THE EFFECTS OF GROWTH REGULATORS ON *MURRAYA PANICULATA* (L.) JACK

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN HORTICULTURE

DECEMBER 1970

by

James Howard Griset

Thesis Committee:

Richard A. Criley, Chairman
Yoneo Sagawa
D. J. C. Friend

We certify that we have read this thesis and that in our opinion it is satisfactory in scope and quality as a thesis for the degree of Master of Science in Horticulture.

THESIS COMMITTEE

Richard A Criley
____
Chairman

Yoneo Sagawa
____

Douglas J C Friend
____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Murraya paniculata (L.) Jack is commonly known as murraya, mock orange or orange jassamine. It is grown extensively in Hawaii as a hedge plant in yards and along roadsides. In a warm climate, the plant grows vigorously and thrives out of doors (Reuther, Batchelor, and Webber, 1967). Therefore, it is necessary to trim the hedge once a month. This presents an economic problem where a great expanse of hedge is concerned, as is involved in landscape work with large companies or government agencies.

Growth retardants have been shown to induce dormancy or inhibit growth of many ornamentals and fruit crops (Hendershott, 1962; Batjer, Williams, and Martin, 1963; Fisons Fertilizers Limited, 1961). If the growth rate of mock orange could be inhibited, the hedge would not have to be trimmed as often, and the cost of maintenance could be lowered.

The present study is an attempt to investigate the possibilility of finding a growth-retarding chemical which would significantly inhibit the growth of *Murraya paniculata* (L.) Jack without causing injury or distortion which would be detrimental to the aesthetic properties of the plant as a hedge material.

REVIEW OF LITERATURE

The Plant

Murraya paniculata (L.) Jack is a member of the Family Rutaceae and belongs to the Subfamily Auranticideae, Tribe Clauseneae, Subtribe Clauseninae. It is believed to have originated in tropical Africa and the monsoon region of Asia. It has spread throughout Asia and the Pacific. This is an extremely old genus, but has evolved at a very slow rate. The small morphological differences which distinquish the var. *ovatifoliolata* are evidence of this, for var. *ovatifoliolata* has been separated from the rest of the world since the Eocene period when Australia (where this variety is found) lost all land connections with the Asiatic mainland (Reuther, Batchelor, Webber, 1967).

Murraya is a handsome evergreen ornamental which bears fragrant white flowers and small red fruits (Lawrence, 1968). It was described by Kurz (1877, *Forest Flora of British Burma*, vol. 1, p. 190) as follows:

> "An evergreen tree, 15-25 feet high, trunk 6-8 feet high, 1½-2 feet in diameter, the young shoots puberulous, leaves unpaired-pinnate or occasionally pinnately 3-foliolate, glossy, glabrous, or sometimes the rachis puberulous; leaflets alternate, cuneateobovate or almost obliquely rhomboid, shortly petioluled, blunt or bluntish acuminate, 1-1½ inches long, coriaceous; flowers rather large, white, in dense but small, almost sessile terminal corymba; petals about ½-3/4 inches long, recurved; stamens 10, alternately shorter; ovary 2-celled, the style long with a capitate glandular stigma; berries ovoid-oblong, bluntish acuminate, nearly ½ inches long, orange-coloured, 1-2 seeded; seeds villous."

The Chemicals

Maleic hydrazide

Maleic hydrazide (3,6-dioxo-1,2,3,6-tetrohydropyridazine) has been used extensively as a growth regulator and a herbicide. The interest in maleic hydrazide as an inhibitor of plant growth has been increasing in recent years.

Maleic hydrazide (MH) has been shown to inhibit the growth of young shoots in many species of citrus (Cooper, 1960). In general, a 0.1% concentration delayed new vegetative growth in citrus when applied for two consecutive years. The length of dormancy varied from one month to six months (Hendershott, 1962). When applied as a spray to topped lemon trees, maleic hydrazide inhibited the growth of the young sprouts with no apparent effect on the rest of the tree (Hield, Coggins, Boswell, 1963). Bud inhibition was observed on grapefruit at a concentration of 1,000 ppm, but dormancy was not complete (Cooper and Peynado, 1955). Spring growth was delayed when maleic hydrazide was applied to Valencia oranges and grapefruit during late winter at concentrations of 500 and 1,000 ppm, but not when a concentration of 100 ppm was used (Erickson, 1952). Concentrations from 0.1% to 0.5% MH have inhibited vegetative growth of sour orange and Cleopatra mandarin seedlings. The older seedlings required higher dosages in order to achieve the same results as observed on the young seedlings (Bynum, 1952). Therefore, the effective concentration range for citrus appears to be from 500 to 5,000 ppm. It is also apparent that there are varietal differences of response to maleic hydrazide since some treatments were successful where others were not or were only partially successful.

Maleic hydrazide was effective in inhibiting the growth rate of several kinds of hedges. Salix acutifolia and Rhamnus cathartica were controlled for several months at a concentration of 0.1%, while Ligustrum vulgare required at least a 1.0% concentration. On the other hand, Caragana arborescens required less than an 0.1% concentration to show inhibition (Freeman, 1952). Maleic hydrazide controlled privet for up to three months. Privet and thorn hedges were inhibited with an application of 750 ppm MH, but elder was badly damaged when sprayed with the same concentration of MH (Webber, 1955; Fisons Fertilizers Limited, 1961). The application of 1,000 ppm MH to chrysanthemums reduced the growth of the plant to a degree that proved to be better than hand pinching (Beach and Leopold, 1953).

In treatments on pea, bean, and sunflower seedlings, maleic hydrazide was shown to be a very strong inhibitor of root growth. Inhibition of extension growth of roots was observed at concentrations of 0.15% MH, and reduction of the number of lateral roots was recorded at 10 to 20 ppm MH (Audus and Thresh, 1956).

Maleic hydrazide was successful in controlling strawberry runners with no bad effects observed. Raspberries were inhibited at 750 ppm (Fisons Fertilizers Limited, 1961; Webber, 1955).

Treatment of the Chinese elm tree with maleic hydrazide at a concentration of 2,500 ppm resulted in a fifty percent twig die back, but the tree grew out of it. At a concentration of 5,000 ppm MH there was a more marked inhibition of growth, but the result was an unsightly plant (Hamilton and Davis, 1967).

Hendershott found that maleic hydrazide was absorbed from 0 to 78% in three days. Under high humidity (90 to 95%) maximum absorption was attained within 24 hours after treatment. Under low humidity (60 to 70%) absorption continued gradually over five days. The rate of absorption of the upper and lower surfaces of the leaf were studied. During the first 25 hours after treatment with maleic hydrazide, no difference in absorption was noted between the upper and lower leaf surfaces. However, after the first 24-hour period, there was more absorption through the lower surface of the leaf. Thus it was found advisable to spray both surfaces of the leaf when using maleic hydrazide (Hendershott, 1962). After treatment, maleic hydrazide was slowly absorbed for approximately 30 hours, then it was translocated downward for the next ten to twelve days. It moved through the plant in the translocation stream and behaved much as phosphates--up the xylem and down the phloem (Webber, 1955; Crafts and Yamaguchi, 1958).

The initial rapid uptake of maleic hydrazide into the nuclei has been observed to inhibit mitosis, but there was a gradual recovery (Callaghan, 1966). It has been shown that low concentrations of maleic hydrazide primarily interfere with the meristematic phase of cell growth (Audus and Thresh, 1956). Pea seedlings were observed to germinate normally after treatment with maleic hydrazide until cell enlargement was replaced by cell division, at which point growth stopped. Further experiments revealed that enzymes which require free-SH groups were irreversibly inhibited while other enzymes were not inhibited. Apparently maleic hydrazide reacted with the protein-SH groups during mitosis through its reactive ethylene double bond (Hughes and Spragg, 1958).

Since the auxin content was a key factor in cell growth, an anti-auxin effect by another chemical would cause a reduction in the auxin content of the cell, resulting in a slower growth rate. Andreae found that maleic hydrazide accelerates the rate of IAA destruction. This anti-auxin effect on growth was attributed to the accelerated removal of endogenous IAA (Andreae, 1952). IAA was also noted to counteract maleic hydrazide inhibition (Povolotskaya, 1960; 1961).

Povolotskaya considered maleic hydrazide to be a uracil antimetabolite, for when it was applied to a plant, the result was a decrease in respiration and nucleic acid synthesis, and uracil restored normal growth. Maleic hydrazide probably inhibited the biosynthesis of ribonucleic acid. Povolotskaya found that riboflavin counteracts maleic hydrazide inhibitions of plant growth possibly by catalyzing light oxidation of maleic hydrazide (Povolotskaya, 1960; 1961).

Cycocel

Another growth regulator which has become popular in the inhibition of growth is (2-chloroethyl) trimethylammonium chloride, commonly known as Cycocel. Cycocel has been shown to reduce shoot length in several vegetables, fruits, and ornamentals (Gliemeroth, 1966). At concentrations of 1.0 to 4.0% Cycocel, the number of buds of *Erica* x hybrida increased with increasing concentrations; and at 4.0% Cycocel, the plant height was decreased over normal. Also, the culture period was shortened from 20 to 12 months (Stahn, 1966). Azalea buds were inhibited at concentrations of 0.2% Cycocel, and poinsettias were inhibited when Cycocel was applied as a soil drench at a concentration of 2.5% (Lemper, 1966; Kiplinger and Miller, 1966). When applied as a 1.5% drench, Cycocel reduced the height of poinsettias, and new growth was reduced by fifty percent when Cycocel was applied in two or three sprays at a 0.25% concentration or as a soil drench at concentrations of 0.125%, 0.25% or 0.5% (Shanks, 1965; 1966). Applications of 2,000 to 3,000 ppm Cycocel delayed bud growth of redblush grapefruit, but lower concentrations required two to five weekly sprays for the same effect (Young and Cooper, 1969). Young and Cooper found that severe stem injury resulted when defoliated grapefruit plants were used, and suggested that the injury may have been due to absorption of toxic amounts of Cycocel through the leaf scars.

At concentrations of 0.5%, 0.75%, and 1.0% Cycocel inhibited the growth of young tomato plants and shortened the internodes (Weichold, 1966). An application of 1 ppm Cycocel increased the height of pea plants, but applications of 100 ppm Cycocel decreased plant height, internode length, and total dry matter (Ormrod and Maurer, 1969).

Two spray applications of Cycocel at a 4% concentration was effective in controlling strawberry runners. One spray application resulted in partial control, and when injected into the soil complete control was attained (Guttridge, Anderson, and Stewart, 1966).

When a 1% solution of Cycocel was applied to cherries, the leaves became shorter, wider and thicker. In the palisades layer the cells were enlarged in length and width, and the spongy mesophyll was more compact than normal. Overtreatment resulted in initial chlorosis, but the plant soon recovered (Cristoferi and Intrieri, 1967; Stuart and Cathey, 1961).

Treatments of Cycocel at 2,000 ppm reduced the movement of photosynthates from the upper leaves downward. It was also effective when applied only to the shoot tips (Shindy and Weaver, 1967).

When Cycocel was used as a dip at 1,000 and 2,500 ppm concentrations the adventitious root initiations were reduced on geraniums, dahlia, and chrysanthemums. The rooting approached that of untreated cuttings after IBA was applied, thus indicating that the effects of Cycocel opposed that of auxin-like chemicals (Read and Hoysler, 1969). Kuraishi and Muir found that Cycocel reduced the level of diffusible auxin in stem apeces. Applications of IAA re-initiated growth, but GA did not. The results of these researchers indicated that the effect of Cycocel was to lower the auxin level in the plant (Kuraishi and Muir, 1963).

Cell proliferation and cell expansion of stem callus tissue was reduced nearly to zero when 100 ppm Cycocel was applied. This effect was not reversed or prohibited by GA_3 (Sachs, 1962). However, Cycocel retards sunflower stem growth, and this effect was overcome by gibberellic acid application (Jones and Phillips, 1966). Other research revealed that Cycocel suppressed gibberellin biosynthesis in Fusarium moniliforme, but did not break down the gibberellins already produced (Harada and Lang, 1965). Furthermore, it was shown that Cycocel changed the gibberellin substances in the sap of Pisum arvense. Here the Cycocel caused blockage of normal gibberellin production and the diversion of gibberellin precursors into the synthesis of "abnormal" gibberellins (Read and Carr, 1967). Reid and Carr felt that Cycocel acted on the biosynthetic pathway of gibberellin production at a relatively advanced level. They further felt that repeated applications of Cycocel may produce more lasting effects than a single application. Such repeated applications may act to divert gibberellic-acid precursors altogether. Criley confirmed that Cycocel in repeated applications reduced the gibberellin production of the root. Both soil drench and spray applications were used. The spray applications did not reduce gibberellin production of the roots as much as would be expected if the shoot apex was the sole source of gibberellin (Criley, 1970). It is thought that Cycocel affects one or more of the steps involved in the conversion of the C-20 gibberellins to C-19 gibberellins.

Cycocel was shown to affect gibberellin biosynthesis, and significantly reduced growth of cherry seedlings after six months. The manifestation of Cycocel inhibition occurred twenty days after application, and persisted forty days after treatment (Faccioli and Intrieri, 1967).

B-Nine

B-Nine (N-dimethylamino succinamic acid) has been used as a growth retardant on several ornamentals and fruits. It has reduced the number of water sprouts and shoot length of fruit trees when applied at a rate of 1 to 3 pounds/100 gallons. It has also been shown to reduce shoot lengths of several fruits, vegetables, and ornamentals (Bryant and Nixon, 1966; Gliemeroth, 1966). B-Nine has reduced growth and shortened the internodes of apples, pears, and cherries. There was an increase of 80 to 100% more leaves per linear unit when the internodes were shortened (Batjer, Williams, and Martin, 1964). Treatments of 4,000 and 8,000 ppm B-Nine were effective in reducing the terminal growth of pear seedlings. Concentrations of 0.05% to 0.5% B-Nine were effective in reducing terminal growth of apples by one-third of normal and cherries by one-half of normal (Brooks, 1964; Batjer, Williams, and Martin, 1963). Internode length of sour cherries was reduced after treatments of 2,000 and 4,000 ppm B-Nine were applied; however, when treated the following year only the 4,000 ppm application was effective in reducing internode length (Unrath, Kenworthy, and Bedford, 1969).

It was found that shoot growth of apples was significantly reduced when treatments of 1,000 and 2,000 ppm B-Nine were applied 14 days after full bloom. The higher concentration was more effective (Forshey, 1970). At 10,000 ppm concentrations, B-Nine retarded shoot elongation of apples to 28% of the control plants. The diameter of stem growth was also retarded (Stembridge and Ferree, 1969). Stembridge and Ferree noted that the maximum effect occurred during the early stages of growth, and found that B-Nine retarded cell division rather than cell elongation.

Azaleas which were sprayed with 10% B-Nine produced retarded growth and reduced sucker development (Lemper, 1966). Two spray applications of B-Nine at 1% concentrations reduced new growth of poinsettias by fifty percent, while treatments of 2,000 to 8,000 ppm B-Nine were successful in reducing height, but were not as effective as a Cycocel soil application (Shanks, 1966; Kohl, Nelson, and Kofranek, 1963).

B-Nine was found to be very water soluble. It was distributed rapidly, probably by moving passively in the transpiration stream, and was resistant to breakdown in the plant. B-Nine reduced the plant's potential to elongate internodes, possibly by interfering with gibberellins (Martin, Williams, and Batjer, 1964). Autoradiographs on almond seedlings showed that ^{14}C-Alar (B-Nine) moved readily from the phloem to the xylem. Undurraga and Ryugo also made autoradiographs of ^{14}C-sucrose with and without B-Nine pretreatment. The results showed that B-Nine induced greater leakage of radioactive material from the symplast to the apoplast, which they felt indicated that B-Nine lowered membrane integrity. These researchers found that B-Nine induced greater leakage of cellular contents than of water, which they felt was attributed to the ability of B-Nine to depress the utilization of respiratory energy necessary for the retention of solutes in the vacuole (Undurraga and Ryugo, 1970).

B-Nine did not inhibit gibberellin biosynthesis, according to Reed, Moore, and Anderson, but did affect the auxin concentration through the inhibition of the oxidation of tryptamine by diamine oxidase. It was found that the diamine oxidase level in B-Nine treated plants was lower than in untreated plants (Reed, Moore, and Anderson, 1965). However, Ryugo and Sachs found that B-Nine is stable and did not break the C-N bond to form succinate and unsymmetrical dimethylthydrazine. They found no proof that the primary effect of B-Nine was to inhibit IAA synthesis (Ryugo and Sachs, 1969). B-Nine did depress the synthesis of GA precursors. Dennis et. al. found a 43% reduction in Kaurene synthesis by Echinocystis endosperm in the presence of 100 ppm B-Nine as compared to the control (Dennis, Upper, and West, 1965). Exogenous GA bypassed the inhibition of GA precursors.

Maintain CF-125

Maintain CF-125 (Methyl-2-chloro-9-hydroxyfluorene-9-carboxylate) is a morphactin developed by E. Mereck AG of Darmstadt, W. Germany. The common name is chlorflurenol. The active ingredient causes interference with the development of seeds and the early growth stages of dicotyledonous and monocotyledonous plants. Maintain acts systemically and is readily translocated from the leaves and the roots throughout the plant to the meristematic tissue. The action of Maintain is slow. Its primary influence is on the portions of the plant which develop after treatment. Maintain has persistant effects among which is inhibition of apical buds, which causes the development of auxillary buds which are stunted.

The Borax Corp. suggests that Maintain be sprayed on the plant at rates of 50 to 500 ppm, but variability with species is expected. Maintain is expected to reduce the necessity for mechanical pruning. Maintain is a new chemical and little information on trials using Maintain is available. It is used in combination with maleic hydrazide on turf with some success, but is not recommended for woody plants or ground covers (U. S. Borax Research Corp., 1968).

Ethrel

Ethrel (2-chloroethylphosphonic acid) has been observed to inhibit growth on Pinto Beans at 1,250 to 5,000 ppm. The higher concentration resulted in better retardation. Corn was reduced in height by 500 to 6,000 ppm Ethrel, while privet was inhibited at rates from 5,000 to 10,000 ppm. Many flowers showed inhibition of growth when Ethrel was applied as a foliar spray at 250 to 500 ppm concentrations. Azaleas sprayed with 4,000 to 6,000 ppm Ethrel concentrations showed a loss of apical dominance and a stimulation of the laterals directly below the terminal bud. Apples showed inhibition of terminal growth with concentrations of 200 to 2,000 ppm Ethrel.

Ethrel breaks down to release ethylene directly to plant tissue. As the pH rises above 3.5 disintegration of the Ethrel molecule releases free ethylene gas and chloride and phosphate ions as shown below:

$$ClCH_2CH_2-\overset{\overset{O}{\|}}{\underset{\underset{O^-}{|}}{P}}-OH + OH^- \longrightarrow CH_2=CH_2 + \overset{\overset{O}{\|}}{\underset{\underset{O^-}{|}}{P}}-(OH)_2 + Cl^-$$

The breakdown of the Ethrel molecule is faster with a higher pH (Amchem Products, Inc., 1969).

AMO-1618

AMO-1618 has shown some growth retardant action on some plants, although many plants have not shown good response to this chemical (Stuart and Cathey, 1961). AMO-1618 has long persistance in the soil since it is strongly bound by colloidal surfaces. Therefore, AMO-1618 seems to be most effective when incorporated into the soil (Marth and Mitchell, 1960; Cathey and Marth, 1960).

AMO-1618 seems to affect gibberellin biosynthesis in somewhat the same way as Cycocel (Negbi and Rushkin, 1966; Harada and Lang, 1967).

Cell proliferation and cell expansion were reduced nearly to zero when a concentration of 25 ppm AMO-1618 was applied to stem callus (Sachs, 1960; 1962). Treatments of 100 to 1,000 ppm AMO-1618 were successful in controlling the height of chrysanthemums with no injury. The control was proportional to the concentration (Box, 1960). Internode elongation was retarded in Datura stramonium at a rate of 500 ppm AMO-1618. The stem diameter was increased, as were the fresh and dry weights in this treatment. There was a significant reduction in root weight, and there was chlorosis along the midrib of the leaves (Dall'Olio, 1965).

Off-shoot-O

The active ingredients of Off-shoot-O are methyl esters of fatty acids. Off-shoot-O is a chemical pinching agent with a surfactant. It is a relatively new chemical, and little information is available on growth inhibition of this compound. However, it apparently stimulates regrowth of the lateral buds. Off-shoot-O is best used as a fine spray, and is effective only when it comes into direct contact with the growing tip. Recommended dosages for Off-shoot-O are 2.8% to 5.6% (Procter and Gamble, Tech. data sheet).

METHODS AND MATERIALS

Screening trial

An initial screening trial was undertaken to determine which, if any, of the available growth regulatory chemicals would show promise as a growth retardant of mock orange. Various concentrations of maleic hydrazide, Maintain CF-125, Cycocel, AMO-1618, B-Nine (Alar 85), Ethrel (Amchem 68-250), and Off-shoot-O were used as well as nine untested chemicals which were NIA-10637 (Niagara Co.), UNI F-529 (Uniroyal Co.), Emgard 20-77, and six chemicals from Pennwalt Agricultural Chemical Co. (TD-692, TD-1123, TD-6068, TD-6265, TD-6266, TD-6586). The concentrations used for each chemical were based on recommended dosages or past experimental results.

Young mock orange seedlings ranging from 20 to 50 millimeters were used for this trial. The measurements were made from the cotyledonary leaves to the apical growing point. The Universal Aerosol Spray Kit (Nutritional Biochem Co.) which is pressurized with dichlorodifluoromethane was used to apply the treatment. The randomized block design with ten replications was used (Snedecor and Cochran, 1937).

Measurements were taken on a weekly basis. Growth rates (mm/wk) were determined for the third and sixth weeks as this covered the time period in which growth must be inhibited in order to effectively lengthen the period between trimmings. Superficial effects were also noted on a weekly basis.

The Analysis of Variance (Snedecor and Cochran, 1937) was used to determine if any significant difference in growth rates at the third and sixth weeks was present. If significance was found the Duncan's Studentized Range Test (Le Clerg, Leonard, and Clark, 1939) was applied to determine which, if any, of the treatment means differed from the control.

Combination trial - MH and Maintain

A combination trial of maleic hydrazide and Maintain CF-125 was tested to determine if there was any synergistic or additive response with these chemicals on mock orange. Five concentrations of each chemical were tested both alone and in combination. Maleic hydrazide concentrations ranged from 375 ppm to 100 ppm while Maintain concentrations ranged from 0 ppm to 30 ppm. The five MH concentrations were arranged in descending order, then added to the five Maintain concentrations which were arranged in ascending order. Thus the lowest concentration of each chemical was combined with the highest concentration of the other as shown in Table I.

TABLE I: TREATMENT COMBINATIONS OF MH AND MAINTAIN IN PPM

Treatment	Maleic hydrazide	Maintain CF-125
1	100	0
2	190	0
3	280	0
4	375	0
5	350	2.5
6	280	10.0
7	190	20.0
8	100	30.0
9	0	10.0
10	0	20.0
11	0	30.0
12	0	40.0
Control	0	0

Three foot tall seedlings were topped at a height of two feet, and the lateral buds were allowed to grow for one week. Five branches of each plant were tagged and measured on a weekly basis.

The chemicals were mixed in one liter volumes and sprayed on the plants with a B & G Co. one-gallon hand sprayer. The fan-shaped fine spray nozzle was used. This trial was of the randomized block design with eight replications.

Dry Weight Analysis. Since the MH-Maintain trial involved a considerable amount of branching, a dry weight analysis was undertaken to determine if there was any difference in growth which escaped measurement.

The plants were removed from their cans and the soil was cleaned from the roots. The plants were then cut into sections and placed in paper bags. They were dried in a drying oven for 36 hours, then weighed. The analysis of variance was determined as in the previous trials.

Combination trial - MH and Cycocel

A second combination trial was undertaken to determine if Cycocel and maleic hydrazide gave any additive or synergistic effects. Seven concentrations of each chemical were used both in combination and alone. The concentrations used in this combination trial are shown in Table II.

Rooted seedlings ranging from 8 to 28 cm. in height were used in this experiment. The randomized plot design was used with an unsprayed treatment serving as a control.

The chemicals were mixed in one liter volumes and sprayed on the plants with a B & G Co. one-gallon hand sprayer. A fan-shaped fine spray nozzle was used as in the MH-Maintain experiment. The Analysis of Variance (Snedecor and Cochran, 1937) was run for each of the above experiments. If significance was found, the Duncan's Studentized Range

TABLE II: TREATMENT COMBINATION OF MH AND CYCOCEL IN PPM

Treatment	Maleic hydrazide	Cycocel
1	100	0
2	1,500	0
3	3,000	0
4	4,700	0
5	6,000	0
6	7,500	0
7	6,000	1,000
8	4,700	1,900
9	3,000	3,000
10	1,500	4,000
11	100	4,900
12	0	5,000
13	0	4,900
14	0	4,000
15	0	3,000
16	0	1,900
17	0	1,000
Control	0	0

Test (Le Clerg, Leonard, and Clark, 1939) was employed to determine if any treatment means differed from the control means.

Mature Hedge Growth Studies

Mature mock orange hedges were studied to determine their growth characteristics under field conditions. Ten foot sections of hedges were chosen for study since such a length would be required when applying treatments in order to eliminate the effects of translocation between treatments. Hedges at Thomas Square, Honolulu, and south of Kuykendall Hall on the University of Hawaii campus were used for study. Such characteristics as growth rate from time of clipping, compactness and effects of shade, water, and fertilizer were studied.

RESULTS AND DISCUSSION

Screening trial

The Analysis of Variance revealed that there was a significant difference at the 1% level for both the third and sixth week growth rates. However, the Duncan's Studentized Range Test resulted in no means differing significantly from the control in the third week growth rates, and only one mean differed significantly at the 1% level in the sixth week growth rates (Table III). Off-shoot-O at 40,000 ppm was significant in increasing the growth rate of mock orange seedlings after six weeks.

Superficial effects were studied for each treatment as shown in Table IV. Those treatments not mentioned showed no change from the control. The control showed good colour and good form as shown in Fig. 1. All superficial effects were overcome by the new growth of the plant except for the deformation of the new growth in the Maintain treatments.

The mean height of the screening trial plants for each treatment are shown in Table V. The measurements are shown at weekly intervals with week "0" being the initial height of the plants when treated.

The high concentrations of maleic hydrazide and Cycocel caused yellowing of the leaves. This effect was overcome by the subsequent new growth of the plants; however, it was undesirable since it detracted from the aesthetic properties of the plant as a hedge. The lower concentrations showed low mean growth rates and no superficial damage. Thus it was indicated that the lower concentrations of these chemicals may prove useful in further trials.

A more serious effect was exhibited by AMO-1618 where treatments

TABLE III: RESULTS OF SCREENING TRIAL

Chemical	Conc. (ppm)	Growth[1]	Mean Growth Rate 3rd Week	Mean Growth Rate 6th Week
MH-30	5,000	Normal	0.64 mm/wk	0.59 mm/wk
	7,500	Yellowing	0.43	1.46
Cycocel	1,000	Normal	0.74	2.18
	3,000	Yellowing	2.26	3.49
AMO-1618	50	Leaf burn	1.81	3.33
	100	Leaf burn	1.81	2.73
	500	Leaf burn	3.27	3.88
Maintain	50	Deformed	4.00	3.36
	100	Deformed	3.77	3.67
	500	Deformed	3.38	3.46
B-Nine	3,000	Normal	2.08	3.03
	5,000	Normal	1.92	3.09
	7,000	Normal	1.57	3.23
Off-shoot-O	40,000	Normal	3.56	6.24**
	50,000	Leaflet drop	2.54	2.95
Ethrel	25	Normal	2.10	2.90
	150	Leaflet drop	2.61	3.30
	1,000	Leaf damage	2.26	2.21
UNI F-529	500	Normal	1.94	3.07
	3,000	Normal	2.06	4.05
	5,000	Normal	1.56	3.13
	7,000	Normal	1.67	3.10
Emgard 20-77	40,000	Normal	3.00	4.23
	50,000	Normal	2.43	4.56
NIA-10637	500	Normal	3.26	4.47
	2,000	Leaflet drop	2.46	4.75
	5,000	Leaflet drop	2.30	4.96
TD-692	500	Normal	2.73	3.82
	2,000	Leaf burn	2.96	2.90
TD-1123	500	Leaf damage	2.77	2.14
	2,000	Leaflet drop	1.87	1.46
TD-6068	500	Leaflet drop	2.72	2.26
	2,000	Leaf damage	1.88	1.73
TD-6265	500	Normal	2.43	3.14
	2,000	Normal	2.14	3.35
TD-6266	500	Normal	1.87	3.29
	2,000	Normal	1.74	4.00
TD-6586	500	Normal	2.33	3.31
	2,000	Leaf damage	1.19	1.54
Control	---	---	2.23	3.10

[1] normal growth was based on the control plants which showed good colour and good form; any deviations were noted and are shown in Table IV.

** significant from the control mean at the 1% level.

TABLE IV: THE EFFECTS OF VARIOUS CHEMICALS ON MOCK ORANGE SEEDLINGS

Treatment	Effect
MH-30	At 7,500 ppm yellowing of the leaflets occurred by the second week.
Maintain	At 50, 100, and 500 ppm slight wilting appearance of the young leaves occurred at first week, and bud break by the second week. By the third week the new growth was grossly deformed--leaflets fusing together.
Ethrel	At 150 ppm there was slight leaflet drop on young leaves during the second week.
	At 1,000 ppm there was leaflet damage on young leaves the first week, with slight leaf burn on the primary leaves and further leaflet drop on young leaves by second week.
Cycocel	At 3,000 ppm there was yellowing at the tips and margins of the leaflets of young mature leaves by the second week.
Off-shoot-O	At 50,000 ppm there was very slight leaflet drop by the second week.
AMO-1618	At 50, 100, and 500 ppm there was slight leaf burn of primary leaves the second week.
NIA-10637	At 2,000 and 5,000 ppm there was leaflet drop on new leaves by the second week.
TD-692	At 2,000 ppm there was slight yellowing and leaf burn.
TD-1123	At 500 ppm there was slight leaf damage the first week.
	At 2,000 ppm there was damage to primary leaves the first week, and some burning, leaflet drop, and colour drain of the leaves by the second week.
TD-6068	At 500 ppm there was some young leaflet drop.
	At 2,000 ppm there was leaf burn, leaflet drop, and extensive damage to young leaves first and second weeks.
TD-6586	At 2,000 ppm there was serious damage to young leaves the first week, with serious burning, chlorotic spots on leaflets, and lateral bud break by second week.

TABLE V: MEAN HEIGHT OF SCREENING TRIAL PLANTS

Chem.	Conc. (ppm)	Mean Height (mm) for Week 0	1	2	3	4	5	6	7	8	10
MH-30	5,000	25.8	26.2	27.2	27.7	28.1	29.1	29.5	30.9	33.5	43.0
	7,500	28.0	28.4	28.9	29.3	30.0	30.5	33.7	34.6	36.8	39.8
CCC	1,000	26.5	27.0	28.7	30.1	32.0	35.1	39.2	40.5	47.9	57.0
	3,000	23.8	24.2	27.4	30.6	31.6	35.1	41.2	42.5	49.3	63.3
AMO	50	28.1	28.2	30.4	33.5	35.6	38.6	43.5	45.8	52.0	62.4
	100	24.8	25.1	27.4	30.2	33.1	34.8	38.4	40.7	43.6	57.0
	500	29.3	30.5	34.3	39.1	41.9	46.2	50.7	53.0	61.0	74.3
Maint.	50	25.5	27.5	33.3	37.5	41.5	44.5	47.6	49.0	55.1	69.3
	100	27.8	29.5	35.3	39.4	44.2	47.7	50.4	51.2	55.3	61.2
	500	28.0	29.2	34.4	38.1	42.7	46.8	48.7	49.5	51.2	53.3
B-Nine	3,000	26.5	27.7	30.1	32.4	34.9	37.1	41.5	42.9	49.8	63.9
	5,000	25.2	26.2	30.0	31.0	33.6	35.2	40.3	42.1	50.2	64.3
	7,000	26.9	27.7	29.7	31.6	33.9	37.8	41.3	43.6	52.4	73.0
Off'O	40,000	29.8	31.2	35.9	40.5	43.9	49.8	59.2	62.9	69.2	88.1
	50,000	25.9	26.0	30.3	33.5	35.9	38.0	42.4	44.4	51.1	63.0
Ethrel	25	25.1	25.5	28.2	31.4	33.2	36.3	40.1	43.1	51.5	62.4
	150	26.7	27.0	30.2	34.5	36.3	39.1	44.4	48.1	56.5	69.9
	1,000	25.0	25.3	26.8	31.8	33.5	35.6	39.4	41.2	44.3	57.1
UNI	500	26.1	26.3	28.9	31.9	34.6	37.2	41.1	43.3	50.6	62.9
	3,000	25.5	25.6	29.0	31.7	34.0	38.4	44.8	46.0	53.4	66.5
	5,000	25.1	25.6	27.2	29.8	32.0	35.1	39.2	40.1	46.9	59.3
	7,000	23.7	24.1	27.1	28.7	31.2	33.6	37.9	40.0	47.2	57.6
Emg.	40,000	26.0	26.3	30.7	35.0	37.8	43.0	47.7	49.9	57.3	68.2
	50,000	25.3	28.0	31.1	34.7	37.2	38.1	47.4	50.1	58.4	76.1
NIA	500	24.3	25.9	29.4	34.1	37.9	42.3	47.5	49.2	56.6	73.1
	2,000	23.2	23.9	26.9	31.6	36.1	41.7	45.9	47.5	49.9	53.9
TD-692	500	28.9	30.3	34.2	37.1	39.6	42.9	48.8	51.0	56.5	77.2
	2,000	26.0	27.9	31.4	35.0	36.5	38.9	43.8	46.8	54.4	65.4
TD-1123	500	26.8	28.0	31.5	35.1	36.1	38.6	41.5	42.9	47.5	57.1
	2,000	28.6	29.0	32.0	35.2	36.2	36.3	38.6	39.5	42.8	47.8
TD-6068	500	20.7	27.6	30.3	33.5	35.6	37.7	40.3	41.5	46.3	58.0
	2,000	24.6	26.2	28.5	30.2	31.1	33.7	35.4	39.9	43.2	48.4
TD-6265	500	25.5	26.0	29.1	32.8	34.4	37.3	43.2	44.2	50.8	64.3
	2,000	28.9	29.4	32.5	35.3	37.9	40.3	44.9	46.9	53.4	67.5
TD-6266	500	24.8	25.8	27.7	30.5	33.0	35.1	40.4	42.3	47.6	59.4
	2,000	24.7	25.5	28.4	29.9	34.1	36.5	41.9	44.8	49.8	67.2
TD-6586	500	26.0	27.0	29.9	33.0	35.1	38.3	42.9	45.5	54.7	68.1
	2,000	27.1	27.6	29.2	30.7	32.0	32.1	35.3	37.9	40.9	52.5
Control	---	27.7	28.7	31.4	34.4	36.2	37.3	43.7	45.8	51.6	63.8

resulted in leaf burn. The plants were not defoliated and were able to overcome this effect by about the fifth week. Since all concentration levels resulted in leaf burn with no indication of growth inhibition it was felt that AMO-1618 was not helpful in growth inhibition trials on mock orange. Internode elongation was not retarded, nor was there any noticeable increase in stem diameter at the 500 ppm concentrations as with Datura stramonium (Dall'Olio, 1965).

B-Nine showed no superficial damage, but was not effective in retarding the growth rate of mock orange. It was not effective in shortening internode length and stem diameter as has been shown with apples. Additional experiments showed that B-Nine treatments caused serious leaf burn and defoliation of mock orange plants when applied with 5% surfactant, but showed no damage when surfactant was not used. Therefore, it may be indicated that B-Nine requires a surfactant to enter the plant in order to be effective.

UNI F-529, Emgard 20-77, TD-6265, and TD-6266 all showed no superficial effects and no inhibition. All the treatment means for these chemicals were close to the control mean, and were not considered for further trials. It was not determined whether addition of surfactants had any effect or not.

Off-shoot-O resulted in slight leaflet drop at the high concentration. This effect was not serious and did not continue past the third week; however, as stated before it was an undesirable effect for aesthetic purposes. It also indicated that higher concentrations should be avoided. The treatment mean gave no indication of growth rate retardation, and thus showed no promise. The 40,000 ppm concentration resulted in a significant increase in the growth rate by the sixth week. Procter and Gamble have stated that little is known about this chemical, but that it apparently stimulates the regrowth of the lateral buds. In this trial the lateral buds did not break. Off-shoot-O seems to have stimulated the apical bud in this case instead of the lateral buds.

Ethrel, NIA-10637, TD-692, and TD-6586 all showed no superficial effects and no inhibition at their low concentrations, but all resulted in leaf damage or leaflet drop at their high concentrations. Therefore, further trials with higher concentrations of these chemicals were not undertaken even when a low treatment mean was found due to the leaf damage effect.

TD-1123 and TD-6068 showed relatively low treatment means, but also showed leaf damage at all concentrations. Therefore, these chemicals were not used in further trials.

Treatments of Maintain showed the most drastic effects. The leaves which developed after treatment were deformed in that the leaflets were fused, and the midvein was shortened as shown in Figs. 2 and 3. Multiple branching of the lateral buds occurred on all plants treated with Maintain. The resulting branches numbered from three to six per node, and were noticeably larger in diameter than normal and stunted. This resulted in a deformed, dense growth around the main stem of the plant as shown in Fig. 3. The Borax Corp. has stated that Maintain interfered with the early growth of dicotyledonous plants, that it acted systematically and was readily translocated from the leaves and from the roots throughout the plant to the meristematic tissue, and that its primary influence was on the portions of the plant which developed after treat-

PLATE 1

FIGURE 1. NORMAL MOCK ORANGE LEAF (0.75X)

FIGURE 2. FUSED LEAFLETS USING MAINTAIN CF-125 (0.75X)

FIGURE 3. DEFORMED GROWTH USING MAINTAIN CF-125 (0.75X)


1


2


3

ment. It was further stated that Maintain had persistant effects among which was the inhibition of apical buds, which caused the development of auxillary buds which were stunted.

The results of this trial seemed to agree with those of the Borax Corp. with one exception. In this trial the apical buds were not inhibited even though vigorous lateral branching and bud growth did occur. It was also noted that Maintain had some persistance in the soil. Weeds which appeared in the pots which contained Maintain treated plants as late as the seventh week after treatment were found to have deformed leaves, but after the eighth week such weeds appeared normal. After the ninth week the new growth of the Maintain treated mock orange plants returned to normal. Since Maintain has been reported to be readily translocated from the roots throughout the plant the duration of the effect of Maintain on the plants in this trial may have been due in part to the confinement of the chemical in the root zone inside the pots.

If the leaf deformity could be controlled and the lateral branching maintained, this might yield a fuller, more compact plant. Furthermore, if maleic hydrazide reacts to a combination treatment with Maintain as it has in grasses, the length of growth could also be shortened.

The screening trial indicated which chemicals may show promise in further trials and eliminated the chemicals or concentrations which showed unwanted effects. Maleic hydrazide and Cycocel showed promise due to their low treatment means. B-Nine at 3,000 ppm ranked among the lowest means with no superficial damage at the sixth week.

<u>Combination trial - MH and Maintain</u>

Since Maintain had been combined with maleic hydrazide and used successfully on grasses, a combination trial was undertaken to determine the effect of such a treatment on mock orange. It was previously stated that low concentrations of maleic hydrazide were thought to interfere with the meristematic phase of cell growth. For that reason a low range of concentrations of maleic hydrazide was used. Maintain concentrations ranging from 0 to 40 ppm were chosen in an attempt to avoid the leaf deformation effect shown by concentrations of 50 ppm and higher.

The Analysis of Variance showed no significant difference in the treatments. The leaf deformation of new growth was evident in all treatments containing Maintain at concentrations of 20 ppm or higher. Treatments containing Maintain at concentrations of 10 ppm or lower resulted in normal growth as shown in Table VI. Either both the multiple branching of lateral buds and the leaf deformation effects were present or neither were--the effects could not be separated by concentration levels. Due to the multiple branching of lateral buds on some of the treatments, length of branch measurements may not represent the true amount of total growth of the treated plants. Therefore, total dry weights of all treatments were compared.

<u>Dry Weight Comparison</u>. The Analysis of Variance revealed that there was no significant difference between treatments on the basis of the dry weight (Table VII). There was no apparent difference in root growth in relation to the treatments. A few of the seedlings had sparse root systems, but these did not correspond to any particular treatment or combination of treatments.

TABLE VI: RESULTS OF MH AND MAINTAIN COMBINATION TRIAL

Treat.	MH + Maintain (ppm)	Mean Growth Rate 3rd Week	Mean Growth Rate 6th Week	Growth[1]
1	100 + 0	6.62 mm/wk	5.12 mm/wk	Normal
2	190 + 0	4.50	6.00	Normal
3	280 + 0	9.25	4.87	Normal
4	375 + 0	6.00	6.50	Normal
5	350 + 2.5	9.12	6.87	Normal
6	280 + 10.0	10.12	8.12	Normal
7	190 + 20.0	6.12	6.62	Deformed
8	100 + 30.0	6.62	6.37	Deformed
9	0 + 10.0	8.50	8.37	Normal
10	0 + 20.0	6.75	5.12	Deformed
11	0 + 30.0	3.75	4.87	Deformed
12	0 + 40.0	4.75	5.50	Deformed
Control	---	6.82	7.44	Normal

1 growth was compared to the control plants. Deformity refers to the effects of Maintain as described in the screening trial.

TABLE VII: RESULTS OF DRY WEIGHT COMPARISON

Treat.[1]	Dry Weight (grams) per Replication 1	2	3	4	5	6	7	8	Mean D. W.
1	17.87	18.36	18.65	22.45	30.73	34.78	45.14	54.85	30.35
2	15.16	18.50	28.19	30.24	37.43	38.82	39.82	47.01	31.90
3	17.43	35.37	44.43	47.39	49.72	50.43	52.22	60.34	44.66
4	16.78	19.14	20.33	24.89	28.86	30.33	47.36	48.85	29.57
5	11.68	17.32	17.90	27.00	28.86	34.34	45.36	45.89	28.54
6	13.73	15.11	27.54	29.56	32.99	36.29	36.73	40.27	29.03
7	17.75	17.75	18.60	23.70	41.29	52.08	55.25	62.82	36.16
8	15.29	17.06	23.76	24.70	28.03	39.37	41.89	44.85	29.36
9	9.08	18.19	28.73	31.72	33.57	35.09	46.92	67.57	33.86
10	6.92	17.39	17.99	19.01	25.32	25.32	45.66	55.48	26.64
11	10.44	18.57	18.70	18.86	20.96	21.91	27.41	45.67	22.81
12	20.11	21.34	24.79	26.04	31.87	33.36	39.44	41.06	29.75
Control	17.67	19.48	21.90	25.86	28.12	36.98	40.12	44.16	29.28

1 treatment concentrations are the same as in Table VI.

All treatments with maleic hydrazide and Maintain both alone and in combination were ineffective. The levels of maleic hydrazide used were too low to be effective, while Maintain was ineffective in retarding growth at all levels. Concentrations of 10 ppm or lower must be used to avoid the deformation effect that Maintain has on new growth of mock orange.

Combination trial - MH and Cycocel

Since Cycocel had been reported to be effective in retarding growth in higher plants, and because of its promising position on the Duncan's Studentized Range Test in the screening trial it was felt that this chemical might show promise in combination with maleic hydrazide. Due to the inactivity of maleic hydrazide in the previous trial, the higher concentrations were used for this combination trial.

The concentration ranges used ran from zero to the highest concentration of each chemical used in the screening trial. The concentrations of chemicals were arranged on the vertical axes of a "horseshoe" graph with the zero point of each on the x-axis. A line was drawn from the high concentration of each chemical to the zero point of the other with the lines intersecting in the middle. Vertical lines were drawn at various points on the x-axis between the two vertical scales to determine the combination concentrations of CCC and MH-30 found in Table II.

The Analysis of Variance showed a significant difference in treatments at the 1% level of significance for both the third and sixth weeks. The Duncan's Studentized Range Test showed no significant difference between the treatment means and the control mean for the third week, but revealed half of the treatment means to differ significantly (1% level) from the control mean for the sixth week as shown in Table VIII.

TABLE VIII: RESULTS OF MALEIC HYDRAZIDE AND CYCOCEL COMBINATION TRIAL

Treatment	Concentrations Maleic hydrazide	Cycocel	Mean Growth Rate 3rd Week	6th Week
1	100	0	11.3 mm/wk	15.3 mm/wk
2	1,500	0	6.1	4.1**
3	3,000	0	3.7	0.9**
4	4,700	0	4.0	0.6**
5	6,000	0	3.5	0.6**
6	7,500	0	4.3	1.2**
7	6,000	1,000	3.2	0.6**
8	4,700	1,900	4.4	0**
9	3,000	3,000	5.2	0.3**
10	1,500	4,000	3.1	3.0**
11	100	4,900	7.1	11.3
12	0	5,000	6.7	12.3
13	0	4,900	5.9	14.6
14	0	4,000	5.9	15.4
15	0	3,000	7.9	12.5
16	0	1,900	6.0	12.3
17	0	1,000	6.7	17.7
Control	---	---	7.6	14.0

** significantly different from control mean at 1% level

Figures 4 and 5 show the weekly growth rates of the MH treatments and the combination treatments. The 100 ppm MH treatment and the combination treatment of 100 ppm MH and 4,900 ppm Cycocel were both not significantly different from the control. All the other treatments shown in the figures were significant at the 1% level when an average growth rate for the fourth, fifth, and sixth weeks were compared. None of the growth rates for the Cycocel treatments differed significantly from the control. It is apparent that the Cycocel has little or no effect on mock orange and the growth inhibition is due to the maleic hydrazide at concentrations of 1,500 ppm or higher regardless of the

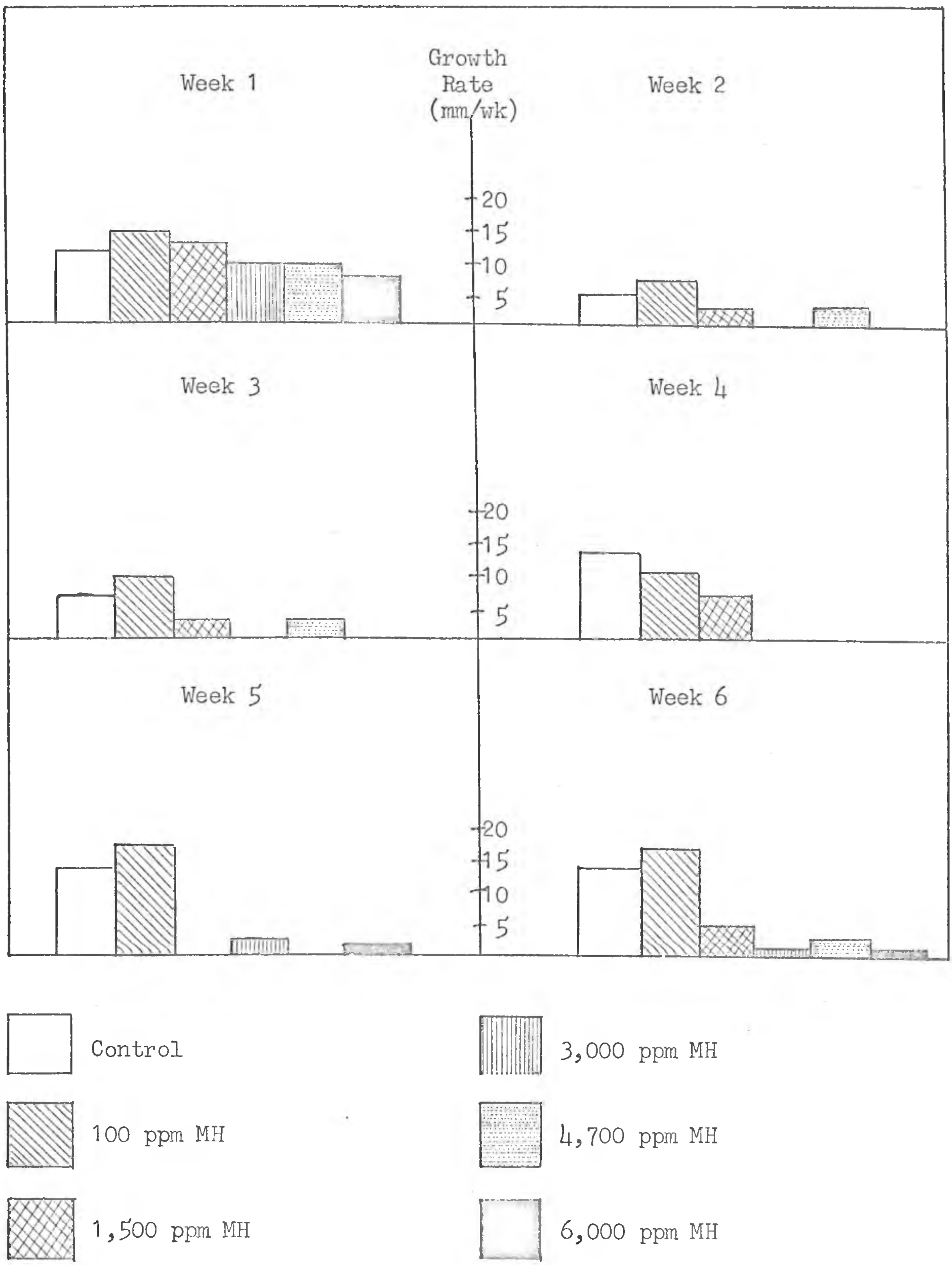

FIGURE 4. WEEKLY GROWTH RATES FOR MH TREATMENTS

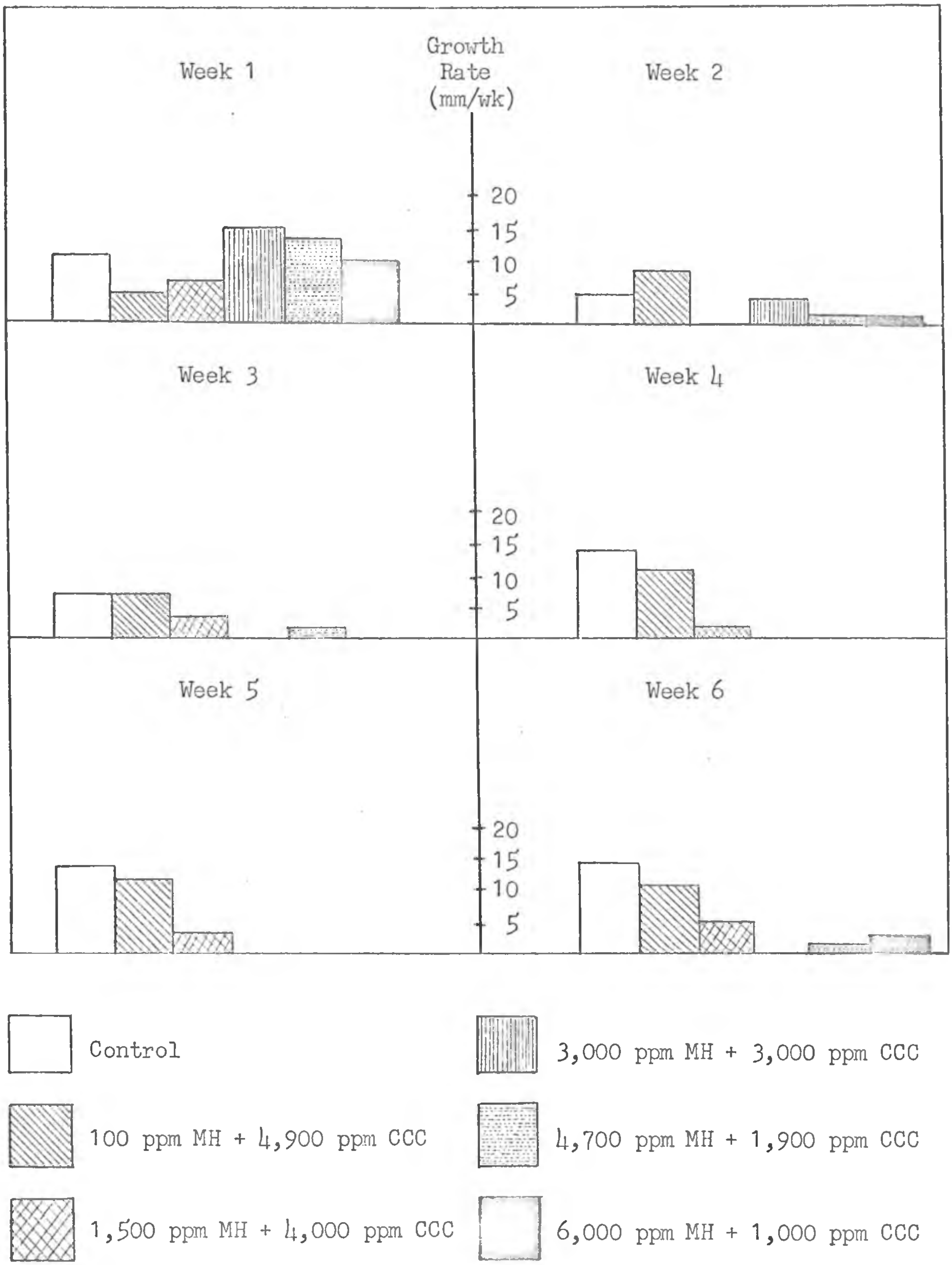

FIGURE 5. WEEKLY GROWTH RATES FOR MH WITH CCC TREATMENTS

presence of Cycocel (Fig. 6). All of the treatments which differed significantly from the control also exhibited definite chemical pinching of the apical growing tip. The pinching characteristic was manifest during the third week when the growing tip died back about one millimeter. Growth was retarded until the eighth week, when the lateral buds broke and the plant began to develop new growth. All of the plants which did not receive MH treatments at the 1,500 ppm concentration level or higher maintained normal growth as compared to the control throughout the trial.

The results of this trial were in agreement with prior research using maleic hydrazide on citrus for which the effective concentration range was from 500 to 5,000 ppm (Cooper; Hendershott; Hield et. al.; Cooper et. al.; Erickson; and Bynum). Erickson found that maleic hydrazide inhibited spring growth of Valencia oranges and grapefruit at concentrations of 500 and 1,000 ppm, but not at a concentration of 100 ppm. The effects of maleic hydrazide on mock orange follow the same pattern.

This trial showed that maleic hydrazide was successful in inhibiting the growth of mock orange if used in concentrations of 1,500 ppm or higher. Cycocel was ineffective at all concentrations and showed no additive or synergistic effects when used in combination with maleic hydrazide.

Mature Hedge Growth Studies

The Kuykendall hedge was not regularly trimmed, watered or fertilized. The hedge was allowed to attain rank growth and was then severely trimmed. This hedge was usually trimmed about two or three times a year. Regrowth after trimming was studied on ten foot sections to determine normal growth rates. The results of this study revealed

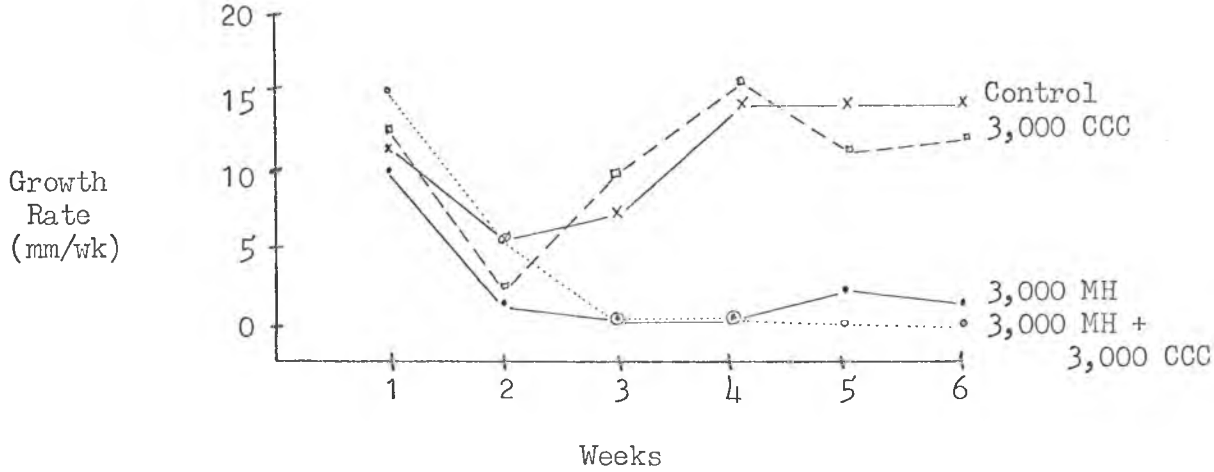

FIGURE 6. REPRESENTATIVE GROWTH CURVES FOR MH-CCC COMBINATION TRIAL

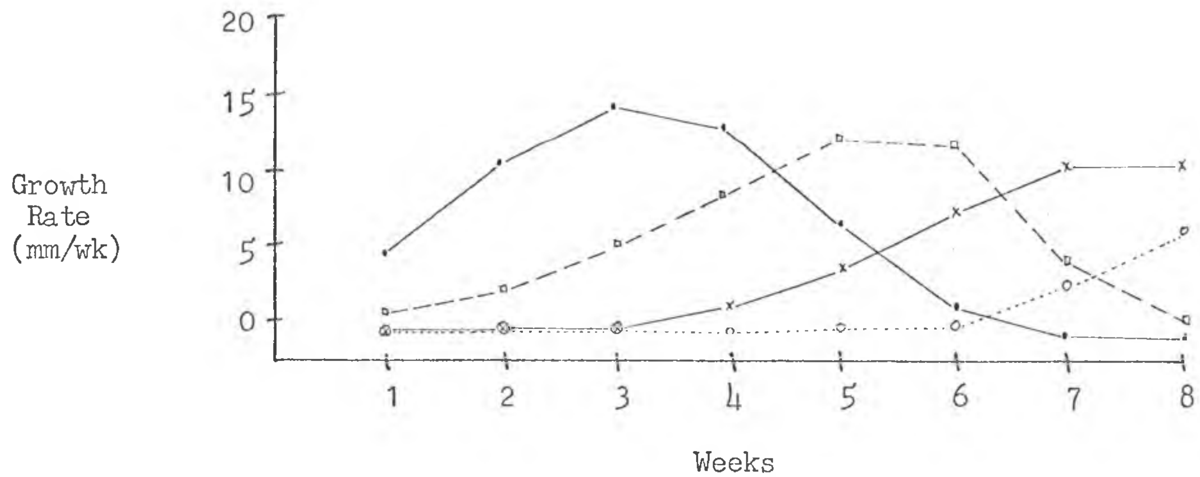

FIGURE 7. GENERALIZED GROWTH RATE CURVES FOR MATURE MOCK ORANGE HEDGES

that the growth rates of different sections of the same hedge are not identical or consistant. The different sections produced the growth rates illustrated in Fig. 7 as well as variations thereof. The different growth characteristics were distributed in a seemingly random fashion throughout the sections of the hedge. Often the same section would repeat the same growth curve after trimming. However, this tendency was found to be unreliable, possibly due to seasonal changes.

The growth seems to follow the same pattern but out of sequence, thus producing the different growth curves in Fig. 7. If the different sections are to be used for the comparison of different treatments then either they must all be in sequence or basic growth data must be obtained in order to use the analysis of covariance.

Part of the Kuykendall hedge was under dense shade. The growth on this part of the hedge was longer, darker, and more rank than on other parts of the hedge. Since this hedge was not watered regularly, this effect may have been due to better retention of water. Another hedge, which was watered regularly, showed longer and faster growth on the portion not under dense shade.

The Thomas Square hedge was watered and trimmed regularly. On this hedge the growth was more compact and shorter. Since the regular trimming program cut short the late growth curves, it was not possible to obtain such data on these hedges. However, it was noted that here again the growth curves differed randomly among the sections. Those sections with early growth curves were easily noticed while other sections appeared to be growing slowly, thus indicating that these sections had late growth curves.

Regular watering and fertilizer programs resulted in greener, more succulent growth and a generally healthier looking hedge, but seemed to have little effect in equalizing the growth rates.

CONCLUSIONS

Maleic hydrazide was found to be the most effective chemical in this study for use in controlling the growth of mock orange. This chemical was effective at a concentration of 1,500 ppm or higher on seedling plants of mock orange. Growth inhibition was most effective during the fourth to eighth weeks after treatment under greenhouse conditions. Cycocel had no effect on this plant when used alone and gave no added response when combined with maleic hydrazide.

Maintain CF-125 showed no synergistic or additive effects when combined with maleic hydrazide. At 20 ppm or higher Maintain had a definite and severe effect on new growth. Unless this deformation was desired, this chemical would not be used on mock orange.

Sections of a mature mock orange hedge under field conditions exhibited various growth curves. Although a regular watering and fertilizer schedule did help to produce a healthier looking hedge, it did not appear to help equalize the different growth curves of the various sections. Soil type may have an effect on this characteristic. Since mock orange plants are grown from seed, genetic variability may also be a contributing factor.

Suggestions for Future Research

Trials on mature mock orange hedges should be preceded by a year of growth rate data on the pre-selected sections of hedge. In this way growth rates under all seasonal conditions can be determined for use in the analysis of covariance.

Other tests have shown that Alar-85 (B-Nine) is more effective on mock orange plants when used with a surfactant or wetting agent. Future research using surfactants in conjunction with B-Nine or other growth retardants may be indicated.

Bynum reports that older citrus seedlings require higher dosages of maleic hydrazide than do younger seedlings for the same effect (Bynum, 1952). Since the results of these trials on mock orange agree so closely with those on citrus, Bynum's report should be given full consideration when experimenting with maleic hydrazide on mature mock orange plants.

LITERATURE CITED

1. Andreae, W. A. The effect of scopoletin and maleic hydrazide on indoleacetic acid oxidation. Abstract paper presented Am. Soc. of Plant Physiologists. p. 25. Ithaca. Sept. 1952.

2. Anonymous. Ethrel (2-chloroethylphosphonic acid) technical service data sheet. Amchem Products, Inc. April, 1969.

3. ________. 1961. Levington Research Station 1961. Fisons Fertilizer Limited. p. 71.

4. ________. Off-shoot-O technical data sheet. Procter and Gamble.

5. ________. Technical data for experimental use of Maintain CF-125. U. S. Borax Research Corporation. April, 1968.

6. Audus, L. J., and Ruth Thresh. 1956. The effects of synthetic growth-regulator treatments on the levels of free endogenous growth substances in plants. Annals of Botany. 20:439-459.

7. Batjer, L. P., M. W. Williams, and G. C. Martin. 1963. Chemicals to control tree size. Proc. Wash. St. Hort. Assoc. p. 107.

8. ________, ________, and ________. 1964. Effects of N-dimethylaminosuccinamic acid (B-Nine) on vegetative and fruit characteristics of apples, pears, and sweet cherries. Proc. Amer. Soc. Hort. Sci. 85:11-16.

9. Beach, R. G., and A. C. Leopold. 1953. The use of maleic hydrazide to break apical dominance of Chrysanthemum morifolium. Proc. Amer. Soc. Hort. Sci. 61:543-549.

10. Box, C. O. 1960. Chemical used to limit weight of chrysanthemums. Miss. Fm. Res. 23(11):7. From Hort. Abstr.

11. Brooks, H. J. 1964. Response of pea seedlings to N-dimethylamino-succinamic acid, a growth retardant. Nature. 203:1303.

12. Bryant, J. H., and P. Nixon. 1966. B-Nine can aid intensive fruit growing. Grower. 66:204-6

13. Bynum, Willard M. 1952. The effect of maleic hydrazide on the growth of citrus seedlings. Proc. Sixth Annual Rio Grande Valley Horticulture Institute. pp. 58-59. In a Literature Summary on Maleic Hydrazide. J. Zukel, ed. 1963.

14. Callaghan, J. J. 1966. An investigation of effects of maleic hydrazide on three higher plant species. Diss. Abstr. 26:6315. From Hort. Abstr.

15. Cathey, H. M., and P. C. Marth. 1960. Effectiveness of a quaternary ammonium carbamate and a phosphonium in controlling growth of Chrysanthemum morifolium (Ramat.). Proc. Amer. Soc. Hort. Sci. 76:609-619.

16. Cooper, J. F. Profitable partnership. Florida Grower and Rancher. Jan., 1960. In a Literature Summary on Maleic Hydrazide. J. Zukel, ed. 1963.

17. Cooper, W. C., and A. Peynado. 1955. Effect of plant regulators on dormancy, cold hardiness, and leaf form of grapefruit trees. Proc. Amer. Soc. Hort. Sci. 66:100-110.

18. Crafts, A. S., and S. Yamaguchi. 1958. Comparative tests on the uptake and distribution of labeled herbicides by Zebrina pendula and Tradescantia fluminensis. Hilgardia. 27:421-454.

19. Criley, R. A. 1970. Influence of (2-choroethyl) trimethylammonium chloride (Cycocel) and daylength on gibberellin-like activity in the root exudate of the poinsettia Euphorbia pulcherrima, Willd. cv. 'Paul Mikkelsen'. Journ. Amer. Soc. Hort. Sci. 95:120-124.

20. Cristoferi, G., and C. Intrieri. 1967. Effeti del Cycocel sulla morfologia e sulla struttura anatomica della foglie di ciliegio (The effects of Cycocel on the morphology and anatomical structure of cherry leaves). Riv. Ortoflorofruttic. Ital. 51:49-52.

21. Dall'Olio, G. 1965. Effecto del prodotto brachizzante "AMO-1618" sulla crescita e sul contenuto in alcaloidi di Datura stramonium L. (The effect of the growth inhibitor AMO-1618 on the growth and alkaloid content of Datura stramonium). G. Bot. Ital. 72:334-340.

22. Dennis, D. T., C. D. Upper, and C. A. West. 1965. An enzymatic site of inhibition of gibberellin biosynthesis by AMO-1618 and other plant growth retardants. Plant Physiol. 40:948-952.

23. Erickson, L. C., et. al. 1952. Responses of orange and grapefruit trees to maleic hydrazide. Botanical Gazette. 114:122-130.

24. Facciolo, F., and C. Intrieri. 1967. Prospettive de Cycocel come "nanizzante" del celiegio (Possibilities of Cycocel as a dwarfing agent for cherry trees). Riv. Ortoflorofruttic. Ital. 51:33-44 (English summary)

25. Freeman, J. A. 1952. Further notes on the use of maleic hydrazide for controlling the growth of several kinds of hedges. Dominion Experimental Farm, Agaisey, B. C. Mimeo sheet 2 pp. In a Literature Summary on Maleic Hydrazide. J. Zukel, ed. 1963

26. Forshey, C. G. 1970. The use of Alar on vigorous 'McIntosh' apple trees. Journ. Amer. Soc. Hort. Sci. 95:64-67.

27. Gliemeroth, K. 1966. Anwendung wachstumsverzogernder stoffe im Gartenbau (The use of growth retardants in horticulture). Dtsche. Gartenb. 13:201-202. From Hort. Abstr.

28. Guttridge, C. G., H. M. Anderson, and W. S. Stewart. 1966. The control of strawberry runners in the field with CCC. Exp. Hort. No. 15. pp. 92-95.

29. Hamilton, W. D., and W. B. Davis. 1967. Chemical growth control of chinese elm trees. Calif. Agric. 21(2):4-5.

30. Harada, H., and A. Lang. 1965. Effects of some (2-chloroethyl) trimethylammonium chloride analogs and other growth retardants on gibberellin biosynthesis in Fusarium moniliforme. Plant Physiol. 40:176-183.

31. Hendershott, C. H. 1962. Absorption of maleic hydrazide by citrus. Proc. Amer. Soc. Hort. Sci. 80:237-240.

32. ________________. 1962. The influence of maleic hydrazide on citrus trees and fruits. Proc. Amer. Soc. Hort. Sci. 80:241-246.

33. Hield, H. Z., C. W. Coggins Jr., and S. B. Boswell. 1963. Some effects of localized maleic hydrazide sprays on lemon trees. Proc. Amer. Soc. Hort. Sci. 81:218-222.

34. Hughes, C., and S. P. Spragg. 1958. Inhibition of mitosis by the reaction of maleic hydrazide with sulfhydryl groups. Biochem. J. 70:205-214.

35. Jones, R. L., and I. D. J. Phillips. 1966. Effects of CCC on the gibberellin content of excised sunflower organs. Planta. 72:53-59.

36. Kiplinger, D. C., and D. E. Miller. 1966. Natural season poinsettia tests in 1965. Ohio Flor. Assoc. Bull. No. 443. pp. 3-6.

37. Kohl, H. C. Jr., R. L. Nelson, and A. M. Kofranek. 1963. Growing short poinsettias. Calif. Agric. 17(6):14-15.

38. Kuraishi, S., and R. M. Muir. 1963. Mode of action of growth retarding chemicals. Plant Physiol. 38:19-24.

39. Kurz, S. 1877. Forest Flora of British Burma. Supt. of Gov't. Publishing. Calcutta. 2 vol.

40. Lawrence, G. H. M. 1968. Taxonomy of Vascular Plants. pp. 556-7. New York.

41. Le Clerg, E. L., W. H. Leonard, and A. G. Clark. 1939. Field Plot Technique. Burgess Publishing Co. Minneapolis, Minn. p. 200.

42. Lemper, J. 1966. Wuchshemmstoffe bei azaleen (Growth inhibitors for azaleas). Gartenwelt. 66:394-396. From Hort. Abstr.

43. Maire, R. 1970. Personal communication.

44. Marth, P. C., and J. W. Mitchell. 1960. Plant growth suppressants with special reference to persistance of AMO-1618 in soil. Proc. Amer. Soc. Hort. Sci. 76:673-678.

45. Martin, G. C., M. W. Williams, and L. P. Batjer. 1964. Movement and fate of labeled N-dimethyl amino succinamic acid (B-Nine), a size controlling compound, in apple seedlings. Proc. Amer. Soc. Hort. Sci. 84:7-13.

46. Negbi, M., and E. Rushkin. 1966. Inhibition of chlorophyll synthesis by growth retardants and counteraction of the effect by gibberellin. Israel J. Bot. 15:73. (Abstract)

47. Ormrod, D. P., and A. R. Maurer. 1969. The response of pea plants to low concentrations of Cycocel, Phosfon and B-Nine. Journ. Amer. Soc. Hort. Sci. 94:321-323.

48. Povolotskaya, K. L. 1961. Mechanism of the action of maleic hydrazide in plants. Isvest. Akad. Nauk. S.S.S.R. 26 Ser. Biol. No. 2:250-255. In a Literature Summary on Maleic Hydrazide. J. Zukel, ed. 1963.

49. Povolotskaya, K. L., et. al. 1960. Interaction of uracil, riboflavin and maleic hydrazide in plants. Fisiol. Rastenii. Akad. Nauk. S.S.S.R. 7:73-80. In a Literature Summary on Maleic Hydrazide. J. Zukel, ed. 1963.

50. Read, P. E., and V. C. Hoysler. 1969. Stimulation and retardation of adventitious root formation by application of B-Nine and Cycocel. Journ. Amer. Soc. Hort. Sci. 94:314-315.

51. Reed, D. J., T. C. Moore, and J. S. Anderson. 1965. Plant growth retardant B-995: a possible mode of action. Science. 148:1469-71.

52. Reid, D. M., and D. J. Carr. 1967. Effects of a dwarfing compound, CCC, on the production and export of gibberellin-like substances by root systems. Planta. 73:1-11.

53. Reuther, W., L. D. Batchelor, and H. J. Webber. 1967. The Citrus Industry. vols. I and II. Univ. of Calif. Press.

54. Ryugo, K., and R. M. Sachs. 1969. "In vitro" and "in vivo" studies of Alar (1,1-dimethylaminosuccinamic acid, B-995) and related substances. Journ. Amer. Soc. Hort. Sci. 94:529-533.

55. Sachs, R. M. 1962. "In vitro" studies with growth retardants. From abstr. in Amer. J. Bot. :656-657.

56. Sachs, R. M., et. al. 1960. Shoot histogenesis: subapical meristematic activity in a caulescent plant and the action of gibberellic acid and AMO-1618. Amer. J. Bot. 47:260-266.

57. Shanks, J. B. 1965. Recent poinsettia research--some observations for future trials. Maryland Flor. No. 118. pp. 1-6. From Hort. Abstr.

58. __________. 1966. The use of chemical growth retardants on poinsettias. Maryland Flor. No. 127. pp. 1-4. From Hort. Abstr.

59. Shindy, W., and R. J. Weaver. 1967. Plant regulators alter translocation of photosynthetic products. Nature. 214:1024-5.

60. Snedecor, G. W., and W. G. Cochran. 1937. Statistical Methods. Sixth edition. The Iowa State Univ. Press. Ames, Iowa. p. 593.

61. Stahn, B. 1966. Qualitatsverbesserung und kullurzertverkurzung durch CCC bei *Erica* x hybrida (Improving the quality and shortening the growing period of *Erica* x hybrida with CCC). Dtsche. Gartenb. 13:205-207. From Hort. Abstr.

62. Stembridge, G. E., and M. E. Ferree. 1969. Immediate and residual effects of succinic acid, 2,2-dimethyl hydrazide (Alar) on young 'Delicious' apple trees. Journ. Amer. Soc. Hort. Sci. 94:602-604.

63. (Stuart, N. W., and H. M. Cathey). 1961. Learning about growth regulators. Agric. Res. Wash. 9(10):10. From Hort. Abstr.

64. Undurraga, M. J., and K. Ryugo. 1970. The effect of Alar on permeability, a possible explanation for its mode of translocation. Journ. Amer. Soc. Hort. Sci. 95:348-354.

65. Unrath, C. R., A. L. Kenworthy, and C. L. Bedford. 1969. The effect of Alar, succinic acid 2,2-dimethyl hydrazide, on fruit maturation, quality and vegetative growth of sour cherries, *Prunus cerasus* L. cv. 'Montmorency'. Journ. Amer. Soc. Hort. Sci. 94:387-391.

66. Webber, E. R. 1955. Maleic hydrazide as a plant growth inhibitor. World Crops. 7:179-183. In a Literature Summary on Maleic Hydrazide. J. Zukel, ed. 1963.

67. Weichold, R. 1966. Hemmstoffe auch im treibgemusebau aktuell? (Are growth retardants also important in forced vegetable growing?). Dtsche. Gartenb. 13:203-205. From Hort. Abstr.

68. Young, R., and W. C. Cooper. 1969. Effect of Cycocel and abscisic acid on bud growth of redblush grapefruit. Journ. Amer. Soc. Hort. Sci. 94:8-10.