ROOTING COMPOUNDS AND THEIR USE IN PLANT PROPAGATION

MICHAEL A. DIRR

Department of Horticulture, University of Georgia, Athens, Georgia 30602

A review of the pertinent literature shows that numerous chemical compounds have been tested for root-promoting activity. It is estimated that well over 10,000 chemicals show positive formative effects (17). The essence of chemical plant propagation began in 1934 with the discovery of a naturally occurring auxin, indole-3-acetic acid (IAA) (15). The demonstration that two synthetic (do not occur in higher plants) auxins, indole-3-butyric acid (IBA) and naphthaleneacetic acid (NAA), induce a greater rooting response was shown by Zimmerman and Wilcoxon in 1935 (21). In 1937, Zimmerman and Hitchcock published a paper (20) showing the comparative effectiveness of the acids, esters and salts of IAA, IBA and NAA in rooting cuttings and other growth responses. The essence of their work is described throughout this paper. I heartily recommend that nurserymen secure copies of these papers for their files.

Modern plant propagation revolves around the use of IBA, NAA, and their derivatives. Both 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP) have been used for rooting cuttings (16,18). They show potent root promoting activity but are readily translocated throughout the cutting and may delay bud break or induce other adverse effects. A nurseryman should experiment with these compounds rather than attempting wholesale use. At the recent International Plant Propagators' Society, Eastern Region, meeting in Orlando, Florida, I talked with a nurseryman who is using 2,4,5-TP in conjunction with IBA-talc to root junipers. He has had fantastic results with about 1200 to 1500 ppm 2,4,5-TP plus 0.8% IBA-talc. Both 2,4-D and 2,4,5-TP are potent weed killers, and extreme caution must be exercised when utilizing these compounds. Perhaps if IBA or NAA are not producing the desired results, then one might experiment.

Commercial preparations (3,8,19) that are/have been available to nurserymen are presented in Table 1. Many are no longer available, and the current crop of favorites includes Hormodin, Hormo-Root, Hormex, Rootone and Dip 'N Gro. The first four are talc (powder) formulations that contain IBA at various concentrations. The Hormodin 1, 2 and 3 formulations represent 0.1%, 0.3%, and 0.8% IBA or 1000, 3000 and 8000 ppm IBA, respectively. Hormo-Root A, B and C are similar in

IBA concentrations except B contains 0.4% IBA. Hormo-Root also contains 15% thiram. Rootone is offered in different talc formations, and the Rootone F contains 4.0% 1-naphthyleneacetamide and 4.0% thiram. Rootone 10 contains only 0.4% 1-naphthenacetamide. Dip 'N Gro is a liquid concentrate that is diluted according to the difficulty of the cuttings being rooted. It contains 1.0% IBA, 0.5% NAA and boron plus an organic solvent as the carrier. There may be other ingredients for it is described as possessing antibacterial and antifungal properties. Other commercial preparations that deserve a casual mention include Seradix, more or less the British equivalent of Hormodin, and Chloromone, a product containing chlorophyll extract derived from alfalfa and NAA. Jiffy Grow may no longer be available but did contain an interesting and apparently effective combination of 0.5% IBA, 0 5% NAA, 175 ppm boron, phenylmercuric acetate, and alcohol as the solvent.

Table 1. Commercial rooting preparations frequently encountered in plant propagation literature *

Auxan	Ree Root
Auxilan	Rhizopan
Chloromone**	Rootagen
Dip 'N Gro**	Rootone**
Hormex 1, 3, 8, 16, 30, 45**	Seradix
Hormodin 1, 2, 3**	Stim Root
Hormo-Root A, B, C**	Synergol (potassium salt of IBA and NAA in liquid formulation)
Hormovita	Wood's Rooting Compound
Jiffy Grow	
Proliferol	

* This list is not exhaustive
** Preparations that are commonly used in the United States

Wood's Rooting Compound is relatively new on the market and has received an EPA label. It contains 10,000 ppm IBA, 5000 ppm NAA and 20% dimethyl formamide as a carrier. The other 80% is ethyl alcohol. It is diluted (1:5, 1:10, etc.) like Dip 'N Grow to approximate the difficulty of the cutting being rooted. One propagator has indicated that it is better than straight IBA on certain plants.

The essence of all the commercial preparations centers around IBA, NAA, and their derivatives. IAA, although naturally occurring, is seldom used as a rooting compound because it is broken down by a naturally occurring enzyme (IAA oxidase) system, is destroyed by light and a bacterium, *Acetobacter* sp., that is widely distributed. This same organism has no effect on IBA or NAA. IBA can be adversely affected by exposure to strong light, but the effect is minimal. NAA seems to be entirely light stable. It should be mentioned that when pure chemicals are purchased the label prescribes storing IBA at 32 to 41°F, IAA at 32°F and NAA at room temperature which serves as an indication of their relative heat stability. The pure chemicals of IBA and IAA usually come in a brown bottle which offers light protection.

A most confusing aspect of IBA and NAA is their designation in chemical catalogs and the literature as α, β or δ forms. I always questioned what difference the form made but in searching the literature came upon the paper by Zimmerman and Hitchcock that answered the question In short, the δ form of IBA is the most effective while the α form of NAA is 100 times more effective than the β form in promoting rooting of cuttings. There is a significant cost difference with the β form of NAA selling for 10 times as much as the α form. As a rule, IBA offers much more latitude than NAA for rooting cuttings. Cuttings of a particular species or cultivar will root over a wide range of IBA concentrations. I know of one large nursery firm that utilizes NAA exclusively for cutting propagation. When a nurseryman compares the cost of NAA to IBA, there is good reason to at least run comparative effectiveness studies between the two chemicals. Combinations of IBA and NAA are often used; the idea being to derive the best effects of both in a single treatment. The literature is full of testimonials to the combination, but there are as many studies that show no superiority of the combination over IBA alone. Mrs. Sue Burd Brogden, one of my former graduate students, conducted an extensive study on rooting cuttings of selected crabapples, 'Bradford' pear, serviceberry, paper birch and silverbell. The cuttings were sampled from May to August and treated with IBA, NAA, or a combination by the concentrated dip method at rates of 0, 2,500, 10,000, 20,000 and 30,000 ppm.

The results showed that·

(1) There were inherent differences among the crabapple taxa as to their degree of rooting.

(2) The earliest sampling date and the lowest concentrations of IBA (2,500 and 10,000 ppm) proved the most effective for rooting crabapples, although there was wide variance in rooting depending on timing, hormone and concentration.

(3) *Amelanchier arborea* and *Betula papyrifera* rooted in low percentages throughout the season although other investigators have had good success with *Amelanchier* spp.

(4) *Halesia carolina* rooted successfully on all four collection dates at low IBA and NAA levels (2,500 and 10,000 ppm).

(5) Cuttings treated with IBA showed greater rooting percentages, numbers and lengths compared to NAA and the combination-treated cuttings.

(6) There was no relationship between callus formation and rooting percentage.

(7) Cuttings which did not receive a hormonal treatment (control) showed limited rooting.

(8) The two highest concentrations (20,000 and 30,000 ppm) often resulted in defoliation or death of the cutting.

(9) Successful transplanting of rooted cuttings is strongly related to root numbers and length. Percentage should not be the sole parameter for evaluating rooting performance

(10) Percentage, root number and length offered valid indices of rooting quality. Callus formation bore no relationship to rooting and should not be used as an index.

Many nurserymen use the concentrated quick dip method. This involves dissolving the acid form of IBA or NAA in an organic solvent. IBA is soluble in ethanol while NAA is soluble at the ratio of 1 to 30 parts alcohol. This presents no problem to the nurseryman for it is doubtful he would need to exceed the solubility limits of NAA. The standard solvent is usually a 50% alcohol/water mixture, but any concentration is acceptable as long as the pure chemical dissolves Isopropyl alcohol is a suitable solvent and is available from the pharmacist. Polyethylene glycol (Carbowax) is frequently used as a solvent and carrier. DMSO, dimethyl sulfoxide, is also used; but care should be exercised. It penetrates skin as well as cuttings, and rubber gloves should be worn The basis for utilizing DMSO is that it "carries" the IBA into the tissue and, therefore, elicits a more uniform and possibly rapid rooting response. In humans, it causes bad breath, something approximating garlic.

A nurseryman can make his own concentrated IBA solution by dissolving ¼ level teaspoon of pure crystals in 3⅓ fluid ounces of 50% alcohol (5). This results in a 4000 ppm IBA solution which is suitable for a great number of woody plants. A full level teaspoon in the same volume results in a 16,000 ppm IBA solution A concentrated solution can be easily diluted to give varying strengths. It is difficult to do the same with a talc preparation because of the mess involved. See Machen (9) for a good discussion of mixing rooting substances.

In addition to the pure acids, various salts of these acids have been formulated and are available (Table 2). They are sold as the potassium or sodium salt. Their cost is comparable and perhaps slightly cheaper than the acids. The advantages are their free solubility in water yet similar effectiveness and stability (20) I recommend that nurserymen who are not interested in worrying with the acid and an alcohol solvent buy the salt. As a rule, the salts are less toxic to the cuttings than the acids.

Table 2. Suppliers of IBA, NAA and their derivatives.

Supplier	Address
Aldrich Chemical Co	940 West Saint Paul Avenue Milwaukee, WI 53233 414-273-3850
Baker, J T Chemical Co	222 Red School Lane Phillipsburg, NJ 08865 201-859-5411
ICN Pharmaceuticals, Inc K&K Labs Division	121 Express Street Plainview, NY 11803 516-433-6262
Pfaltz and Bauer, Inc	375 Fairfield Avenue Stamford, CT 06902 203-357-8700
Sigma Chemical Co.	P O Box 14508 Saint Louis, MO 63178 800-325-3010
United States Biochemical Corporation	P O Box 22400 Cleveland, OH 44122 800-321-9322

The cost of IBA and NAA from 3 suppliers is presented in Table 3. It is worth noting that the differences in price are significant.

A great controversy rages as to the relative effectiveness of talc formulations compared to quick dips (2,4,6,10,12,13,14). I prefer quick dips and use them in all my work. There is ample evidence to indicate the superiority of the quick dip over the powders. Meahl and Lanphear (11) reported that a quick dip was equal or superior to powder in the promotion of rooting. They also noted that, on an equivalent basis, 0.8% IBA powder was not as good as 0.8% IBA solution. Approximately 1500 cuttings can be treated with an ounce of the quick dip solution Supposedly, one pound of the powder treats 35,000 cuttings. My guess is that with the waste involved with powders something like 25,000 cuttings could be treated. This would approximate the number that could be treated with 16 ounces of a quick dip. Never return the powder to the can or the solution to the stock bottle. Use a small vessel for the powder or the solution. Never stick the cuttings in the original talc can or in the stock solution.

Table 3. Cost of IBA, NAA, and naphthaleneacetamide from the chemical supply companies

	Price per 5 grams		
Supplier	IBA	NAA	Naphthaleneacetamide
1	9 25	0 50	1 50
2	6 25	0 43	
3	10 20	1 30	

The general superiority of quick dips is probably related to the uniformity of coverage and perhaps the more rapid absorption of IBA. It is reasonable to assume that IBA or NAA in solution will be more rapidly absorbed by the cutting than that applied in a powder form which has to be solubilized.

The question has been raised many times as to how the 5-second dip became standard. Earlier work (11) showed that a 5-second dip was as effective as a 160-second dip in promoting rooting. A 320-second dip decreased rooting. It was determined that the decrease was caused by the 50% alcohol and not the IBA. This may be one of the few occasions when "haste does not make waste". It should be mentioned that extremely concentrated quick dips of 20,000 to 40,000 ppm IBA or NAA will often "burn" the base of the cutting. Rooting may occur in the untreated region just above the "burn".

Another technique that has been used is a dilute IBA or NAA solution and a longer soaking period. The solution may range from 20 to 200 ppm and the soak period from 6 to 24 hours. This technique appears to be effective but involves a time lag that is not inherent in the quick dip method. Howard (7) reported that similar levels of rooting were obtained with dipping times of 5000 ppm IBA for 5 seconds, 500 ppm for 30 seconds, and 50 ppm 18 minutes. The need for 24-hour soaks in aqueous solutions is due to the low solubility of IBA in water. Howard has also shown that best rooting occurred when cuttings were dipped as shallow as possible. Most nurserymen dip the cutting about one inch, and this is perfectly acceptable

Recently, a report (1) has surfaced relative to the "Willow Rooting Substance". Dr. Max Kawase, The Ohio State University, has shown that willow extracts, in combination with IBA, show synergistic properties. Yellow birch, *Betula alleghaniensis,* was rooted from cuttings by using the willow extract and IBA. IBA alone did not work Dr. Kawase is attempting to identify the chemical constituents of the willow extract. He mentioned that it was quite stable, has been refrigerated for six years and still retained its effectiveness. Apparently, most willow species will work with equal effectiveness. Current year stems (leaves removed) are cut into small pieces, packed into a container, and covered with water. This mixture is allowed to steep for 24 hours and is then drained off The resultant extract is used to treat the cuttings. Cuttings should be placed upright into the willow extract and allowed to absorb for 24 hours and then stuck.

Many commercial rooting products, some promising fantastic results, have come and gone since the 1940's The essence of their effectiveness, no matter how sophisticated the name, is based on IBA, NAA and their derivatives. Perhaps some new chemicals will make in-roads into modern cutting propagation, but only time will tell. Since 1935, IBA and NAA have proven to be two of the plant propagator's most valuable tools

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RANDY HEFNER: This is in the form of a comment to Dr Dirr. One advantage of a liquid dip is your ability to experiment. Talc is difficult to do that with

PETER DEL TREDICI. Does DMSO have any effect on rooting?

MICHAEL DIRR. It is mainly a carrier to get compounds into cuttings faster. I am not aware that it has any effect on rooting

PAUL BOSLEY, SR.. Life Science Industries, Cleveland, Ohio says that NAA is extremely poisonous. Do you agree?

MICHAEL DIRR. All I can say is that EPA has approved its use for the nursery industry

Tuesday Afternoon, December 8, 1981

The afternoon session was convened at 1.30 p.m with Rick Allred serving as moderator

EFFICIENCY IN PROPAGATION

BLAIR MASTBAUM
Scarff's Nursery, Inc.
New Carlisle, Ohio 45344

Labor costs in America have steadily increased while worker productivity has in many cases declined. The survival of our businesses depends largely on our ability to increase efficiency Labor costs comprise approximately 60% of my total budget Coupled with decreasing worker productivity I feel this is the first and most logical place to work on becoming more efficient

We begin by taking an unbiased look at our operation. Are the facilities efficient? Is everyone producing an equal amount and is the amount enough? Assuming the facilities and procedures are efficient and the goals are in order then the area to concentrate on is labor efficiency. What amount of production can we reasonably expect from our workers? I think one answer lies in the use of production standards. A production