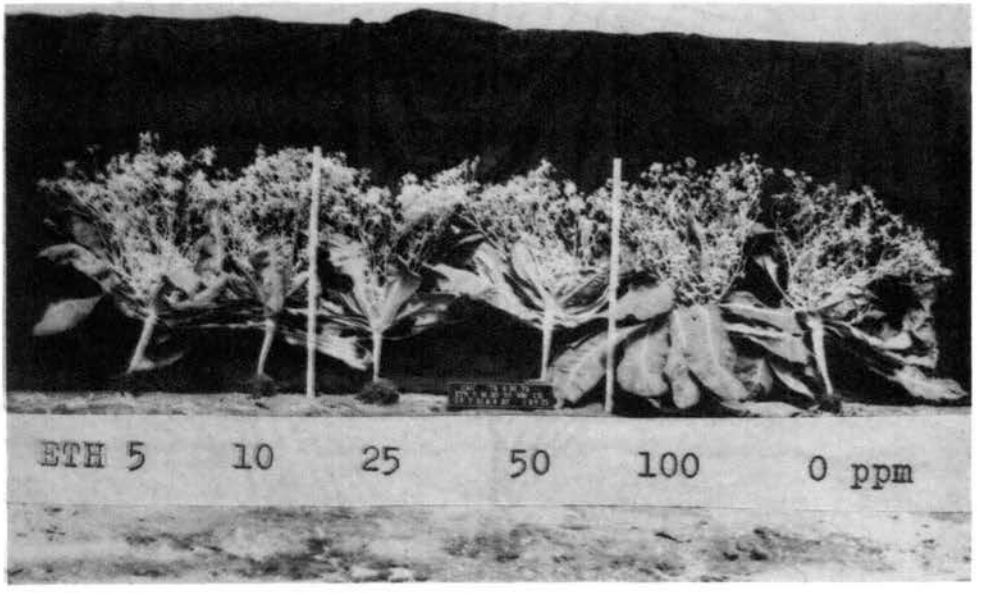


Treatments of Ethrel at 5, 10, 25, 50, 100, and 0 ppm on the plant height of cabbage*.

*Applications were made 7/21/72 and 8/25/72. Photo taken 1/29/73.

APPENDIX B

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL ON FLOWERING OF CAULIFLOWER

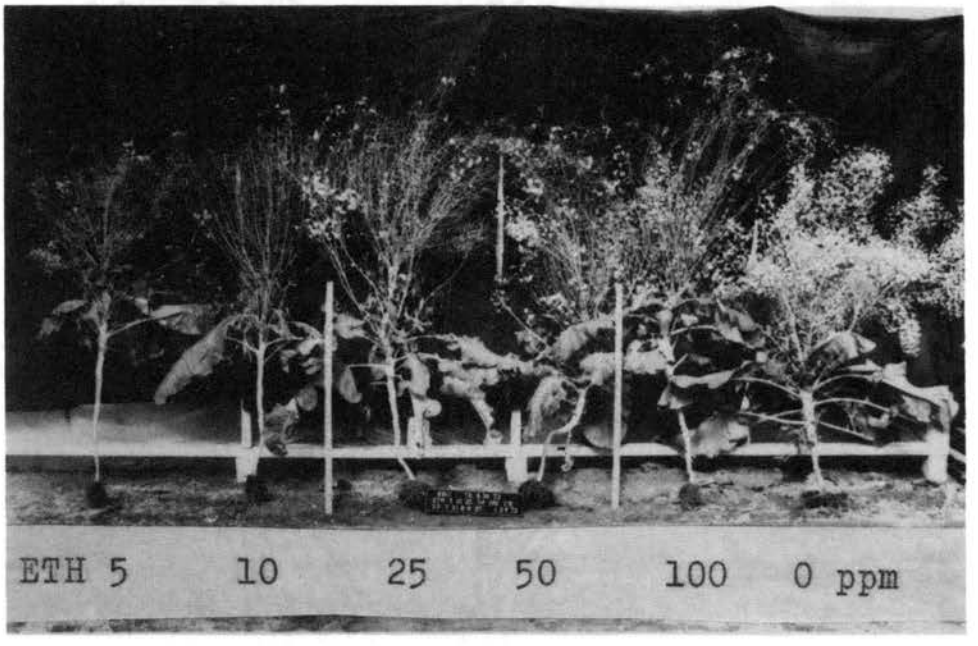


Treatments of Ethrel at 5, 10, 25, 50, 100, and 0 ppm on flowering of cauliflower*.

*Applications were made 7/21/72 and 8/25/72. Photo taken 1/29/73.

APPENDIX C

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL ON FLOWERING OF BROCCOLI

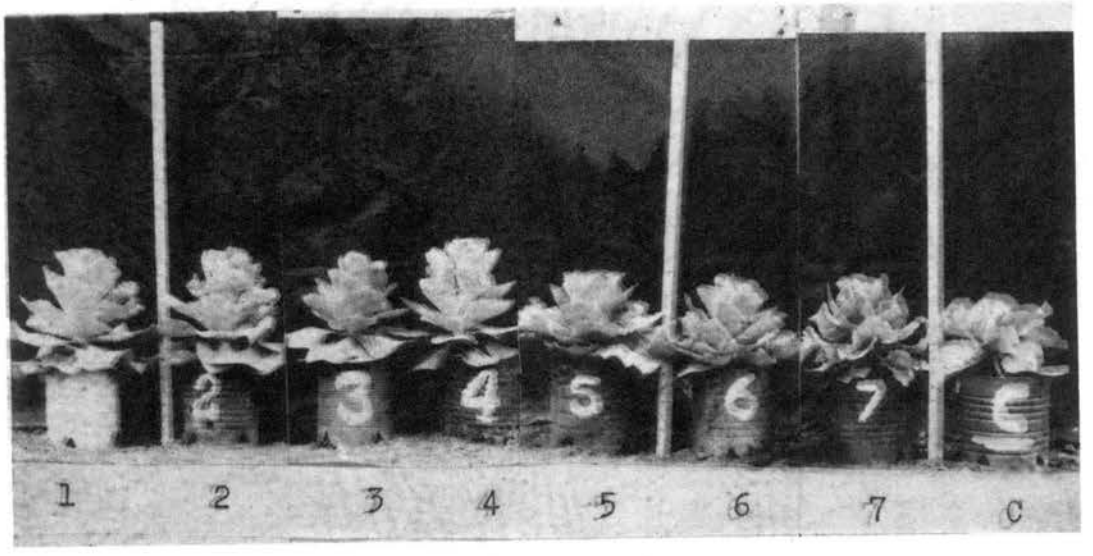


Treatment of Ethrel at 5, 10, 25, 50, 100, and 0 ppm on flowering of broccoli*.

*Applications were made 7/21/72 and 8/25/72. Photo taken 1/29/73.

APPENDIX D

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL, ALAR (10/24/72), AND GIBBERELLIC ACID (1/15/73) ON PLANT HEIGHT OF CABBAGE

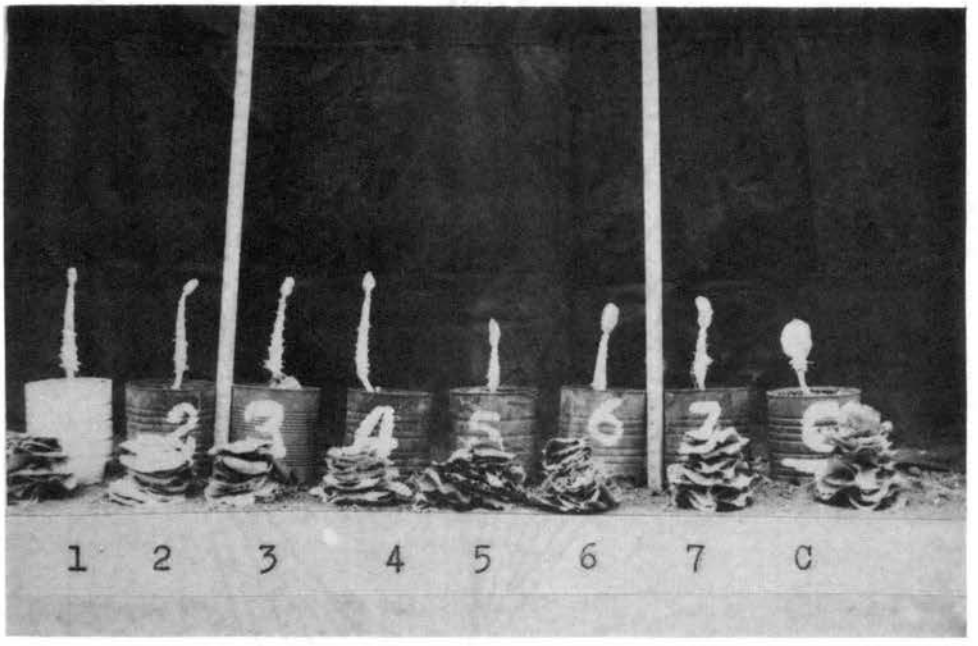


The treatments are: 1-Ethrel at 100 ppm; 2-Ethrel at 200 ppm; 3-Ethrel at 500 ppm; 4-Ethrel at 1,000 ppm; 5-Alar at 2,500 ppm; 6-Alar at 5,000 ppm; 7-Alar at 7,500 ppm; C-check (10/24/72). Each treated plant was sprayed with 1,000 ppm GA (1/15/73).

Photo taken 2/19/73.

APPENDIX E

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL, ALAR (10/24/72), AND GIBBERELLIC ACID (1/15/73) ON PLANT HEIGHT OF CABBAGE

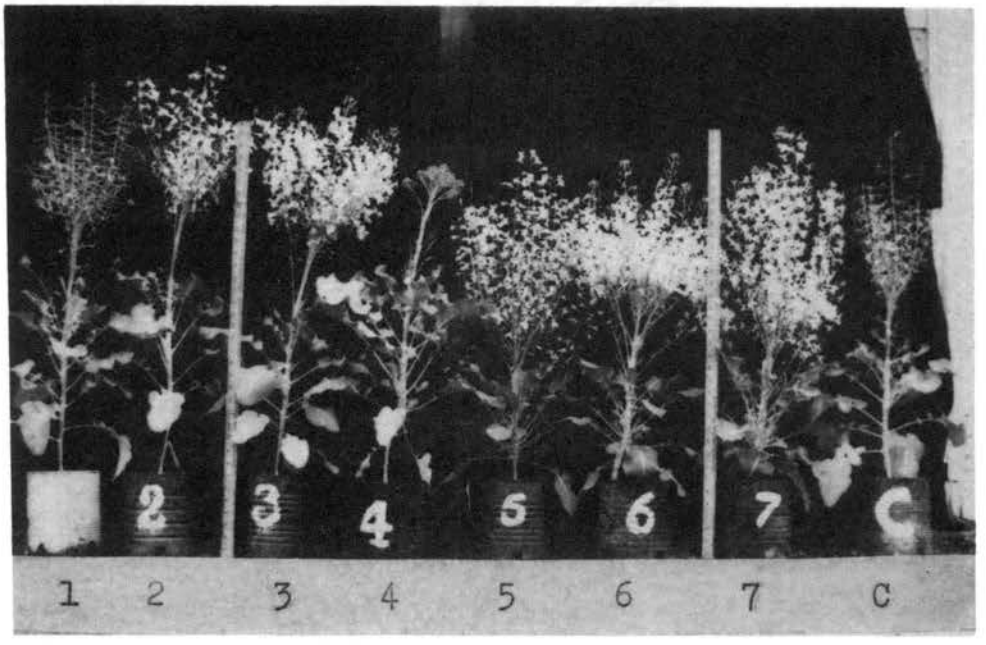


The treatments are: 1-Ethrel at 100 ppm; 2-Ethrel at 200 ppm; 3-Ethrel at 500 ppm; 4-Ethrel at 1,000 ppm; 5-Alar at 2,500 ppm; 6-Alar at 5,000 ppm; 7-Alar at 7,500 ppm; C-check (10/24/72). Each treated plant was sprayed with 1,000 ppm GA (1/15/73).

Photo taken 2/19/73.

APPENDIX F

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL, ALAR (10/24/72), AND GIBBERELLIC ACID (1/15/73) ON FLOWERING OF BROCCOLI

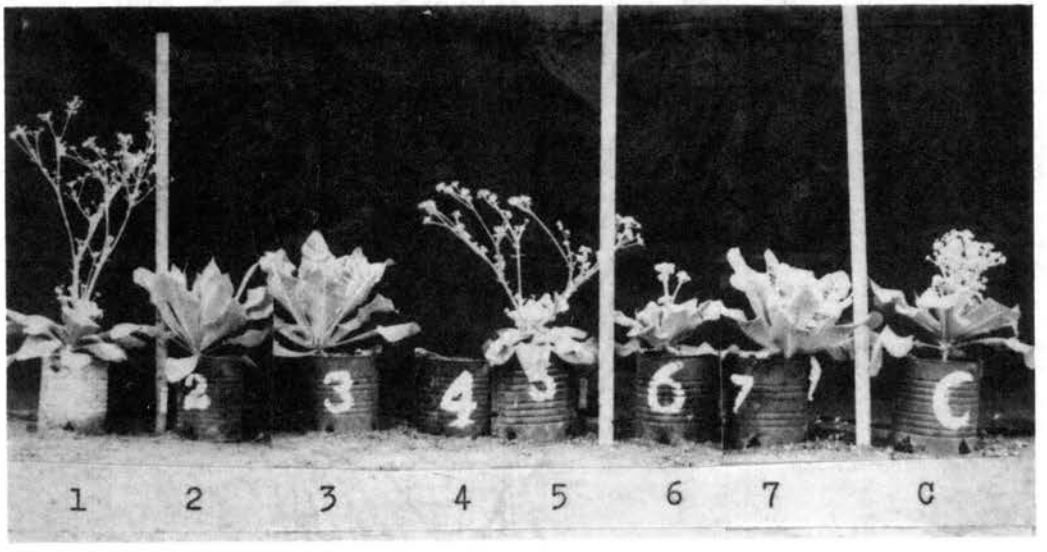


The treatments are: 1-Ethrel at 100 ppm; 2-Ethrel at 200 ppm; 3-Ethrel at 500 ppm; 4-Ethrel at 1,000 ppm; 5-Alar at 2,500 ppm; 6-Alar at 5,000 ppm; 7-Alar at 7,500 ppm; C-check (10/24/72). Each treated plant was sprayed with 1,000 ppm GA (1/15/73).

Photo taken 2/19/73.

APPENDIX G

THE EFFECT OF VARIOUS CONCENTRATIONS OF ETHREL, ALAR (10/24/72), AND GIBBERELLIC ACID (1/15/73) ON FLOWERING OF CAULIFLOWER



The treatments are: 1-Ethrel at 100 ppm; 2-Ethrel at 200 ppm; 3-Ethrel at 500 ppm; 4-Ethrel at 1,000 ppm; 5-Alar at 2,500 ppm; 6-Alar at 5,000 ppm; 7-Alar at 7,500 ppm; C-check (10/24/72). Each treated plant was sprayed with 1,000 ppm GA (1/15/73).

Photo taken 2/19/73.

VITA

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