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Directed Growth *of* Ornamental Plants *with* Chemicals

Agricultural Experiment Station
AUBURN UNIVERSITY
E. V. Smith, Director Auburn, Alabama

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TOKUJI FURUTA, *Department of Horticulture*[1]

CONTROL OF environment has been a means of regulating plant behavior and growth, both in research and commercial production for many years.

Regulation of daylength to accurately time flowering of plants has been used on poinsettias and chrysanthemums. Control of temperatures has regulated growth and flowering time of many plants, such as Easter lily, azalea, and bulbous iris. Other factors, including moisture, light intensity, and soil fertility, have been precisely regulated to achieve control of plant growth. Management of most environmental factors, however, is practiced only for crops grown in greenhouses.

The control of plant behavior with growth-regulating chemicals is a recent development. Sufficient evidence has been accumulated to clearly show their effects. These chemicals are used to modify the growth pattern under various environmental conditions.

Potentially, chemicals to direct plant growth have widespread use, not only with crops intensively cultivated in greenhouses, but also in extensive field plantings. The control or modification of the environment may be difficult to achieve, but application of chemicals is easy and practical.

There are definite limitations under present technology. However, chemical means of directing plant behavior are practical. Cost of chemicals in some cases is a limiting factor. With further developments in manufacturing and as supplies become more plentiful this objection may be overcome.

Chemical influences on plant behavior are not noted often because chemicals are screened for a particular purpose and ac-

[1] Resigned.

cepted on that basis. For example, one of the retardants was initially screened as a herbicide and rejected for that use. After several years it was recognized as a growth retardant. Another herbicide has been effective in controlling growth development of snapdragons—and procedures for its use are currently under development.

Presented here are results of experiments that show diversity of plant behavior controlled by chemicals and the influence of some factors on effectiveness of a given dosage of plant growth regulator.

METHODS OF APPLICATIONS

To study the influence of growth regulators on plants, numerous experimental procedures and methods have been developed to ensure presence of a chemical at the exact location of the desired growth effect. For whole plants, means must be used so that the chemical is absorbed and transported to the point of growth activity. In these studies, most regulators were applied to whole plants by spraying foliage and other aerial portions. In addition, soil drench was used where previous work showed it to be an effective method or where there was injury following spray applications or both. These methods were used for large scale studies.

Other methods of application for small scale studies were: (1) placing the growth regulator in a lanolin paste and applying this to a part of the plant, and (2) allowing a solution containing the growth regulator to be absorbed through an injury such as a cut leaf or detached bud.

RATES OF APPLICATION

Many rates of application were used in the experiments. There was usually increased response to heavier rates or dosages. However, the degree of response was not always proportional to the dosage, i.e., double dosage did not result in twice the response.

Growth regulators that induced similar responses were compared, as were equivalent dosages of the chemicals.

Only selected dosages are used to illustrate the desired modification of plant growth. Dosage was selected on the basis of safe response resulting in a commercially acceptable product.

LOCATION OF EXPERIMENTS

Most of the experiments were conducted in greenhouses and under precisely controlled conditions in plant growth rooms. Some were outdoors with plants grown in containers or in the ground. The type of growth response was not dependent upon location—i.e., retardation of stem elongation from use of B-nine occurred under all conditions mentioned. The degree of response depends somewhat upon the location, however, since environment has an influence on effectiveness of growth regulators studied.

GROWTH RETARDANTS FOR CONTROL OF STEM ELONGATION

A group of chemicals has been developed, the chief growth response of which is retardation or inhibition of cells in the internode. Although these chemicals are not structurally related, their observable effect on plant growth is similar. Their effectiveness on various plant species, and possible methods of application also differ.

The compounds commonly available for use on ornamental crops are:

1. **Phosfon**—Available as a liquid or dust, the compound is, (a) Phosfon D; 2,4-dichlorobenzyl-tributyl phosphonium chloride, and (b) Phosfon-S; 2,4-dichlorobutylammonium chloride. These materials cannot be used as a spray on plant foliage, but may be applied to the soil. However, they persist for a long period of time in the soil and are relatively stable under steam sterilization. When used in high concentrations they are toxic to plants. Symptoms of overdosage are lack of green color in the leaf veins and a permanent marginal browning. These chemicals are effective only on certain plants, such as chrysanthemums and Easter lilies.

2. **AMO-1618** — Chemically, 4-hydroxyl-2-isopropyl-5-methylphenyl trimethyl ammonium chloride, 1-piperidine carboxylate, the compound is effective on only a few plants. It may be applied as a foliar spray as well as a soil drench. Only in massive doses are toxic symptoms evident—marginal browning of foliage. This compound persists for many years in soil and is relatively stable when soil is steam sterilized.

3. **Cycocel**—Also known as CCC—is (2-chlorothyl) trimethylammonium chloride. It may be applied as a foliar spray or soil drench. In the soil, it persists only 3 to 4 weeks, and loses its effectiveness upon steam sterilization. Although effective on many plants, a symptom of overdose is yellowing of the younger leaf near blade base. The leaf will recover normal green coloration. Several closely-related chemicals are also active as growth retardants.

4. **B-nine** (B-995) is chemically N-dimethylamino succinamic acid. Relatively nontoxic, it is effective on a wide range of plants and may be applied as a spray or a soil drench. Its persistence in the soil is short and it is decomposed by steam sterilization.

FACTORS INFLUENCING EFFECTIVENESS OF RETARDANTS

The chief influence of the chemicals listed previously has been inhibition of internodal elongation. Effectiveness as measured by the amount of slowing of stem growth was influenced by the method of application and dosage rate, as well as the existing plant environment.

Two methods of application—soil drench and foliar spray—were compared using a number of crops. Spraying requires less labor and time since the volume of liquid applied as a soil drench must be carefully controlled. Otherwise dosages would not be consistent for each plant. Soil drench is more effective than foliar sprays because of the amount of chemical absorbed. A plant will absorb only a limited amount of spray. The environment will greatly influence absorption of foliar sprays.

Since the number of spray applications influences the amount of inhibition this fact can be used to achieve desired results. However, observed retardation is not proportional to the number of applications. Hexe azalea plants were grown under controlled conditions and sprayed twice, with 7 days between applications. A spray concentration of 0.30% active material in a water solution was used. (7.5 oz. of 5% B-nine per gallon of water.) See Appendix Tables 1 and 2. Resulting stem lengths were as follows:

No. of applications	*Stem length as per cent of check*	
	Cycocel	*B-nine*
1	58.1	43.2
2 (7 days between)	50.0	35.1

Likewise, the degree of retardation is not proportional to dosage. The following results with the Hexe azalea will illustrate.

Concentration of material in spray	*Stem length as per cent of check*	
	Cycocel	*B-nine*
0.07%	62.9	59.7
0.15%	46.8	43.5
0.30%	35.5	32.3

Growth retardants were more effective at low light intensity. For example, on Bonnaffon Deluxe chrysanthemums, the following results were obtained under controlled growth room conditions. Each retardant was applied at a rate of 20 mg. per plant as a soil drench.

Light intensity	*Stem length as per cent of check*		
	Cycocel	*B-nine*	*Phosfon D*
Low (1,000 foot candles)	90	91	28
High (3,000 foot candles)	97	93	41

However, untreated shoots were shorter (7.80 cm.) in high intensity light than in low intensity light conditions (9.13 cm.).

Temperature has a tendency to influence effectiveness of soil applications of the growth retardant B-nine but not of the others. These results on chrysanthemums are typical.

Temperature	*Stem length as per cent of check*		
	Cycocel	*B-nine*	*Phosfon D*
50°F.	94	98	34
70°F.	93	85	35

Air temperature also influenced effectiveness of foliar sprays. These results on azaleas were obtained under controlled conditions with uniform light intensities of 2,000 foot candles for 16 hours a day. A spray concentration of 0.07% active material was used. (Cycocel = 0.7 oz. per gallon of water.) (B-nine = 1.75 oz. per gallon of water.)

Temperature	*Stem length as per cent of check*	
	Cycocel	*B-nine*
50°F.	62.9	59.7
70°F.	82.4	62.2

Fertilization program did not influence effectiveness where a 20-20-20 fertilizer was compared with $(NH_4)_2SO_4$ and $NaNO_3$.

Soil mixtures influenced effectiveness of cycocel on poinsettia plants. The retardant was more effective in mixtures containing clay. These results were obtained when 0.2 g. of cycocel was applied as a soil drench to each plant.

Soil mixture	*Plant height as per cent of check*
1 perlite, 1 peat	82
1 clay, 1 peat, 1 sand	73
1 clay, 1 manure, 1 sand	75

The effect of growth retardants on internodal elongation may be reversed by application of gibberellic acid. See Appendix Table 3 for dilution. For example, with plants of Scarlet O'Hara morninglory, the following results were obtained:

Treatment	*Plant height in inches*
None	3.5
B-9 (0.15% spray)	2.5
B-9 (0.15% spray) plus gibberellic acid (100 p.p.m. spray)	5.5
CCC (0.18% spray)	3.0
CCC (0.18% spray) plus gibberellic acid (100 p.p.m. spray)	6.0
Gibberellic acid (100 p.p.m.)	8.0

RETARDANTS INDUCE INCREASED FLOWERING

Certain side effects have been noted when growth retardants are used. Increased flowering is one.

Plant	*Flowers per plant*	
	Untreated	*Treated*
Camellia japonica		
'Prof. Sargent'	1.0	1.8
'Mrs. Charles Cobb'	1.4	3.2
Azalea		
'Coral Bell'	303	384

This effect seems to be the result of internodal elongation reduction rather than a direct effect on flower formation.

TIME OF FLOWERING REGULATED WITH GIBBERELLINS

The time of azalea flowering is dependent in part on a period of cold to condition the flower bud for opening. Where rest was not broken, delayed and irregular flowering resulted. Applications of gibberellic acid induced rapid opening of flower buds without the necessity of a cold period. Spray applications at 4-day intervals were effective, using a concentration of 500 p.p.m. gibberellic acid.

Effectiveness of any treatment to bring on rapid opening is dependent on the maturity of the flower bud. Unless the bud is mature, gibberellic acid is not effective. Temperature influences rate of flower bud development, and partially determines time when flower buds are mature and responsive to gibberellin treatment. Temperatures of 60°F. and above are necessary for most rapid initiation and development of azalea flower buds to a rest condition.

Relatively high dosages of gibberellic acid were needed to bring on development of unchilled azalea flower buds. Incorporation of Kinetin, 6-furfurylamino purine, with gibberellic acid increased the action of gibberellic acid. Combination of indoleacetic acid with gibberellic acid did not produce the same results.

Chemical and concentration	*Days to full bloom*
Check—no chemical treatment	81.0
Gibberellic acid—100 p.p.m.	63.5
—500 p.p.m.	31.7
Gibberellic acid (100 p.p.m.) plus Kinetin (100 p.p.m.)	31.7
Indoleacetic acid—100 p.p.m.	62.3
Gibberellic acid (100 p.p.m.) plus indoleacetic acid (100 p.p.m.)	58.8

Flowering of *Camellia japonica* plants may be hastened with gibberellic acid. Either a spray applied to the leaves and buds, or an injection of the solution, or paste application of gibberellic acid is effective. Injection is the most effective.

CONTROL OF TERMINAL DOMINANCE OF CHRYSANTHEMUMS

Maleic hydrazide applications, 1,000 p.p.m. solution sprayed on the plants of chrysanthemums resulted in suppression of terminal bud growth. Lateral bud growth was encouraged. Flowering was delayed.

Gibberellic acid did not counteract the effect of maleic hydrazide. The plants treated with gibberellic acid were taller, a result of internodal elongation.

The application of a lanolin paste of transcinnamic acid (1%) to shoots of chrysanthemums resulted in growth of axillary buds below the area of treatment. Similar application of 3-indoleacetic acid (0.5%) and phenylbutyric acid (0.5%) resulted in curvature of stem toward the side of treatment. Application of 2,4-dichloroanisole (1%) resulted in curvature away from the side of treatment.

FLOWERING OF CHRYSANTHEMUMS UNDER ADVERSE TEMPERATURE CONDITIONS

Flowering time of chrysanthemums is delayed when the night temperature is high. At an average night temperature of 60°F., the Sea Gull variety flowered in an average of 57 days. When the temperature was raised to an average of 83.5°F., full bloom was delayed 7 days. This delay was a result of retarded development. Rate of development of flower buds as measured by bud size was the same for the first 25 days. However, subsequent development was delayed at higher night temperature. Application of 2,4-dichloroanisole resulted in faster flowering at high temperature. Application of indoleacetic acid, indolebutyric acid and 2,3,5-triiodobenzoic acid resulted in delayed flowering.

Night temperature	*Chemical*	*Bud size* 25 *days*	*Bud size* 42 *days*	*Days to flowering*
		mm.	*mm.*	
60°F.	untreated	4.1	15.3	57
83.5°F.	untreated	4.9	11.7	63
83.5°F.	2,4-dichloroanisole	5.0	15.0	60
83.5°F.	Indoleacetic acid	4.8	12.3	65
83.5°F.	Indolebutyric acid	4.0	9.6	69
83.5°F.	2,3,5-triiodobenzoic	3.8	9.1	71

ECONOMIC CONSIDERATIONS

The foregoing results show the broad spectrum of chemical uses to direct plant growth and behavior. Before widespread usage is made of these techniques, however, the costs involved must be carefully evaluated. Use of some of these chemicals is prohibitive economically—others are within reason. For example, to effectively flower azaleas with gibberellin experimentally, the cost is approximately 14¢ per plant in 1 gallon containers for material alone. Labor and equipment costs must be added to this figure—11 applications were necessary.

SUMMARY

The use of chemicals presents another way to tailor plants for specific requirements, to ensure maximum returns and profit, and to overcome adverse environmental effects.

The grower should be aware of the subtle influence of environment on effectiveness of given dosage of growth regulators. Wherever less than best results are achieved, environment must be considered as well as plant species, and dosage.

The influence of other chemicals must be recognized also. The combined effect of Kinetin on the action of gibberellic acid in inducing earlier opening of unchilled azalea buds is an example. It is also possible to use additives to counteract effect of a growth regulator.

Chemical manipulation of plant growth is used by many commercial firms. As information accumulates, more uses will be made, not only on high value specialized crops, but on other crops. The use of chemicals will replace costly manipulation of environmental factors to achieve some degree of control over plant growth.

APPENDIX

TABLE 1. CYCOCEL DILUTION TABLE

Desired percentage	Concentration	Ounces of 11.8% Cycocel per gallon water
	p.p.m.	*Oz.*
1.0	10,000	10.84
0.75	7,500	8.13
0.50	5,000	5.42
0.30	3,000	3.25
0.25	2,500	2.71
0.20	2,000	2.17
0.10	1,000	1.08
0.09	900	0.97
0.07	700	0.76
0.05	500	0.54
0.03	300	0.32
0.02	200	0.22
0.01	100	0.11

TABLE 2. B-NINE DILUTION TABLE

Desired percentage	Concentration	Ounces of 5% B-Nine per gallon water
	p.p.m.	*Oz.*
1.0	10,000	25.0
0.75	7,500	19.0
0.50	5,000	12.0
0.30	3,000	7.5
0.25	2,500	6.0
0.20	2,000	5.0
0.10	1,000	2.5
0.09	900	2.2
0.07	700	1.75
0.05	500	1.2
0.03	300	0.75
0.02	200	0.5
0.01	100	0.25

TABLE 3. GIBBERELLIC ACID DILUTION TABLE

Desired concentration	Parts of 1% Gibberellic Acid per 100 parts water
p.p.m.	*No.*
1,000	10
500	5
100	1