THE ACTION OF PHOTOPERIOD AND GROWTH REGULATORS IN THE PROPAGATION OF VARIOUS ORNAMENTAL PLANTS

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By

BERNHARD STORJOHANN, JR.

AN ABSTRACT

Submitted to the College of Agriculture Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Horticulture

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ABSTRACT

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The influence of different photoperiods, and growth regulators on the root formation of various ornamental plants was investigated to determine practical boundaries for use in the field of plant propagation. It has previously been reported that low concentrations of a growth inhibitor and a combination of a growth inhibitor and an auxin will stimulate an increase in root formation.

In this investigation cuttings of *Ligustrum amurense*, *Philadelphus lemoinei*, *Chrysanthemum hortorum*, *Pelargonium hortorum* and *Taxus cuspidata* were made in the usual commercial manner and placed in sand media under photoperiods of: normal day length, eight hours, sixteen hours and continuous illumination and treated with two growth inhibitors, maleic hydrazide and the sodium salt of alpha-beta-dichloroisobutyric acid, applied as a dip or spray at 500 or 3000 p.p.m. or a combination of either one or the other of the growth inhibitors and a commercial root promoting substance, Hormodin No. 2.

After a given length of time, the cuttings were removed from the media and graded as to root formation. The results indicated root formation of the various ornamental cuttings was influenced by certain growth inhibitors and varied in influence with the method of application, concentration and photoperiod. In no instance did a growth inhibitor, of the two concentrations used, significantly increase root formation. However, in some cases root growth was greater than that of the control. When a growth inhibitor was used in conjunction with the root promoting compound, root formation was significantly increased from the control.

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INTRODUCTION

The use of certain root promoting substances in the asexual propagation of ornamental plants has become a commercial practice. These root promoting substances have been classified as growth regulators and generally are used in very dilute concentrations. In some instances, application of too high a concentration of a growth regulator will inhibit root formation. This inhibition due to a high concentration of a growth regulator has been reported to be relieved by the application of an anti-auxin (21).

It has further been reported that an increase in root formation may be stimulated by a low concentration of a growth inhibitor (3) and by a combination of a growth inhibitor and an auxin (50). It remains to be determined whether the inhibitor antagonizes the auxin or whether it stimulates the effect of the auxin present.

The practical question is, can growth inhibitors or a combination of a growth inhibitor and an auxin be used commercially in plant propagation to stimulate the formation and promotion of root growth? With this in mind, an effort was made to determine the effect of photoperiods, the boundaries of concentration, method of application and effect of certain growth regulators on the promotion of roots of various ornamental cuttings.

REVIEW OF LITERATURE

In the asexual propagation of plants a most important phase is that of root formation. The root, one of the primary organs of the vascular plant, is typically subterranean, serving to anchor and support the aerial portions of the plant axis. It is responsible for the absorption and conduction of water and mineral nutrients and in the storage of reserve foods, in addition to being capable, in some instances, of developing adventitious shoots (18).

I. Classification, Anatomy and Origin of the Root

Roots that are profusely branched and penetrate in all directions make up a fibrous root system. The opposite is a tap root system, consisting of a single main root penetrating deeply in the soil and much stouter than the lateral roots that arise from it. The root system of many plants are intermediate between two main types (38). Roots that are a direct continuation of the main root of young seedling plants are known as primary roots and branches arising from these are called secondary roots. The primary root normally grows directly downward, while the secondary or lateral roots at first grow horizontally and then obliquely downward.

A young root, internally, is composed of three well defined regions in trans-section, an epidermis, a cortex and a stele (18). The epidermis consists of a single layer of cells outermost to the other two regions. The cortex lies just under the epidermis and consists for the most part of round, thin-walled cells and serves as a means of conduction of water and dissolved substances from the root hairs to the conductive tissues in the stele. Later, it functions as a storage region for reserve food and gradually is sloughed with age. The innermost ring of cells of the cortex are called endodermal cells. Central to the endodermal cells is the stele, which consists of the core of the root. It is composed of the pericycle, xylem, phloem and vascular cambium. The pericycle constitutes the outermost layer of the stele, next to the endodermis cells. The xylem forms the central axis of the stele cylinder and is made up of radial arms that extend centrifugally to the pericycle. Between the radial arms of the xylem there are located two to several groups of primary phloem. And, between the phloem and xylem zones there is a layer of undifferentiated cells called vascular cambium.

In older roots the sequential difference occurs in the stele. The cambium growth increases xylem and phloem cells to form a concentric ring with each year's growth. Lateral roots are generally initiated in the pericycle of both gymnosperms and angiosperms.

Under certain conditions roots may appear on other parts of the plant, particularly on stems and leaves (27). Such roots are called adventitious roots, arising from meristematic tissue in the node or internode of the stem or in the petiole or veins of the leaves.

Those portions of the plant used for the purpose of propagation are called cuttings. Cuttings may be classified into either stem cuttings, root cuttings or leaf cuttings depending upon their origin. Stem cuttings may be soft, slightly lignified, completely lignified, or from evergreens and may be called softwood cuttings, greenwood cuttings, hardwood cuttings or evergreen cuttings (2).

The first recognizable structure in the formation of a root on a cutting is called a root primordium (48). In some instances root primordia are present in stems of growing plants, but generally they are formed after the cuttings have been severed from the parent plant and placed in a favorable environment. Root primordia may be formed in various tissues of the stem, but most commonly originate in the pericycle (11).

II. Effect of Internal Factors on Root Formation

A. Auxin

Beginning with Sach's (9) work in 1880, investigators have tried to explain the initiation of root primordia on cuttings by the accumulation of special root-forming substances near the base. C. Darwin (1880), showed that shoot apices perceived and transmitted towards the base a stimulus produced by light. Later this stimulus was called heteroauxin or auxin (53).

The first extensive study of root formation using internal factors was that of van der Lek (53) in 1925, who assumed that developing buds produced one or more hormones responsible for root formation. He found that the presence of leaves or buds definitely stimulated root formation. Removal of buds stopped root formation almost completely. Van der Lek also found dormant Populus cuttings taken in December or January when buds were dormant no longer initiated root formation, while two months later, after the commencement of the activity of the bud, root formation occurred.

Went (53), also found that the presence of buds and leaves promoted formation of roots. Working with Acalypha he found that debudded and defoliated cuttings formed few roots. If, however, a diffusate from *Acalypha* leaves was applied to the defoliated cuttings an increase in the number of roots was obtained.

In 1935, Thimann and Koepfle (47) induced root formation on pea cuttings with a synthetic growth substance, indoleacetic acid (IAA). In this same year Hitchcock (20) described the activity of 3-indole-propionic acid and Hitchcock and Zimmerman (21) reported IAA, indole-proprionic, indolebutyric and naphthaleneacetic acids increased initiation of roots on cuttings.

In 1940 Hitchcock and Zimmerman (22) discovered that combinations of root inducing substances of equal activity did not improve root formation, but that those of different activity improved rooting. Zimmerman (55) reported indole compounds usually produced a more fibrous root system than the alpha-naphthaleneacetic acid (NAA), and indole-butyric acid did not inhibit terminal bud growth as much as NAA.

Skoog (39) in 1944 demonstrated that root formation was dependent upon auxin concentration to certain plant constituents (Purines). If the ratio of auxin to some plant constituent was low, bud and leaf primordia were formed; intermediate, simple callus was formed; and at a high ratio, root primordia were stimulated.

Stoutemyer (43) demonstrated different methods of applying plant hormones such as: powder preparations, concentrated solution dips, sprays and prolonged soaking of cuttings in dilute solution. Stoutemyer and O'Rourke (46) reported higher rooting percentages in sprayed cuttings taken from growth regulator treated stock plants than from non-treated plants.

Many growth regulators can be used for rooting cuttings, but indolebutyric acid is the most commonly used (31). It has weak activity and slow destruction by auxin destroying enzymes. Strong growth regulating substances are undesirable as they inhibit bud and root development.

Skoog, Schneider and Malan (40), in 1942 first suggested a molecular reaction for auxin's effect on growth. He stated auxins act as co-enzymes to which some substrate attaches onto an enzyme controlling growth. Later, Veldstra (31), suggested that the ring structure influenced the degree of fat solubility. It was thought that the water solubility was influenced by a side chain structure, and could be correlated with auxin activity. In 1951, Muir and Hansch (32) postulated that molecules of auxin were attached to a receptor at two points. In 1952 this two-point attachment theory was confirmed by Foster, McRae and Bonner (13). They found that growth could be inhibited if one or both points were not connected. McRae and Bonner (30) in 1953 suggested that an obstruction of the ring attachment of an auxin-like compound resulted in an incomplete attachment of auxin to the receptor. Similar incomplete attachments occurred if an appropriate acid group of the side chain was lacking, or configuration limited (27). A high concentration of auxin inhibited growth as a result of two auxin molecules becoming attached to the receptor, one at each of the two points and each inhibiting activity of the other.

Van Overbeek, Gordon and Gregory (49) found cuttings supplemented with reducing and non-reducing sugars and nitrogenous compounds in solution responded as if leaves were present, and that the concentration regulated the amount of response. According to Leopold (27), nutrient materials are important in rooting, not only in relation to their ratio with auxin, but in the amount of substrate present for actual root growth. He also stated that rooting responses to auxin are quantitative. The use of auxin concentrations above optimum reduced rooting, but not the number of root primordia formed.

B. Anti-Auxin

A large variety of compounds, other than high concentrations of growth regulator; called anti-auxins, have been reported to inhibit plant growth (27). Their action is not clearly understood. Leopold (27) reported two anti-auxin naphthalene derivatives which reduced inhibition of root growth. It is thought that anti-auxins inhibit auxin-induced growth (1), alleviate auxin inhibition, prevent respiratory responses to auxins (23), remove apical dominance, prevent tropic and epinastic responses to auxin sprays (5). A fourth type of anti-auxin is one that apparently is attached at both points of the receptor but possesses relatively weak activity (27).

Maleic hydrazide, an inhibitory growth regulator, sprayed on plants profoundly influences their development. Schoene and Hoffman (37) first observed maleic hydrazide treated young tomato plants ceased growth and lost apical dominance.

Leopold and Klein (28) found pea roots inhibited by low concentrations of maleic hydrazide were completely relieved of inhibition by adding auxin. Conversely, growth inhibition by high concentrations of auxin can be relieved by the addition of maleic hydrazide at various acidity levels. Leopold in his book (27) reported Andreae and Andreae (1953) thought maleic hydrazide reduced auxin effectiveness by stimulating enzymatic destruction of indoleacetic acid.

Audus and Das (3) reported that Alberg (1950 and 1952) found certain homologues of auxin, auxin antagonists, promoted an extension of root growth when applied in low concentrations. From their work Audus and Das concluded that the idea of stimulation, by antagonism of endogenous growth inhibitors, may have to be abandoned because it seems that auxins and growth inhibitors act in identical ways. Van Raalte (50), working with leaf cuttings of *Ageratum* found that certain combinations of IAA and indole, a growth inhibitor, increased the rooting effect of IAA.

C. Other Internal Factors

It is realized certain growth regulating substances may be directly responsible for root formation of cuttings, but there are certain practical aspects which experience has shown influence rooting formation. Zimmerman (56) in 1925 reported that certain three-inch sections of *Weigelà* shoots, planted serially apex to base, produced roots more readily than the others. In some years certain pieces cut from shoots rooted more readily than others, influenced by the rate of growth and the season.

Some species of plants root readily from winter hardwood cuttings, while in others, early summer wood roots more readily (56). Commercially, hardwood cuttings are taken in late autumn or early winter before heavy freezing (4), but in some instances they may be taken late in the winter or early spring. Chadwick (7) obtained better rooting from stock taken in late winter or early spring before growth started. Haun and Cornell (17) stated some clones root at specific seasons and cannot be induced with hormones to root at other seasons. Cuttings of

Prunus tomentosa taken between May 15 and June 1 rooted well, thereafter declining in rooting until December 20, after which date they did not root (56).

Starring (42) found that cuttings of various species of plant material, severed at the node varied in rooting response. Chadwick (7) stated that the position of the basal cut was less important on hardwood cuttings which varied anatomically from softwood cuttings. Chadwick also concluded basal cuts sometimes influenced the number of basal roots produced, the amount and size of the callus, and time of rooting.

In 1915 Kraus, and Kraybill (26), found relatively high carbohydrate content combined with relatively low soluble nitrogen increased root growth, whereas the reverse stimulated shoot growth. Pearse (35) reported cuttings taken from minerally starved stock plants rooted readily, in contrast to those receiving adequate or excessive nutrition. Haun and Cornell (17) reported that more nitrogen reduced mortality of rooted cuttings and increased root length. Cuttings from stock plants receiving high potassium with medium or low nitrogen and high phosphorous with low nitrogen rooted best. In some instances defoliated cuttings did not root (36), but if their leaves were allowed to remain intact maximum rooting occurred.

III. Effects of Environmental Conditions on Root Formation

The formation of roots, like other types of growth, is governed to a great extent by various combinations of environmental conditions. It is thought that these environmental factors do not have a direct effect on rooting, but rather an indirect effect, such as the controlling of chemical and physical processes and to a great extent the synthesis and destruction of auxins.

A. Light

In 1935 Went studied the effect of different colored lights on root formation (53). He found that red rather than blue light effectively promoted rooting. Went (1935) also reported that root initiation was inhibited when the entire plant (roots and stem) was lighted (27). Stoutemyer and Close (45) also found that light color effected the stock plant in subsequent rooting of cuttings.

The leaves are considered perceptive organs of a photoperiod stimulus, which is translocated to meristems and other plant parts. This was verified by Moshkov, (1935), and Cailahjan, (1936) (33).

Galston, and Hand (15) suggested non-auxin systems were responsible for growth inhibition. Brief exposure to white light, before, during and after auxin treatments decreased the efficiency of IAA root-initiation processes of etiolated pea epicotyles.

Galston (14) excised asparagus stem tips which formed roots when exposed to appropriate concentrations of IAA in the dark, but not in light. He concluded that other materials than auxins were essential for root initiation and that they were formed by light, stored in the seed and depleted by prolonged darkness.

In 1938, Hammer and Bonner (16) reported that portions of a plant under long photoperiods were influenced by a portion of the same plant given short photoperiods. This floral initiating substance was not identical to IAA.

Stoutemyer and Close (44) found photoperiods most favorable for rooting varied from plant to plant; some species rooting best under continuous illumination, others under short photoperiods. Leopold (27) reported that Smith (1926) found photoperiodic effect was influenced primarily by carbohydrates in the plant. In contrast, illuminated cuttings occasionally simulated an increase in rooting (44).

B. Other Environmental Factors

Chadwick (7) reported buds and meristematic tissues, other than basal root initials, of cuttings possess a rest period. He also stated that callusing of hardwood cuttings (exposure to temperatures between 70° - 100° F.) speeded rooting, and that media temperatures of 40° F. retarded root development. Wells (52), suggested that optimum media temperatures of 68° to 72° F. was ideal for rooting. In the rooting of certain evergreen cuttings, Chadwick and Swartley (8) reported better rooting at 70° - 75° F. than at 80° - 85° F. Zimmerman (56) suggested that forms which root with difficulty may be benefited by specific temperatures.

Cuttings of many plants when rooted in propagation sand produce coarse, brittle, sparsely branched root systems, while those in peat moss produce very slender, flexible, well branched roots (29). Chadwick (6) reported a better root system was produced when a fine grade of vermiculite was used, though most grades of vermiculite and propagation sand were satisfactory.

Myhre and Schwartze (34) found most evergreen species root well in sand or sand-peat. These media had a minor influence on rooting (36). Exper and Roof (12) and Hitchcock (19), also used these media.

Esper and Roof (12) stated slag, sand, and peat, used alone were not ideal as a rooting medium but that various combinations were valuable.

The amount and frequency of watering varies with time of year, type of rooting medium and type of cutting. Overhead watering was considered by Chadwick (6) to be superior to manual or constant level subirrigation. Houston and Chadwick (24) found controlled humidity of 75 percent, ideal for rooting softwood cuttings during the summer.

The pH range for ideal rooting varies with the different varieties, but generally falls somewhere between an acid range of 4.5 to 7.0 (25). Chadwick and Swarthey (8) reported that acidified growth substances were effective and more toxic than regular hormones. Zimmerman (56), (1925) suggested that a sand and acid peat mixture be used for plants which root better under acid and high moisture conditions.

Zimmerman (56) using Salix cuttings, found normal root growth occurred when the atmosphere contained 12 percent carbon dioxide, 25 percent oxygen and 63 percent nitrogen. Approximately normal rooting occurred with 25 percent carbon dioxide, provided oxygen content remained 25 to 33½ percent. Best rooting was obtained when 15 to 33 1/3 percent oxygen was mixed with 66 2/3 to 85 percent nitrogen.

MATERIALS AND METHODS

In order to determine the influence of various photoperiods and growth inhibitors in promoting roots, different types of ornamental plant materials were used. Cuttings were obtained in the usual commercial manner, given appropriate treatments and propagated under greenhouse conditions prevailing at East Lansing, Michigan from February 4 to June 20, 1956.

The cuttings were exposed to photoperiods of normal day length, eight hours, sixteen hours and continuous illumination. In order to obtain photoperiods longer than normal day length, additional illumination was supplied by 40-watt white fluorescent tubes. In addition to various photoperiods, plant growth regulators were used. Two growth inhibitors, maleic hydrazide[1] and the sodium salt of alpha-beta-dichloroisobutyric acid[2] at concentrations of 500 and 3000 p.p.m. were applied either as a dip, at the time of setting or sticking of the cuttings, or as a spray, when shoot growth was evident. Dipped cuttings were completely immersed in the solution for several seconds. In the spray applications, the leaves were sprayed until run-off of the solution was observed. In addition to the plant growth inhibitors, so-called root "promoting" hormones were used. A commercial preparation, Hormodin No. 2 (31), containing indolebutyric acid, was applied to the basal ends of some of the cuttings. Chemical treatments and plant materials used in this experiment are shown in Table I.

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1) Obtained from Rohm and Hass Company, Philadelphia, Pennsylvania.

2) Obtained from Naugutuck Chemicals, Division of U. S. Rubber Co., Naugutuck, Conn.

TABLE I

List of Chemical Treatments and Plant Materials Used Under Four Different Photoperiods in the Various Experiments on Root Formation.

Plant Material	Chemical Treatments									
	Control	Hormodin No. 2	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric acid			
			500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
			dipped	sprayed	dipped	sprayed	dipped	sprayed	dipped	sprayed
Chrysanthemum hortorum (var. Indianapolis Yellow)	x		x	x	x	x	x	x	x	x
Pelargonium hortorum (var. Better Times)	x		x	x	x	x	x	x	x	x
Ligustrum amurense	x		x	x	x	x	x	x	x	x
Philadelphus lemoinei (var. Avalanche)	x		x	x	x	x	x	x	x	x
Taxus cuspidata (spreading form)	x	x	x*	x	x*	x	x*	x	x*	x

* An additional lot of cuttings were dipped in a growth inhibitor and then treated with Hormodin No. 2 as a basal dip.

x Containing four photoperiods, normal day length, eight hours, sixteen hours and continuous illumination, with three replications of 10 cuttings each.

Stem cuttings were prepared in the usual commercial manner (4). Hardwood cuttings of Ligustrum amurense[3] and Philadelphus lemoinei[3] 6 and 5 inches in length were made from previous season's wood on January 14 and 28 respectively, hot callused for one day, stored at 41° F. until the cuttings were placed in the rooting media on February 4 and 5. The cuttings were sprayed with chemicals on February 23, removed and graded on March 22 and May 20, respectively.

Softwood cuttings of Pelargonium hortorum[4] and Chrysanthemum hortorum[5] 4 and 3 inches in length were made from tips of shoots, respectively. Cuttings were made on February 16 and 18, placed in the rooting media on February 17 and 19, sprayed on February 25 and March 1, and removed and graded on March 28 and 20, respectively.

Evergreen cuttings approximately 6½ inches in length were made from tips of previous season's growth of Taxus cuspidata[3]. The cuttings were prepared on February 8, placed in the rooting media February 10, sprayed March 3, removed and graded June 3.

Cuttings were removed or pulled in the usual commercial manner and given a top and root index which was obtained by grading the cuttings according to the amount of growth which had occurred on both tops and roots. The various grades consisted of heavy, medium, light or zero (Figure 1). An index number was obtained by assigning a numerical value of five for heavy, three for medium, one for light and none for zero.

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3) Cuttings obtained from Campus of Michigan State University.

4) Cuttings obtained from Sunset Gardens, Lamita, California.

5) Cuttings obtained from rooted cuttings from Neal Brothers, Toledo Ohio.

All experiments were arranged in a randomized block of three replications with 10 cuttings to a treatment. All cuttings were placed in a medium of quarts sand and fine limestone gravel on a bench in a greenhouse fluctuating between 70° F. at night and about 80° F. during the day.

Figure 1. Arbitrary grades used to determine degree of rooting of <u>Taxus cuspidata</u> cuttings from left to right, heavy, medium, light and zero.

EXPERIMENTAL RESULTS

It was evident at the time of removal of cuttings from the rooting media that there were variations in the rooting of the various plant materials. It was believed that length of day was an important factor in the rooting of cuttings. However, no statistical comparison was made between the photoperiods, although statistical comparisons were made between chemical treatments within the photoperiods.

The growth inhibitors had a pronounced inhibiting effect upon both root formation and shoot growth under all photoperiods. The effect of these inhibitors on root formation of softwood cuttings of Chrysanthemum hortorum, (variety Indianapolis Yellow) is shown in Table II. Maleic hydrazide significantly inhibited root formation in softwood cuttings of Chrysanthemum hortorum. There was also a significant difference in inhibition by maleic hydrazide due to concentration, but not method of application. The sodium salt of alpha-beta-dichloroisobutyric acid inhibited root formation of Chrysanthemum hortorum cuttings. The degree of inhibition was not nearly as pronounced as in the case of maleic hydrazide.

The effect of concentration and method of application of maleic hydrazide and the sodium salt of alpha-beta-dichloroisobutyric acid on root formation and top growth of softwood cuttings of Pelargonium hortorum, (variety Better Times) is shown in Table III. The result indicates that maleic hydrazide when applied to cuttings as a dip at 500 and 3000 p.p.m. and as a spray at 3000 p.p.m. inhibited subsequent root formation. The sodium salt of alpha-beta-dichloroisobutyric acid applied to cuttings as a dip at 3000 p.p.m. significantly inhibited root formation. It was observed that the amount of top or shoot growth was associated with amount of root growth. When root growth was severely inhibited by chemical treatment, top growth was also inhibited (Table III).

The results of various concentrations and methods of application of maleic hydrazide and sodium salt of alpha-beta-dichloroisobutyric acid on root formation and top growth of hardwood cuttings of Ligustrum amurense are presented in Table IV. When either maleic hydrazide or the sodium salt of alpha-beta-dichloroisobutyric acid was applied as a dip treatment at 3000 p.p.m. to cuttings, root formation was inhibited. Some stimulation of root growth was observed at lower concentrations, but was not significant.

Shoot growth on Ligustrum amurense cuttings appeared to be closely correlated with root formation (Table IV). Greatest shoot growth inhibition occurred when the cuttings were treated with maleic hydrazide as a dip at 3000 p.p.m. Some inhibition of shoots occurred when maleic hydrazide was used on cuttings as a 500 p.p.m. dip treatment and with the sodium salt of alpha-beta-dichloroisobutyric acid applied to the cuttings at 3000 p.p.m. as either a spray or a dip.

The results of the effect of various concentrations and methods of application of maleic hydrazide and the sodium salt of alpha-beta-dichloroisobutyric acid to shoot and root growth of hardwood cuttings of Philadelphus lemoinei (variety Avalanche) is presented in Table V. Maleic hydrazide applied as a dip at both 500 and 3000 p.p.m. significantly inhibited root growth of cuttings. No effects were observed when the sodium salt of alpha-beta-dichloroisobutyric acid was applied as either a dip or a spray at either 500 or 3000 p.p.m.

Shoot growth of Philadelphus lemoinei (variety Avalanche) was closely correlated with root formation (Table V). The treatments that inhibited shoot growth significantly was the dip applications of 500 and 3000 p.p.m. of the sodium salt of alpha-beta-dichloroisobutyric acid and maleic hydrazide at 3000 p.p.m. applied as a spray and a dip.

The effect of a commercial root promoting hormone (Hormodin No. 2) applied simultaneously with maleic hydrazide and the sodium salt of dichloroisobutyric acid on the root formation of evergreen cuttings of Taxus cuspidata (spreading form) is shown in Table VI. Taxus cuspidata (spreading form) cuttings treated with Hormodin No. 2 either alone or in combination with maleic hydrazide or the sodium salt of alpha-beta-dichloroisobutyric acid significantly increased rooting (Table XIII, Figures 2, 3, 4 and 5). Maleic hydrazide, by itself, applied by means of a spray at 3000 p.p.m. significantly inhibited root formation (Figure 6).

The effect of interaction between photoperiods, and the various growth regulators on root formation of the various ornamental cuttings is shown in Tables VII through XIV. It is invalid, statistically, to compare the interaction of the various photoperiods, due to the lack of replications of the photoperiods. The effect on root formation of the interaction of the different photoperiods and untreated and maleic hydrazide, applied by means of a dip at 3000 p.p.m. treated Ligustrum amurense cuttings is shown in Figure 7.

TABLE II

Effect* of Concentration and Method of Application of Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on the Root Formation of Softwood Cuttings of Chrysanthemum hortorum, (Variety Indianapolis Yellow).

Treatment	Rooting Index
Control	47.2
Maleic Hydrazide, 3000 p.p.m. dipped	.83
" " , " " sprayed	3.83
" " , 500 p.p.m. dipped	12.25
" " , " " sprayed	14.91
Na-alpha-beta-isobutyric acid, 3000 p.p.m. dipped	38.33
" " " " " , " " sprayed	38.33
" " " " " , 500 p.p.m. dipped	33.33
" " " " " , " " sprayed	40.41
L.S.D. at 5% level	9.99

Date put in medium: Feb. 19, 1956
Date sprayed: March 3, 1956
Date pulled: March 20, 1956
No. of days in the medium: 30 days

* Average of four photoperiods, three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE III

Effect* of Concentration and Method of Application of Maleic Hydrazide and Na-alpha-beta-dichloroiso-butyric Acid on the Root Formation and Top Growth of Pelargonium hortorum, (Variety, Better Times).

Treatment	Rooting Index	Top Growth Index
Control	11.06	17.83
Maleic Hydrazide, 3000 p.p.m. dipped	1.83	10.75
" " , " " sprayed	2.83	12.58
" " , 500 p.p.m. dipped	1.41	13.41
" " , " " sprayed	9.99	17.33
Na-alpha-beta-dichloroisobutyric acid, 3000 p.p.m. dipped	4.49	13.82
" " " " " , " " sprayed	10.58	16.66
" " " " " , 500 p.p.m. dipped	6.74	15.66
" " " " " , " " sprayed	9.16	15.83
L.S.D. at 5% level	4.68	4.92

Date put in the medium: Feb. 17, 1956
Date dipped: Feb. 17, 1956
Date sprayed: Feb. 23, 1956
Date pulled: March 28, 1956
Days in the medium: 40

* Average of four photoperiods of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE IV

Effect* of Concentration and Method of Application of Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on the Root Formation and Shoot Growth of Hardwood Cuttings of *Ligustrum amurense* .

Treatment	Rooting Index	Shoot Index
Control	36.58	39.99
Maleic Hydrazide, 3000 p.p.m. dipped	17.08	18.49
" " , " " sprayed	38.66	38.27
" " , 500 p.p.m. dipped	32.88	31.58
" " , " " sprayed	39.91	38.41
Na-alpha-beta-dichloroisobutyric acid, 3000 p.p.m. dipped	31.83	32.88
" " " " " , " " sprayed	33.33	31.48
" " " " " , 500 p.p.m. dipped	38.42	40.48
" " " " " , " " sprayed	38.00	36.83
L.S.D. at 5% level	4.08	4.20

Date put in medium: Feb. 4, 1956
Date dipped: Feb. 4, 1956
Date sprayed: Feb. 23, 1956
Date pulled: March 22, 1956
Days in the medium: 47

* Average of four photoperiods of 3 replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE V

Effect* of Concentration and Method of Application of Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on the Root Formation and Shoot Growth of Hardwood Cuttings of Philadelphus lemoinei, (Variety, Avalanche).

Treatment	Rooting Index	Shoot Index
Control	12.16	21.66
Maleic Hydrazide, 3000 p.p.m. dipped	4.42	12.41
" " , " " sprayed	8.83	17.91
" " , 500 p.p.m. dipped	10.08	18.41
" " , " " sprayed	7.66	18.41
Na-alpha-beta-dichloroisobutyric Acid, 3000 p.p.m. dipped	6.33	13.66
" " " " " , " " sprayed	8.08	18.58
" " " " " , 500 p.p.m. dipped	7.16	16.50
" " " " ", " " sprayed	12.49	20.16
L.S.D. at 5% level	4.44	4.53

Date put in the medium: Feb. 5, 1956
Date dipped: Feb. 5, 1956
Date sprayed: March 1, 1956
Date pulled: May 20, 1956
Days in the medium: 105

* Average of four photoperiods of 3 replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE VI

Effect* of Hormodin No. 2 on the Concentration and Method of Application of Maleic Hydraside and Na-alpha-beta-dichloroisobutyric Acid in the Root Formation of Evergreen Cuttings of *Taxus cuspidata*.

Treatment	Rooting Index
Control	14.00
Hormodin No. 2	24.33
Maleic Hydraside, 3000 p.p.m. dipped	13.33
" " , " " " , Hormodin No. 2	21.50
" " , " " sprayed	7.92
" " , 500 p.p.m. dipped	11.17
" " , " " " , Hormodin No. 2	26.08
" " , " " sprayed	13.17
Na-alpha-beta-dichloroisobutyric acid, 3000 p.p.m. dipped	11.95
" " " " " , " " " , Hormodin No. 2	23.3
" " " " " , " " sprayed	12.83
" " " " " , 500 p.p.m. dipped	12.75
" " " " " , " " " , Hormodin No. 2	26.5
" " " " " , " " sprayed	15.08
L.S.D. 5% level	5.59

Date put in the medium: Feb. 10, 1956 Date pulled: June 3, 1956
Date dipped: Feb. 10, 1956 Days in the medium: 113
Date sprayed: March 1, 1956

* Average of four photoperiods, three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

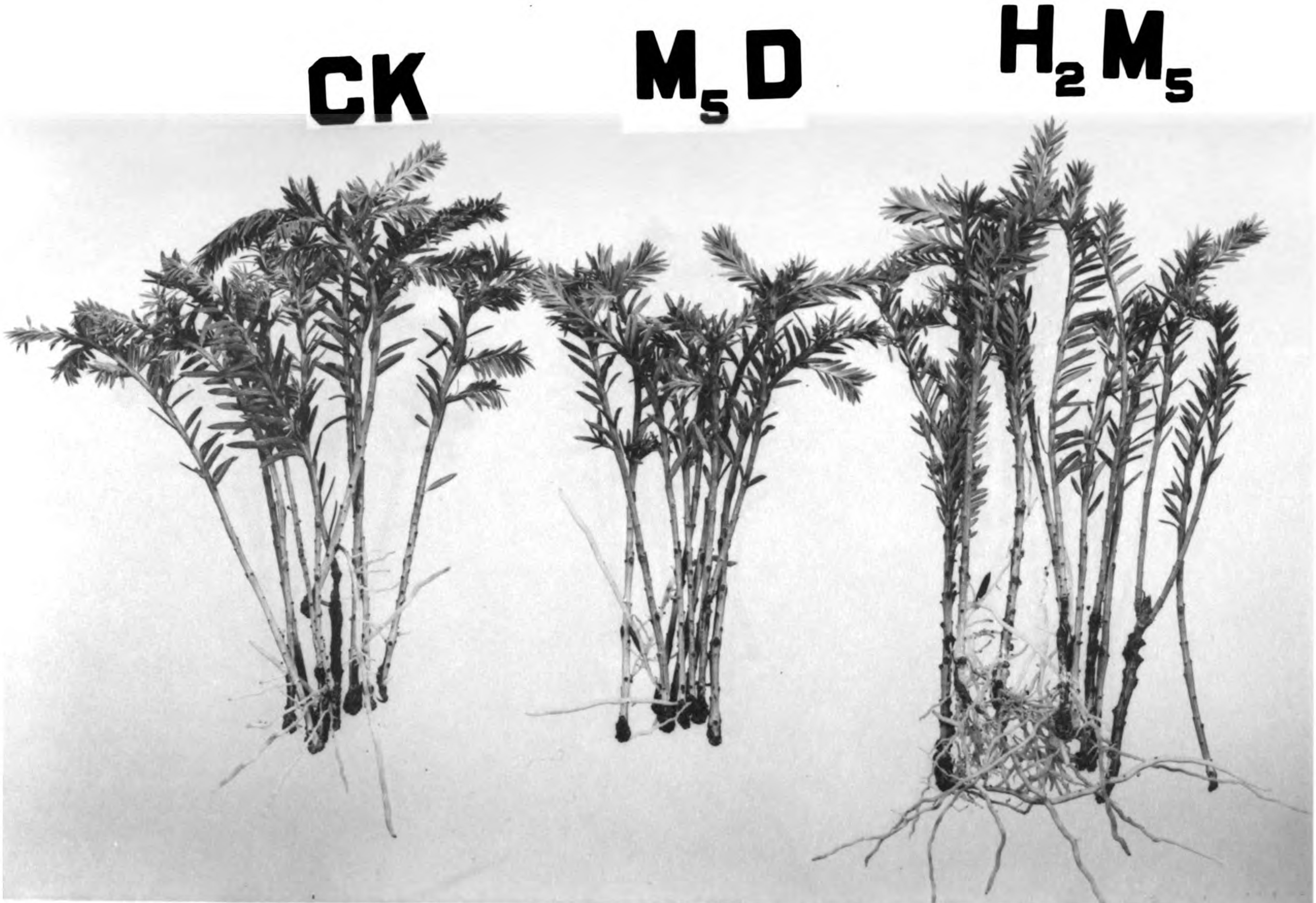

Figure 2. <u>Taxus</u> <u>cuspidata</u> cuttings untreated (CK), treated with maleic hydrazide, 500 p.p.m. dipped (M_5D) and a combination of maleic hydrazide dipped and Hormodin No. 2 (H_2M_5)

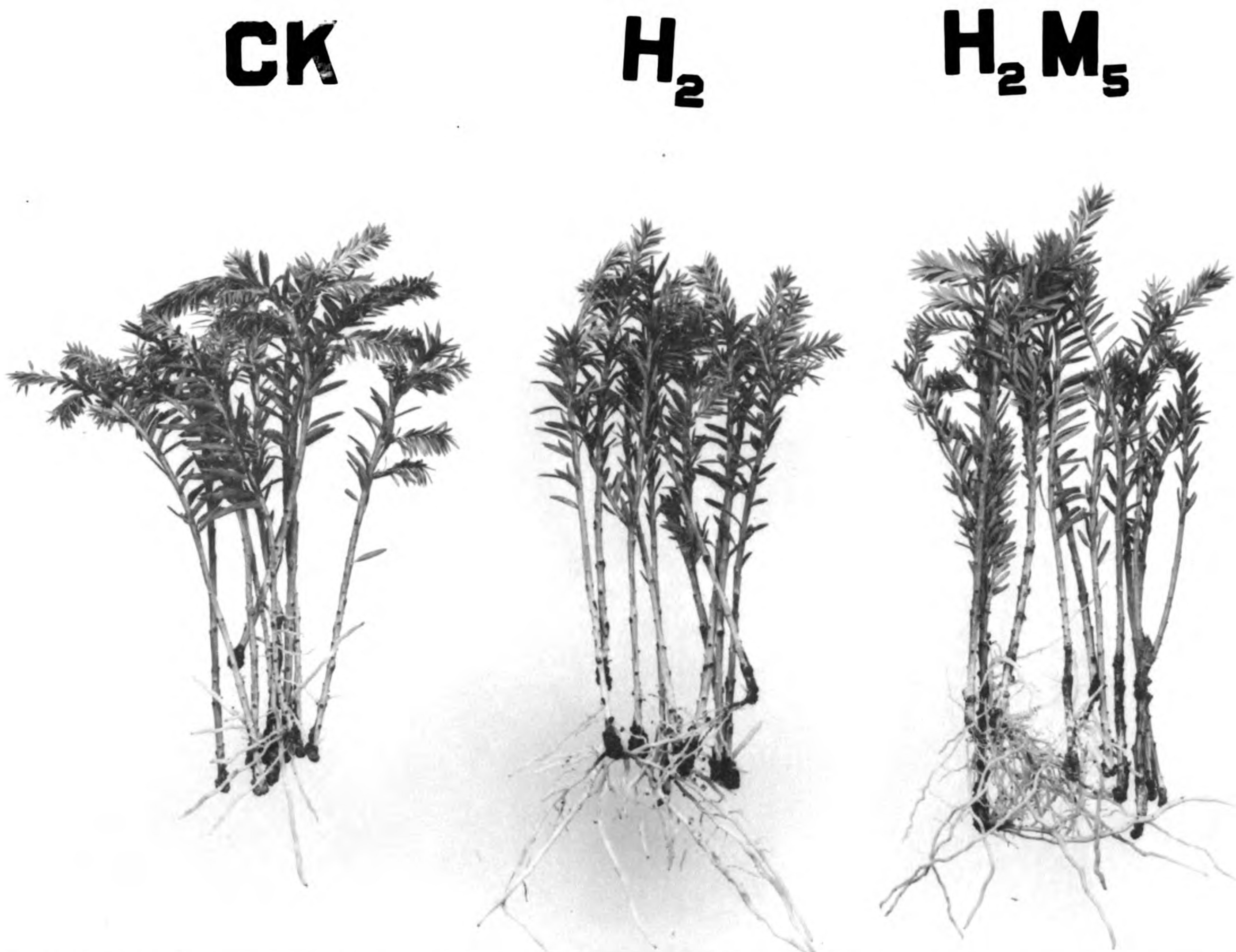

Figure 3. __Taxus cuspidata__ cuttings untreated (CK), treated with Hormodin No. 2 (H_2) and a combination of maleic hydrazide, dipped at 500 p.p.m. and Hormodin No. 2 (H_2M_5)

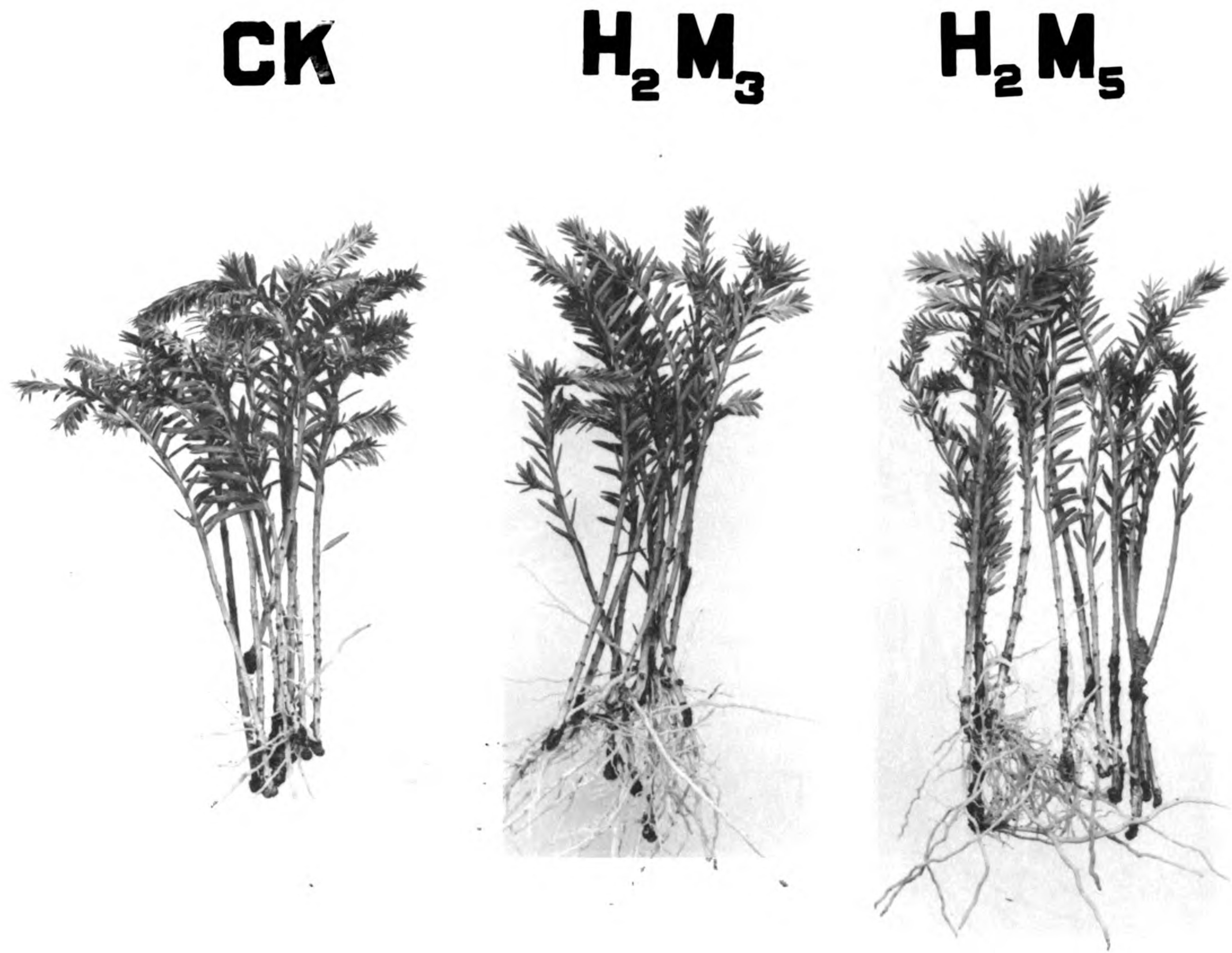

Figure 4. <u>Taxus cuspidata</u> cuttings untreated (CK), treated with a combination of Hormodin No. 2 and maleic hydrazide as a dip of 500 p.p.m. (H_2M_5) and 3000 p.p.m. (H_2M_3)

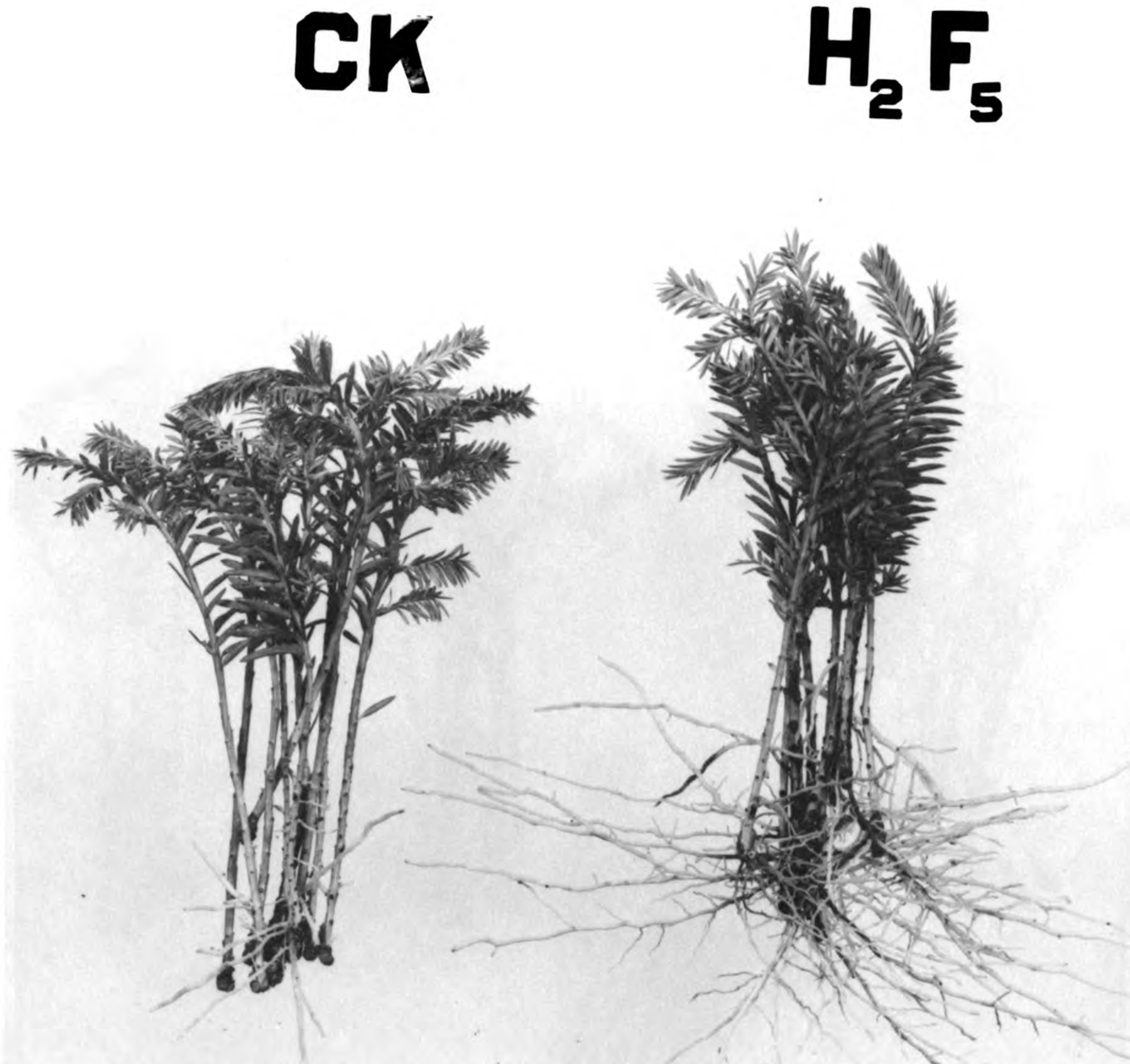

Figure 5. *Taxus cuspidata* cuttings untreated (CK), treated with a combination of Hormodin No. 2 and the dip of sodium salt of alpha-beta-dichloroisobutyric acid at 500 p.p.m.

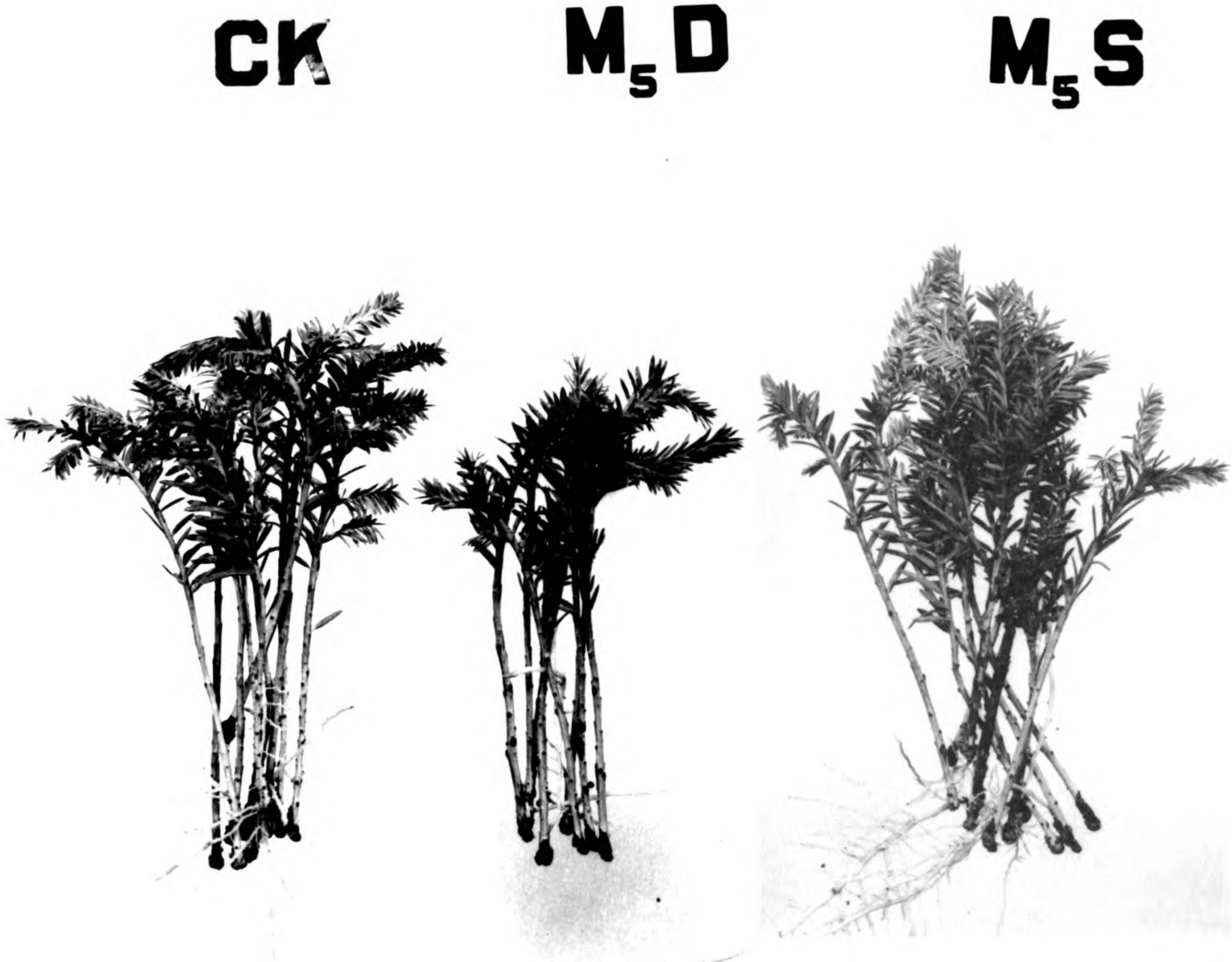

Figure 6. *Taxus cuspidata* cuttings untreated (CK), with maleic hydrazide, 500 p.p.m. as a dip (M_5D) and as a spray (M_5S)

TABLE VII

A Rooting Index* Showing the Effect of Interaction Between Photoperiod and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on Root Formation of Softwood Cuttings of Chrysanthemum hortorum, (Variety Indianapolis Yellow).

Photoperiod	Chemical Treatment								
	Check	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric			
		500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
		Dip	Spray	Dip	Spray	Dip	Spray	Dip	Spray
8 hours	43.0	12.00	16.66	0	4.00	32.66	46.66	35.66	31.33
Normal	48.0	28.00	11.00	0	4.33	37.33	33.33	35.33	34.66
16 hours	48.0	4.33	16.66	3.33	2.33	29.66	40.33	38.00	49.33
Continuous	50.0	4.66	15.33	0	4.66	33.66	41.33	44.33	38.00

Date put in medium: Feb. 19, 1956
Date dipped: March 3, 1956
Date sprayed: March 3, 1956
Date pulled: March 20, 1956
Number of days in the medium: 30 days

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE VIII

A Rooting Index* Showing the Effect of Interaction Between Photoperiod and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on the Root Formation of Softwood Cuttings of Pelargonium hortorum, (Variety, Better Times) (1).

Photoperiod	Chemical Treatment								
	Check	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric			
		500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
		Dip	Spray	Dip	Spray	Dip	Spray	Dip	Spray
8 hours	9.66	.66	8.66	4.66	4.66	8.0	3.66	4.66	4.66
Normal	13.33	2.33	15.00	0.33	2.33	9.0	19.00	5.33	22.00
16 hours	10.33	1.33	11.66	1.66	1.66	8.66	3.66	2.66	5.33
Continuous	13.33	1.33	4.66	0.66	2.66	1.33	10.33	5.33	10.33

Date put in medium: Feb. 17, 1956
Date dipped: Feb. 17, 1956
Date sprayed: Feb. 23, 1956
Date pulled: March 28, 1956
Days in the medium: 40 days

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

(1) Pulled immature due to heavy infestation of disease

TABLE IX

A Top Growth Index* Showing the Effect of Interaction Between Photoperiod and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid in the Top Growth of Softwood Cuttings of *Pelargonium hortorum*, (Variety, Better Times).

Photoperiod	Chemical Treatment								
	Check	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric			
		500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
		Dip	Spray	Dip	Spray	Dip	Spray	Dip	Spray
8 hours	18.33	15.33	22.0	12.0	12.66	15.66	14.0	17.66	16.0
Normal	18.66	11.66	18.66	11.66	14.33	20.00	24.66	13.66	23.0
16 hours	15.33	14.66	15.33	12.0	13.33	17.33	10.0	11.33	12.0
Continuous	19.00	12.00	13.33	7.33	10.00	9.66	14.66	12.66	15.66

Date put in the medium: Feb. 17, 1956
Date dipped: Feb. 17, 1956
Date sprayed: Feb. 23, 1956
Date pulled: March 28, 1956
Days in the medium: 40

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE X

A Rooting Index* Showing the Effect of Interaction Between Photoperiod and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on Root Formation of Hardwood Cuttings of <u>Ligustrum amurense</u>.

Photoperiod	Check	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric			
		500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
		Dip	Spray	Dip	Spray	Dip	Spray	Dip	Spray
8 hours	33.00	30.66	36.66	17.00	39.66	39.00	40.00	29.00	33.33
Normal	41.33	28.66	42.33	14.33	40.66	39.00	37.66	27.33	37.33
16 hours	39.33	36.00	40.66	9.00	38.66	40.33	39.33	36.33	30.33
Continuous	32.66	35.33	40.00	28.00	35.66	35.33	31.00	34.66	32.33

Date put in medium: Feb. 4, 1956
Date dipped: Feb. 4, 1956
Date sprayed: Feb. 23, 1956
Date pulled: March 22, 1956
Days in the medium: 47

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE XI

A Top Growth Index* Showing the Effect of Interaction Between Photoperiod and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid in Top Growth of Hardwood Cuttings of *Ligustrum amurense*.

Photoperiod	Check	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric			
		500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
		Dip	Spray	Dip	Spray	Dip	Spray	Dip	Spray
8 hours	36.66	28.66	30.66	16.66	37.00	38.66	37.33	32.66	29.00
Normal	41.33	29.00	41.66	16.00	38.66	40.00	36.66	29.66	33.33
16 hours	38.00	29.33	38.66	13.33	39.33	39.33	36.00	31.33	27.00
Continuous	44.00	39.33	42.66	28.00	38.00	44.00	37.33	37.00	36.66

Date put in the medium: Feb. 4, 1956
Date dipped: Feb. 4, 1956
Date sprayed: Feb. 23, 1956
Date pulled: March 22, 1956
Days in the medium: 47

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

Figure 7. Root Formation of <u>Ligustrum</u> <u>amurense</u> cuttings (above) untreated and (below) treated with maleic hydrazide as a dip at 3000 p.p.m. in the various photoperiods. Photoperiods (above left to right) normal, sixteen hours, eight hours and continuous illumination. (Below left to right) continuous, eight hours, normal and sixteen hours of light.

TABLE XII

A Shoot Growth Index* Showing the Effect of Photoperiod and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on the Shoot Formation of Hardwood Cuttings of Philadelphus lemoinei, (Variety Avalanche).

Photoperiod	Check	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric			
		500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
		Dip	Spray	Dip	Spray	Dip	Spray	Dip	Spray
Normal	25.66	16.33	13.33	6.0	17.33	18.33	12.33	11.33	14.33
8 hours	19.00	8.66	22.66	12.0	21.66	16.00	29.00	11.33	21.00
16 hours	17.33	20.66	14.66	17.33	11.33	14.66	15.66	11.66	16.66
Continuous	21.66	28.00	23.00	14.33	21.33	17.00	23.66	20.33	22.33

Date put in medium: Feb. 5, 1956
Date dipped: Feb. 5, 1956
Date sprayed: March 1, 1956
Date pulled: May 20, 1956
Days in the medium: 105

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE XIII

A Rooting Index* Showing the Effect of Photoperiod and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on the Root Formation of Hardwood Cuttings of *Philadelphus lemoinei*, (Variety Avalanche).

Photoperiod	Chemical Treatment								
	Check	Maleic Hydrazide				Na-alpha-beta-dichloroisobutyric			
		500 p.p.m.		3000 p.p.m.		500 p.p.m.		3000 p.p.m.	
		Dip	Spray	Dip	Spray	Dip	Spray	Dip	Spray
Normal	6.66	10.66	7.00	2.00	6.00	2.00	8.33	6.66	1.66
8 hours	7.66	3.33	20.00	5.00	10.33	6.33	20.00	3.00	13.33
16 hours	12.66	13.33	7.33	2.66	4.66	7.33	7.00	8.66	7.66
Continuous	21.66	13.00	14.33	8.00	14.33	13.00	14.66	7.00	9.66

Date put in medium: Feb. 5, 1956
Date dipped: Feb. 5, 1956
Date sprayed: March 1, 1956
Date pulled: May 20, 1956
Days in the medium: 105

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

TABLE XIV

A Rooting Index* Showing the Effect of Photoperiod, Hormodin No. 2 and Maleic Hydrazide and Na-alpha-beta-dichloroisobutyric Acid on the Root Formation of Evergreen Cuttings of <u>Taxus cuspidata</u> (spreading form).

Photoperiod	Chemical Treatments													
	Check	Horm.**	Maleic Hydrazide						Na-alpha-beta-dichloroisobutyric					
			500 p.p.m.			3000 p.p.m.			500 p.p.m.			3000 p.p.m.		
			Dip		Spray	Dip		Spray	Dip		Spray	Dip		Spray
			Horm.	No Horm.		Horm.	No Horm.		Horm.	No Horm.		Horm.	No Horm.	
8 hour	13.3	26.7	28.3	10.7	13.7	20.7	11.0	11.3	33.0	16.3	13.3	21.3	10.0	10.3
Normal	12.0	25.7	32.3	7.3	11.7	23.0	18.0	6.0	27.3	15.7	11.0	21.0	8.0	7.3
16 hour	10.3	23.3	20.7	12.0	12.7	20.3	15.0	6.3	18.7	15.7	12.0	23.0	14.3	12.7
Continuous	20.3	21.7	23.0	14.7	14.7	22.0	9.3	8.0	27.3	12.7	14.7	27.0	13.3	19.0

Date put in the medium: Feb. 10, 1956
Date dipped: Feb. 10, 1956
Date sprayed: March 1, 1956
Date pulled: June 3, 1956
Days in the medium: 113

* Average of three replications of 10 cuttings each, graded according to an index with the highest possible value of 50.

** Horm. abbreviation for Hormodin No. 2.

DISCUSSION

An attempt has been made to determine the practical boundaries of the usage of photoperiod and growth inhibitors in the asexual propagation of various types of ornamental plants. Results of this experiment indicate root formation of various ornamental cuttings influenced by certain growth inhibitors varies with the method of application, the concentration and the photoperiod.

In no instance did a growth inhibitor, used alone, significantly increase root formation. However, it was evident that in some cases root growth was greater than that of the control. When a growth inhibitor was used in conjunction with a root promoting compound, root formation was significantly increased from that of the control.

In softwood cuttings of Chrysanthemum hortorum and Pelargonium hortorum it was evident that maleic hydrazide significantly inhibited root formation, while the sodium salt of alpha-beta-dichloroisobutyric acid inhibited root formation, but not significantly at the 3000 p.p.m. concentration. No differences between the methods of application in softwood cuttings was observed. Hardwood cuttings of Ligustrum amurense and Philadelphus lemoinei and evergreen cuttings of Taxus cuspidata were inhibited more by dip applications of the inhibitors. This would suggest that softwood cuttings are more sensitive to maleic hydrazide than the sodium salt of alpha-beta-dichloroisobutyric acid. While in hardwood cuttings both inhibitors affected root formation in the same manner. It is also evident that concentration of an inhibitor is more critical in softwood cuttings, than in hardwood cuttings and that hardwood cuttings are effected more by a dip application than by a spray application. In evergreen cuttings of _Taxus cuspidata_, it was concluded that an inhibitor could be combined with a root promoting substance to increase rooting.

SUMMARY

1. The effects of certain concentrations and methods of applications of growth inhibitors, combinations of a growth inhibitor and a root-promoting substance and photoperiod on root formation were investigated.

2. Root formation was significantly increased on _Taxus cuspidata_ cuttings by the use of Hormodin No. 2 or a combination of Hormodin No. 2 and either maleic hydrazide or the sodium salt of alpha-beta-dichloroisobutyric acid.

3. Root formation was not significantly increased by the sole use of either maleic hydrazide or the sodium salt of alpha-beta-dichloroisobutyric acid at 500 or 3000 p.p.m. applied by means of a dip or a spray.

4. Maleic hydrazide applied as a dip at 3000 p.p.m. inhibited root formation of the various plant materials used in this experiment.

5. In certain instances the sodium salt of alpha-beta-dichloroisobutyric acid also inhibited root formation.

6. It was evident that root formation was closely associated with top growth in _Pelargonium hortorum_, _Ligustrum amurense_ and _Philadelphus lemoinei_.

7. Though it was evident that photoperiod influenced rooting, no statistical comparisons could be made due to the lack of replications of the various photoperiods.

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