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The World's Finest Plant Rooting Products
Hortus IBA Water Soluble Salts® and Rhizopon® AA

Use Rooting Hormones, or Not?
Multiple Applications May Be Best

Second Edition

Foliar applied Rooting Hormones in the form of K-IBA rooting solutions are used to propagate leafy plants from cuttings either by single or multiple applications.

- Basics of single and multiple rooting hormone applications
- The need for rooting hormones when propagating plants from cuttings
- Comparing single and multiple rooting hormone applications
- Cutting juvenility and maturity related to the use of rooting hormones
- Case studies, and trial blocks
- Considerations
- Conclusions, grower decisions, and final word
- Methods and materials

Plant Propagation: Basics of single and multiple rooting hormone applications

Cuttings taken from stock plants are used to propagate new plants. Using needed rooting hormones, growers are sometimes confronted with slow-to-root and hard-to-root cuttings. Multiple Rooting Solution foliar applications may improve root formation. Solutions may be applied once or multiple times in ten day to two week internals, and customized programs. Multiple solution applications use the foliar Spray Drip Down® Method which does not disturb planted cuttings.

The need to use Rooting Hormones when propagating plants from cuttings

The '*Use Rooting Hormone or Eat Ice Cream?*' article by BallFlora Plant's Advisors, squashes the myth by growers who feel 'any' roots produced on cuttings are enough. The article says, to produce high quality plants, the cuttings need high quality roots. Cuttings given rooting hormone applications produce higher quality roots and better root mass compared with untreated controls. Trials used the Spray Drip Down® Method of application using Hortus IBA Water Soluble Salts® rooting solutions.

Roots on cuttings are formed by the natural plant substances IAA (*Indole acetic acid*) and IBA (*Indole butyric acid*) in ways not fully understood by researchers. The substances, called 'auxins', are used by the cuttings to induce root cell division and root formation. Auxins are also called '**Rooting Hormones**'. Plant produced IAA and IBA are likely inadequate on their own to induce root formation on cuttings. Externally applied IBA boosts the cutting's natural rooting ability.

To enhance root production, rooting hormones are '*foliar*' applied to the leaves of plant cuttings, or to the basal ends (first application). Rooting solutions are used at the time of sticking and/or multiple foliar times; multiple foliar applications must be done by the **Spray Drip Down® Method**. Only at the time of sticking, dry powder rooting hormones are sometimes applied to the basal ends of cuttings.

The **Spray Drip Down® Method** uses rooting solutions with **IBA in the water soluble [aqueous] form K-IBA**, made with **Hortus IBA Water Soluble Salts** or **Rhizopon AA Water Soluble Tablets**. The cuttings are to be in the growing, non-dormant, state. Aqueous K-IBA rooting solutions are required for foliar applications. IBA and K-IBA rates are considered to be the same. The rooting solution is sprayed onto leaves of plant cuttings until there is a 'drip down' off the leaves. Entering the plant's vascular system through open stomata, IBA (K-IBA) translocates by polar transport to the basal end of the cuttings. At the basal end, the cuttings use IBA to induce root formation.

One Foliar K-IBA Application — *1X at Time of Sticking*

Two Foliar K-IBA Applications — *1X at Time of Sticking + 1X at Ten Days*

Foliar Spray Drip Down Method using Hortus IBA Water Soluble Salts K-IBA rooting solution on Osteospermum cuttings (photo 21 days after sticking)

Comparing single and multiple rooting hormone applications

Trials must be made to compare a single rooting product application with multiple foliar Spray Drip Down Method applications. Near or at the time of sticking, the cuttings are treated by any basal or foliar method. For multiple foliar applications the Spray Drip Down Method is used in either ways:

- Repeat foliar sprays in the next two to three days.
- Repeat foliar sprays in about ten day to two week intervals.

Multiple rooting solution applications need to be tested on various plant varieties. *If a particular plant species or variety is known to have low-rooting-ability, then beneficial multiple applications may be slow to be effective.*

The speed of root formation may be within a few days for physiologically 'juvenile' herbaceous plant cuttings, to many weeks for 'mature' hardy plant cuttings. When K-IBA rooting solutions are applied to the cuttings several times over an extended period, root formation may be speeded up.

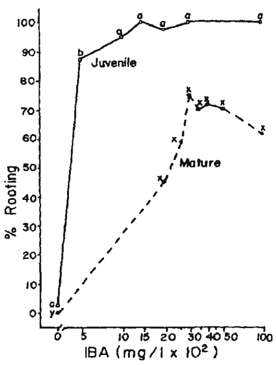
- For **'fast-to-root cuttings'** an initial application may be adequate.
- For **'slow-to-root cuttings'** it may be necessary to increase K-IBA rates. An application may be made the day of sticking, then several foliar applications in ten day to two week intervals.
- For **'hard-to-root cuttings'**, some 'mature' cuttings may benefit from several foliar applications in the first days after sticking, then additional applications in ten day to two week intervals. These cuttings should be taken at the time of the growing season when rooting ability is known to have high root yield.

Case studies

Decker Nursery propagates plants from cuttings by the Spray Drip Down Method using Hortus IBA Water Soluble Salts® aqueous K-IBA rooting solutions. Decker applies a fine spray mist, where the solution lightly covers all the cuttings. Rooting solutions are applied either by:

- first application within the day of sticking, then applications two additional days after sticking,
- first application within the day of sticking, then several applications in two week intervals.

Other growers use coarser sprays where the sprayed rooting solution drips down the leaves by the Spray Drip Down Method. Based upon the size of the cuttings, the common rooting solution rate is about 300-400 square feet per gallon (75-100 sf./liter).



← In Dr. Davies' *Ficus pumila* study, optimum IBA solution rates were first established by block test in a wide range of rates. The study concluded, juvenile cuttings required lower IBA rates, and produced roots faster than mature cuttings. **"Mature cuttings did not root as efficiently as juvenile material. IBA treated mature cuttings required higher exogenous [external] auxin levels and longer time to obtain maximum rooting than juvenile cuttings."** Juvenile cuttings given multiple IBA applications had increased rooting in all secondary application dates. Mature cuttings required a longer time between first and secondary applications to achieve improved root formation. Also noted, application of IBA “above the optimum level reduced root length and quality indicating the primordia elongation [origin length] was decreased.” (The decrease rooting effect was also noted in Dr. Hammer’s Osteospermum trial block upper and lower rates.) *The Fucus pumila study indicates there are positive benefits from multiple rooting solution applications.*

Cutting juvenility and maturity: use of multiple rooting hormone applications

Juvenile cuttings

- *Comparisons*: The best juvenile plant cuttings may be taken from stock plants started in the current growing year. Cuttings-from-cuttings are desirable. Perennial and woody plant cuttings may be taken either juvenile or mature depending when they are taken in the growing season.
- *Rooting ability may be influenced by juvenility and/or genotypes, such as color variations.*
- *Applications*: Juvenile cuttings may need secondary foliar applications fewer times, at shorter intervals, than mature cuttings.
  Some growers foliar apply on the day of sticking with additional applications in ten day intervals.
- *Rates*: Juvenile cuttings likely require lower rooting solution rates than mature cuttings.
- *Season*: Juvenile cuttings taken early in the season likely require lower rooting solution rates than mature cuttings taken later in the season.

Mature cuttings

- *Applications*: Mature cuttings may need secondary foliar applications several times, at longer intervals, than juvenile cuttings.
  Some growers foliar apply solutions in each of the first three days after sticking; additional applications are made in two week intervals.
- *Rates*: Mature cuttings likely require higher rooting solution rates than juvenile cuttings.
- *Season*: Cuttings taken from old stock plants may have rooting difficulty. Mature cuttings taken later in the season likely require higher rooting solution rates than juvenile cuttings taken early in the season. Hard-to-root cuttings are best taken at the time of year known to produce higher root yields.
- Hard-to-root mature cuttings may react slower to additional applications compared with easier to root cuttings.
- *Mature cuttings may react best to K-IBA applications in days close to the time of sticking. Several applications in two week intervals may be beneficial.*

Trial blocks

Cuttings used in Dr. Hammer’s *Osteospermum* study were taken from plantations. These plantations maintain physiologically juvenile stocks where mother plants are established from cuttings-from-cuttings. Trials used the Spray Drip Down Method of application using Hortus IBA Water Soluble Salts rooting solutions. Using the optimal rate, the study showed, there may be no apparent downside to multiple applications. It was shown, before making production decisions, there is a need to trial a wide range of rates. It is first necessary to set the optimal rate by doing a block of trials on un-rooted cuttings including low and high rates.

This study used four rates: 200, 400, 600 and 1200 *ppm* IBA (K-IBA) using Hortus IBA Water Soluble Salts rooting solutions. IBA and K-IBA rates are the same.

- Slowed root formation was observed at 200 *ppm* (low) and 1200 *ppm* (high) IBA (K-IBA) rates.
- At 600 *ppm* IBA there was optimum rooting for both single and two time foliar applications.
- Two time applications at 600 *ppm* IBA (K-IBA) had the best root mass. Applications were made at the time of sticking and again at ten days after sticking.

Considerations

Rooting hormone application, and cutting storage: The initial rooting product application (dry powder or rooting solution) does not necessarily have to be done the same day of sticking; it may be done the day after sticking. Cuttings may also be are treated then stored for later sticking.
Level crops: To level crops, additional sequential applications may be made in about ten day to two week intervals.
Many different production lots: Growers who root many crops and cultivars at once should separate

the production lots according to rate needs. “IBA” marked flags have been used to show the ‘IBA (K-IBA) RATE’ for each lot.

Rooting solution and dry powder rooting hormone selection: K-IBA rooting solution rates for foliar Spray Drip Down and Total Immerse Methods are lower than used for the basal Quick Dip Method. Dry Powder rooting hormone powder concentrations are not directly correlated to rooting solution rates. Quick Dip and Dry powder rooting hormones are only used for first applications. To compare, if for specific plant cuttings a high percentage IBA dry powder rooting hormone is needed for rooting, then a high rooting solution rate is needed too.

Inhibit bud formation: Rooting solution applications inhibit the growth of lateral buds so that the plant grows upward more than outwards. This reduces the need for otherwise applied growth regulators to produce that effect.

Temperature needs: Foliar spray operations should NOT be done when cuttings are dormant due to high or low temperature.

- The rooting solution enters the plant’s vascular system through open stomata. Stomata close in cold or hot temperatures; the solution can not enter the plant. The solution may be washed off when cuttings are foliar hydrated; further entry of the IBA will be stopped or diminished.
- Using the Spray Drip Down Method at cold temperatures below about 45°F there may result in delayed rooting and leaves which show irregularities. Generally it is best to applying both the rooting solutions and cuttings above 60°F.
- In hot climates the cuttings are stuck during the day and maintained with mist. The foliar Spray Drip Down Method is done early the following day when temperatures are cool.

Transplanting: To improve transplanting, rooted transplants may be treated using Spray Drip Down Method IBA rooting solution sprays once or in about two week intervals. Solution rates are similar to those used for initial rooting. Grass division transplants are typically treated by this technique.

Conclusions and grower decisions

Great cutting roots yield great plants. Rooting hormone applications are needed to produce high quality roots on cuttings. Some cutting benefit from one application, others need several applications. The **Spray Drip Down® Method** is used for sequential applications. Applications use K-IBA rooting solutions made using **Hortus IBA Water Soluble Salts®** or **Rhizopon® AA Water Soluble Tablets**.

Decisions must be made to make one or multiple rooting solution applications.

The cuttings: The best cuttings must be selected. Maturity level of the cuttings is critical for good root formation. Physiologically 'juvenile' cuttings require lower rooting hormone rates and produce roots faster compared with ‘mature’ cuttings.

The rates: Each plant variety requires trials to determine the optimum solution rates. Likely the same rate is used for first and multiple applications. Optimum rooting rates are established through a range of block trials from very high to very low.

The protocols: Foliar application protocols to apply K-IBA rooting solutions are influenced by cutting characteristics. Variety and genetic variations may be a determining factor to determine the procedures. Annual plant cuttings likely need single applications to produce required roots, some require several applications. Perennial and woody plant cuttings likely need multiple applications.

It is worthwhile to use multiple rooting solution applications when propagating plants from cuttings. Labor and material needs are relatively small to get superior roots!

Methods and Materials for Basal and Foliar Methods *(single & multiple use)*

DRY POWDER ROOTING PRODUCTS AND METHOD

Products

- **Rhizopon AA #1 (0.1% IBA)** for easier-to-root cuttings
- **Rhizopon AA #2 (0.3% IBA)** for moderate-to-root cuttings
- **Rhizopon AA #3 (0.8% IBA)** for harder-to-root cuttings

First Application Method

Dry Dip Method *(only used for a first rooting hormone application).*

- The basal ends of the cuttings are dipped about 3/4 inch into the powder then stuck in media

Trial Rates

Dry Dip Powder Trial Rates

- Annual plant cuttings: Rhizopon AA#1, or Rhizopon AA#2
- Perennial plant cuttings: Rhizopon AA#1, Rhizopon AA#2, or Rhizopon AA#3
- Woody plant cuttings: Rhizopon AA#2, or Rhizopon AA#3

ROOTING SOLUTION PRODUCTS AND METHODS

Products

- **Hortus IBA Water Soluble Salts®** water soluble to make over 100,000 *ppm* K-IBA *(aqueous)* rooting solutions.
- **Rhizopon® AA Water Soluble Tablets** count and mix to make K-IBA *(aqueous)* rooting solutions; may replace Hortus IBA Water Soluble Salts

Hortus IBA Water Soluble Salts and **Rhizopon® AA Water Soluble Tablets,** dissolved in water make aqueous IBA (K-IBA) rooting solutions; *the only labeled rooting products for use by foliar methods.* Zero hour REI.

Single or Multiple Applications

- Foliar applications are used on leafy cuttings in the growing state. *(Not for use when cuttings are without leaves or dormant.)*
- ***For single applications:*** the Spray Drip Down Method® *(or multiple applications)*, Total Immerse or Basal Quick Dip Methods may be used.
- ***For multiple applications after the first application***: only the Spray Drip Down Method® is used.

Methods

Basal Quick Dip Method *(only used for a first rooting solution application)*

- The basal ends of the cuttings are dipped about 3/4 inch into the rooting solution then stuck in media. Rates are established per plant variety.

Spray Drip Down® Method *(used for first or secondary rooting solution applications)*

- The cuttings are stuck in media. A skilled worker sprays the rooting solutions onto the leaves until the rooting solution drips down. Spraying is done soon after sticking or when not under heat stress, such as early morning. An excess of solution is best rather than a starved liquid volume. Facility appropriate spray equipment is used such as backpack, hydraulic, booms, or robots.

Total Immerse Method *(only used for a first rooting solution application).*

- The cuttings are totally immersed a few seconds in the rooting solution then stuck in media.

Trial Rates

IBA and K-IBA ppm rates are considered to be the same for foliar and basal applications

Spray Drip Down Method *(any application)* and **Total Immerse Method** *(for first application)* trial rooting solution rates using Hortus IBA Water Soluble Salts. The first foliar and supplementary applications are at the same K-IBA rate

- Annual, perennial, chrysanthemum plant cuttings: 80-250 *ppm* K-IBA *(typical 100-200)*
- Herbaceous & hard-to-root perennial plant cuttings: 250-1500 *ppm* K-IBA *(typical 750-1000)*
- Woody ornamental plant cuttings: 500-2000 *ppm* K-IBA *(typical 750-1500)*

Use Rooting Hormone or Eat Ice Cream?

A vegetative breeder tests whether rooting hormone is really worth using on the most popular varieties.

Kris Carlsson, featuring research from Luís Muñoz

Growing up, I remember reading an article about my favorite baseball player, Rickey Henderson, where it said Rickey ate a gallon of ice cream every night after the ball game. Rickey attributed this gallon of ice cream to making him one of the best base stealers in baseball history. I tried to convince my mom way back when that she should let me eat a gallon of ice cream every night, but no success. What does this have to do with rooting hormone? I think the hormone is like the ice cream for your cuttings—it won't allow them to steal a base faster, but they will root faster.

There are many methods and techniques used to propagate successfully. They can vary from carefully planning and preparing every detail to having a fancy propagation system in place, but can rooting hormone be a contribution to this success? What's the right rooting hormone to use? What technique should I use to apply rooting hormone? Today, we plan to answer this question.

The trials

We set up a trial to evaluate cuttings stuck with no hormone compared to powder dipping of Hormex #1 and #3, liquid dipping in Hortus IBA Quick Dip Solution, and overhead sprays of Hortus IBA at 100 ppm and 200 ppm. All of these applications were made at stick with propagation-difficult crops like osteospermum and lantana. We also did the same treatment to calibrachoa, which many growers do not use rooting hormone on.

Finally, we looked at geraniums under the same treatments. My colleague Luís Muñoz was pulling 10 cuttings every other day to evaluate development as the cuttings callused, initiated roots and rooted to the edge of the Ellepot. In the initial stages before root development, all cuttings were pulled randomly from the tray and dumped after evaluation so that results were not skewed by damaged cuttings stuck back into the Ellepot.

Osteospermum

At approximately five days after stick, Osteo Serenity Pink Magic cuttings had a higher callus initiation percentage when using rooting hormone. Pink Magic cuttings that were stuck into 105 trays with no hormone averaged about 40% callusing at five days after stick, while cuttings that were stuck with no hormone, then treated with an IBA 100 ppm hormone spray right after stick, had an average of 90% callus initiation five days after stick.

This later translated into quicker rooting with the hormone spray application and, two weeks after stick, we noticed a larger difference in rooting (see Figure 1). Hormone use proved to have promoted a better, more developed liner, which ultimately allowed us to pull liners out of mist and propagation about four days sooner than our no-hormone treatment.

Calibrachoa

Calibrachoa is typically a crop we don't use rooting hormone on because it roots fairly well, but we still put it to the test. Calibrachoa Cabaret Deep Yellow at five days after stick with no hormone had an average of 80% of cuttings show some sort of callus. This is really great for a crop that requires no rooting hormone. However, when we compared it to our IBA 100 ppm spray treatment, we noticed a difference. At five days after stick, we had 100% of cuttings showing callus and about 50% of those had small roots beginning to root into the soil. Another detail we noticed was that for the first 10 days, IBA treatments displayed more wilting/leaf curl than our no-hormone treatment.

Approximately two weeks after stick, 90% of cuttings stuck with no hormone began to show some roots emerging out to the edge of the liner, while cuttings that received the hormone application were already developing roots outside of the liner (see Figure 2). They appeared to have at least twice as many roots as our no-hormone treatment. This allowed us to remove the hormone treatment out of mist earlier and out of propagation one week sooner. All signs of wilt from the IBA spray disappeared at 10 days after stick.

Geranium

Hormone use on geraniums is optional. We chose to try our Geranium Dynamo Dark Red and repeated the same treatments. Geraniums that were stuck ▶

Osteo Serenity Pink Magic
No Rooting Hormone

Osteo Serenity Pink Magic
IBA 100 ppm Spray

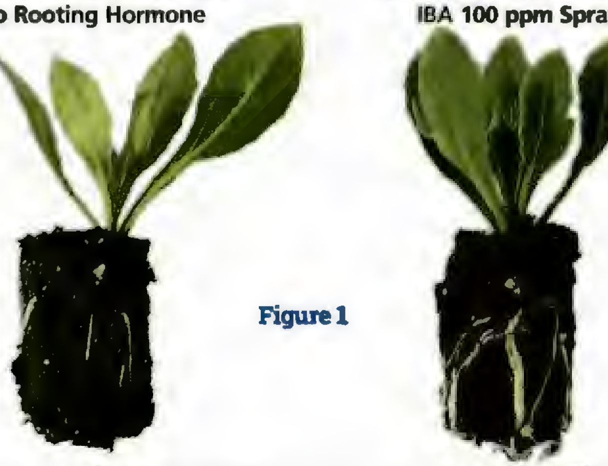


Figure 1

Calibrachoa Cabaret Deep Yellow
No Rooting Hormone

Calibrachoa Cabaret Deep Yellow
IBA 100 ppm Spray

Figure 2

Geranium Dynamo Dark Red
No Rooting Hormone

Geranium Dynamo Dark Red
IBA 100 ppm Spray

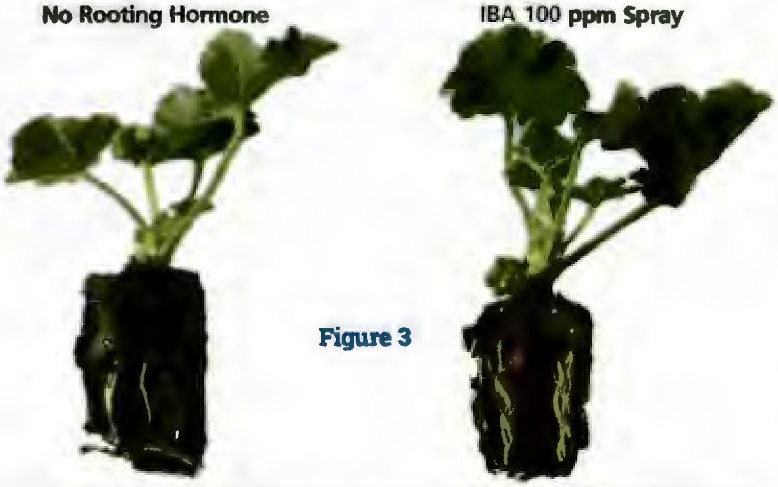


Figure 3

Lantana Landmark Rose Sunrise
No Rooting Hormone

Lantana Landmark Rose Sunrise
IBA 100 ppm Spray

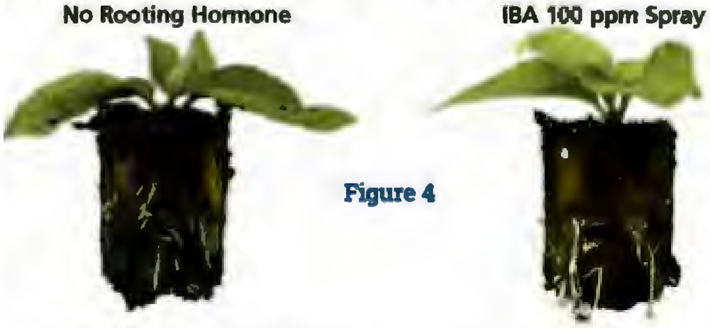


Figure 4

with no hormone only resulted in about 50% of callusing at five days after stick. Whereas geraniums that received an IBA 100 ppm spray after stick had 100% of cuttings begin to callus five days after stick. Once again, IBA application seemed to cause wilting/leaf curl symptoms for about 10 days before they grew out of it.

Two weeks after stick, no-hormone treatment only had about 60% of liners showing minimal rooting and our IBA 100 ppm spray once again provided better results. One hundred percent of liners were more developed and showed a much larger amount of roots (see Figure 3). This allowed us to remove from propagation four days ahead of the no-hormone treatment.

Lantana

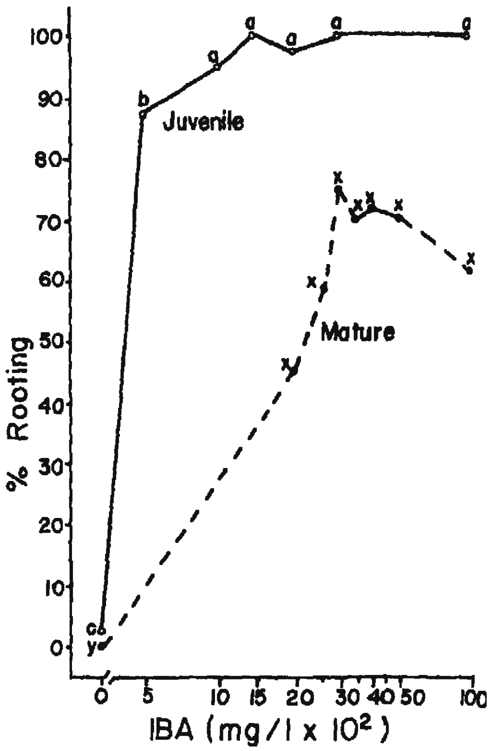
Lantana Landmark Sunrise Rose had 100% of cuttings initiate callusing five days after stick with no hormone. (I guess Luís is a really good lantana propagator!) Lantanas that received the IBA 100 ppm spray also showed some advantage. They were all callused as well, but about 40% of them showed some minimal signs of roots beginning to sprout. For lantanas, it took a little longer for differences to show. Two weeks after stick, no-hormone treatment only had about 30% of cuttings achieve very small root growth to the edge of the Ellepot. Our IBA 100 ppm spray was only able to get us to 50%, achieving some growth to the Ellepots as well. Slightly larger roots than our no-hormone treatment, but not enough to make a huge difference.

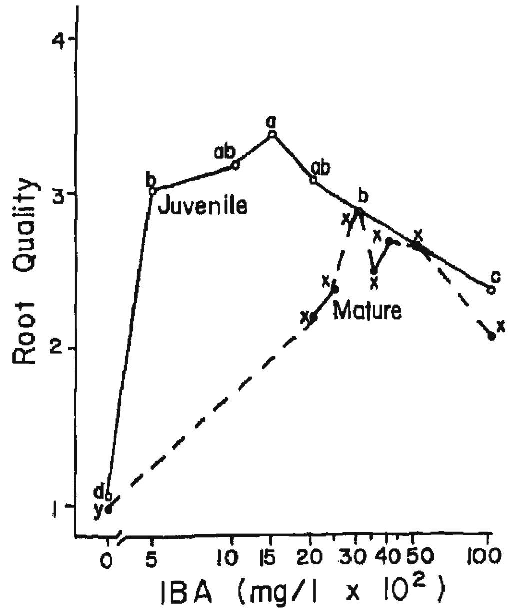
Lantana Landmark Sunrise Rose stuck with no hormone were finally ready to be moved out of propagation about four weeks after stick. Lantana with IBA 100 ppm spray treatment were ready to be moved out of propagation approximately 25 days after stick, only giving it about a three-day head start compared to the no-hormone treatment. You can see a small difference for liners receiving the IBA 100 ppm spray in the picture taken approximately four weeks after stick (see Figure 4). Is it worth it? Please trial under your propagation conditions to check.

So, in conclusion, if you want to root cuttings as fast as Rickey Henderson steals bases, you should use rooting hormone. I think that you should start a trial today—even on crops that don't require rooting hormone to see if you can root faster, high-quality liners. Our conclusion was that IBA spray at 100 ppm gave the best rooting results while providing the lowest input cost during stick.

Also, please feel free to eat a gallon of ice cream every night. Just keep in mind you better start running fast like Rickey or you're going to feel the extra pounds!

Kris Carlsson is the Global Product Manager and Luís Muñoz is Culture Research Technician for Ball FloraPlant. Both are stationed in Arroyo Grande, California. Please visit ballfloraplant.com for the full presentation of their trials.





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Growth Regulator Effects on Adventitious Root Formation in Leaf Bud Cuttings of Juvenile and Mature *Ficus pumila*[1]

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Additional index words. indolebutyric acid, 6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine, gibberellic acid, creeping fig

Abstract. Adventitious root formation was stimulated with foliar application of indolebutyric acid (IBA) from 1000 to 1500 mg/liter for juvenile and 2000 to 3000 mg/liter for mature leaf bud cuttings of *Ficus pumila* L. IBA increased cambial activity, root initial formation, and primordia differentiation and elongation. IBA stimulated rooting when applied to juvenile cuttings at 3, 5, or 7 days after experiment initiation, but had no effect on mature cuttings when applied at day 15, the final treatment period. The interaction of IBA/gibberellic acid (GA_3) did not affect early root development stages, but reduced root elongation and quality once primorida had differentiated. IBA/6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine (PBA) inhibited rooting at early initiation stages.

Recent researchers have generally agreed that adventitious root formation (ARF) involve sequences of histological steps with each step having different requirements for growth substances (5, 8, 9, 10, 11). Eriksen (5) and Mohammed and Eriksen (8) found that auxins and cytokinins had different affects on ARF depending on developmental stage. Sircar (11) reported 5 different histological stages in which GA_3 and IAA alternately promoted or inhibited ARF. Hypocotyl cuttings of herbaceous annuals have been used in previous sequencing

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The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

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experiments, but herbaceous material may not give a true index of changes occurring in mature woody materials.

The woody ornamental creeping fig *(Ficus pumila)* exhibits strong dimorphism (2) and differences in rooting between the juvenile and mature forms. Objectives of this study were to determine the effect of IBA, PBA, and GA_3 applied at different rooting developmental stages to juvenile and mature leaf-bud cuttings (LBC) of *F. pumila.*

Materials and Methods

F. pumila cultivated on the University of Florida campus at Gainesville were used as stock plants. Leaf bud cuttings (LBC-lamina, petiole and 2.5 cm piece of stem with attached axillary bud) were rooted under an intermittent mist system in a medium of sterilized mason sand maintained at 24°C with a 2 hr night light interruption previously described (4). Juvenile LBC were harvested after 21 days and mature cuttings 42 days after experiments were initiated. All growth regulators were applied as aqueous sprays with 0.25 ml/liter of surfactant, emulsifiable A-C polyethylene and octyl phenoxy polyethoxy ethanol (Plyac).

In an experiment to establish optimum IBA concentration required for rooting, cuttings were taken in November and IBA applied at 500, 1000, 1500, 2000, 3000, and 10,000 mg/liter to juvenile and 2000, 2500, 3000, 4000, 5000, and 10,000 mg/liter to mature LBC at time of insertion. The design was a randomized complete block with 4 replications and 40 cuttings per treatment.

To characterize growth regulator effects at different root development stages a factorial experiment was initiated in May with 2 forms (juvenile, mature LBC) × 2 IBA pretreatments (control, treated) × 3 growth regulators (IBA, PBA, GA_3) × 3 application dates. An IBA spray of 1000 mg/liter was applied to half the juvenile cuttings and 3000 mg/liter to half the mature material at the time of insertion. Growth regulators were then applied after 3, 5, or 7 days for juvenile and 3, 9 or 15 days for mature cuttings: IBA at 1000 mg/liter for juvenile and 3000 mg/liter for mature cuttings, 1000 mg/liter PBA and 3000 mg/liter GA_3 for both types. The design was a randomized complete block with 4 replications and 32 cuttings per treatment. To determine stage of ARF 10 cuttings of each treatment combination were selected at each of the 3 time intervals and fixed in formalin-acetic acid-ethanol (FAA) *in vacuo,* dehydrated in ethanol-tertiary butyl alcohol series and embedded in Paraplast-plus. Blocks containing stem pieces with one surface exposed were soaked in distilled water *in vacuo* for 5 days to soften tissues prior to sectioning. Serial cross and longitudinal sections were cut at 8 and 11 um and strained with safranin and fast green.

Cuttings were measured for percent rooting, root number, and root length (average of 3 longest roots) and rated on a quality scale of 1 to 4 with 1 = no rooting, 2 = small root system, 3 = intermediate root system and 4 = extensive root system.

Results

Optimum IBA concentration. IBA treatments stimulated ARF in both juvenile and mature LBC (Fig. 1, 2, 3, 4). At high IBA levels root length was reduced in both forms (Fig. 3) and root quality in juvenile cuttings was poor (Fig. 4). Best horticultural responses were obtained in juvenile material treated with 1000-1500 mg/liter and mature cuttings treated with 2000-3000 mg/liter IBA considering root number, length and quality (Fig. 2, 3, 4). The performance of IBA-treated juvenile LBC was better than IBA-treated mature cuttings.

Hormonal effects during rooting stages. Percent rooting in IBA pretreated cuttings was unaffected by additional IBA at any of the 3 time intervals after insertion, however, root length was reduced in all treatments (Table 1, 2). In juvenile LBC receiving no IBA pretreatment, later IBA application increased rooting in all dates (Table 1), but in mature cuttings only the first or second application period was stimulatory (Table 2).

GA_3 reduced root length and quality in IBA-pretreated cuttings (Table 1, 2 and Fig. 5, 6). In juvenile cuttings without IBA pretreatment, GA_3 reduced root length (Table 1), but had no effect on mature LBC without IBA pretreatment (Table 2).

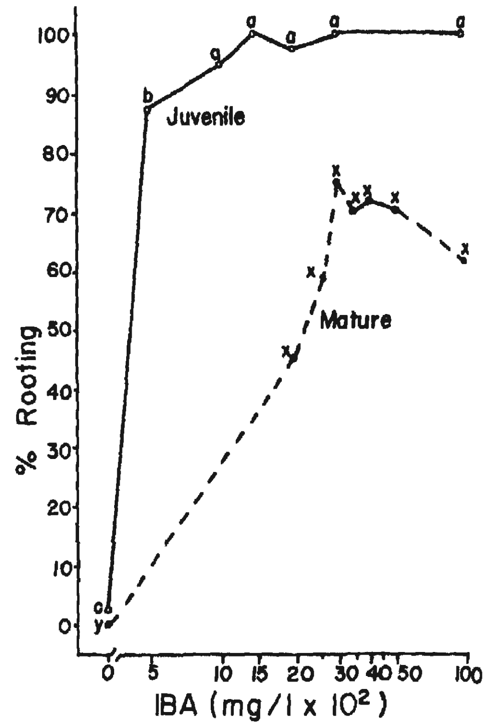

Fig. 1. Effect of IBA on rooting in juvenile and mature leaf bud cuttings of *Ficus pumila.* Points with same lower case letters are not significantly different.

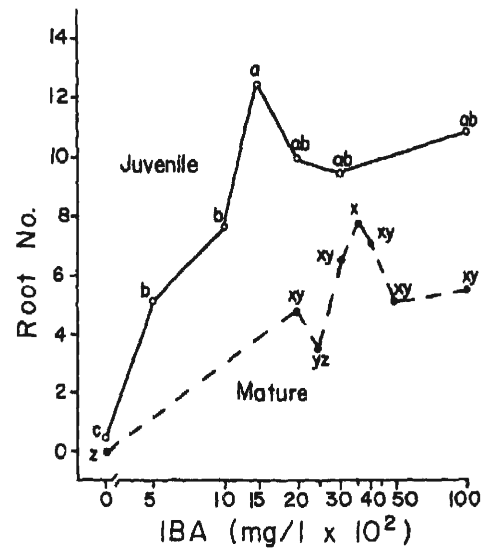

Fig. 2. Effect of IBA on root number in juvenile and mature leaf bud cuttings of *Ficus pumila.* Points with same lower case letters are not significantly different.

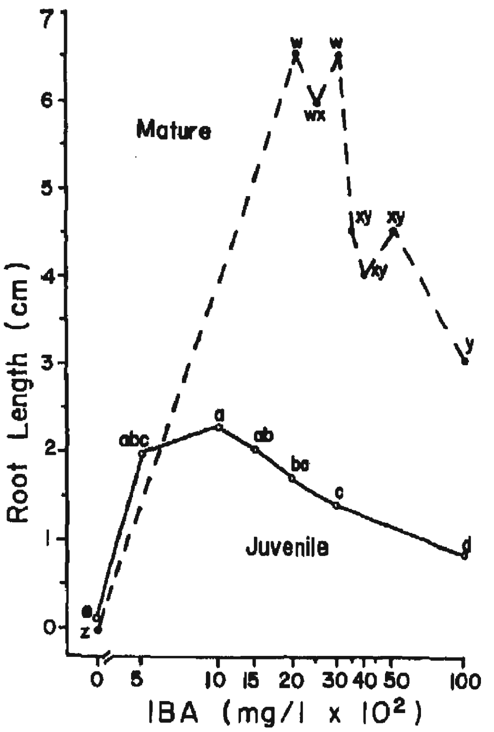

Fig. 3. Effect of IBA on root length in juvenile and mature leaf bud cuttings on *Ficus pumila*. Points with same lower case letters are not significantly different.

PBA effectively limited ARF in IBA-pretreated cuttings when applied during the first or second time intervals (Tables 1, 2). In juvenile LBC the greatest inhibition occurred during the first time interval which coincided with increased cambial activity associated with the dedifferentiation phase of ARF (Table 3). PBA caused less inhibition of ARF the second application period when root initials and primordia were first observed. Half the LBC rooted by the third interval (Table 3); thus PBA application at this time did not affect % rooting but did reduce root number, length and quality. In mature cuttings PBA treatment at first application period completely inhibited ARF (Table 2) when no cambial activity was observed. PBA was less effective in inhibiting ARF during second application when cambial activity was first observed (Table 2, 4). Root length and quality were reduced with PBA application at any period, but had no effect on % rooting or number during the third treatment period.

Table 1. Adventitious root formation in juvenile leaf bud cuttings of *Ficus pumila* treated with 3 growth regulators at 3, 5, or 7 days after experiment initiation. Half the cuttings were pretreated with 1000 mg/liter IBA.

IBA pre-treatment (mg/liter)	Growth regulator post treatment	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
0	IBA (1000 mg/liter)				
	day 3	100a[z]	9.5e	1.1bcde	2.6de
	day 5	100a	11.0bcde	1.1bcde	2.8cd
	day 7	100a	10.3cde	1.0bcde	2.5de
	GA_3 (3000 mg/liter)				
	day 3	31c	0.7h	0.8cde	1.3gh
	day 5	28c	0.8h	0.7de	1.3gh
	day 7	34c	1.0h	1.5bcd	1.5g
	PBA (1000 mg/liter)				
	day 3	0d	0h	0h	1.0h
	day 5	25c	0.9h	1.2bcde	1.3gh
	day 7	25c	0.9h	1.4bcd	1.3gh
	Control	31c	0.8h	1.7b	1.3gh
1000	IBA (1000 mg/liter)				
	day 3	100a	12.7b	1.5bc	3.0abc
	day 5	100a	15.2a	1.3bcd	3.2ab
	day 7	100a	12.4bc	1.0bcde	2.7cd
	GA_3 (3000 mg/liter)				
	day 3	100a	10.8bcd	1.3bc	2.7cde
	day 5	100a	9.0ef	1.5bc	2.8cd
	day 7	100a	10.2de	1.7b	2.8bcd
	PBA (1000 mg/liter)				
	day 3	38c	1.3h	0.5ef	1.4gh
	day 5	66b	5.3g	1.3cde	2.0f
	day 7	88a	7.2fg	1.2bcde-	2.3ef
	Control	100a	11.9bcd	2.5a	3.4a

[z]Root quality scale range from 1 to 4 with 1 = no root system, 2 = small root system, 3 = intermediate root system and 4 = extensive root system.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.

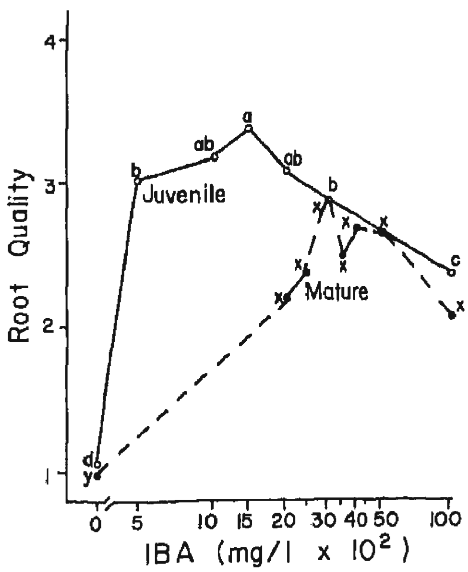

Fig. 4. Effect of IBA on root quality in juvenile and mature leaf bud cuttings of *Ficus pumila*. Points with same lower case numbers are not significantly different.

PBA reduced rooting in juvenile cuttings not pretreated with IBA when applied during the first treatment period when neither root initials nor primordia were observed (Table 1, 3). In mature cuttings PBA had no statistical effect on rooting; however, none of the treated cuttings formed roots, nor were root initials or primordia observed (Table 2, 4).

Discussion

Mature *F. pumila* cuttings did not root as efficiently as juvenile material. Thus, IBA-treated mature cuttings required higher exogenous auxin levels and longer time to obtain

Table 2. Adventitious root formation in mature leaf bud cuttings of *Ficus pumila* treated with 3 growth regulators at 3, 9, or 15 days after experiment initiation. Half the cuttings were pretreated with 3000 mg/liter IBA.

IBA pre-treatment (mg/liter)	Growth regulator post-treatment	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
0	IBA				
	(3000 mg/liter)				
	day 3	84abc[z]	13.1abc	3.4ab	3.0ab
	day 9	94ab	8.6cde	3.0ab	2.7abc
	day 15	53cdefg	2.7fg	1.0cde	1.7efg
	GA_3				
	(3000 mg/liter)				
	day 3	44efg	2.0fg	0.7de	1.5fgh
	day 9	41fg	1.9fg	0.8cde	1.5fgh
	day 15	38fg	1.1fg	0.8cde	1.4gh
	PBA				
	(1000 mg/liter)				
	day 3	0h	0g	0e	1.0h
	day 9	0h	0g	0e	1.0h
	day 15	0h	0g	0e	1.0h
	Control	22gh	1.5fg	1.1cde	1.3gh
3000	IBA				
	(3000 mg/liter)				
	day 3	81abcd[z]	11.1bcd	2.1bcd	2.6bcd
	day 9	100a	16.1a	3.1ab	3.2ab
	day 15	91ab	13.7ab	2.1bcd	2.7abc
	GA_3				
	(3000 mg/liter)				
	day 3	66bcdef	8.4cde	1.6cd	2.0def
	day 9	50defg	6.0ef	1.7cd	1.8efg
	day 15	66bcdef	7.3de	2.2bc	2.1cde
	PBA				
	(1000 mg/liter)				
	day 3	0h	0e	0e	1.0h
	day 9	28gh	1.6fg	1.0cde	1.3h
	day 15	75abcde	9.2bcde	1.3cde	2.2cde
	Control	94ab	13.3abc	3.8a	3.2a

[z]Root quality scale ranged from 1 to 4 with 1 = no root system, 2 = small root system, 3 = intermediate root system and 4 = extensive root system.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

maximum rooting (3) than juvenile LBC. Mature cuttings may have lower endogenous auxin levels and/or other endogenous chemicals needed to stimulate root initiation. When ARF was measured on a daily basis (3), IBA-treated mature cuttings rooted slower than juvenile LBC, but equalled juvenile controls by day 20, giving strong evidence that endogenous auxin levels were acting as a possible limiting factor in root initiation.

IBA increased ARF in both juvenile and mature cuttings by stimulating initiation of cambial activity, root initials and primordia, which agrees with reports that auxins trigger early formation of root primordia (6). However in *F. pumila*, application of auxin above the optimum level reduced root length and quality indicating that primordia elongation was decreased.

In both juvenile and mature cuttings the combination of IBA/GA_3 retarded rooting after primorida were differentiated, since % rooting was not influenced but root length and quality were reduced. The conflicting reports on exogenous gibberellin influence on rooting (1, 7, 12) may be related to species differences. Our results agree with Hassig (7) who reported that initiating primordia were least affected by GA_3 but that cell number was reduced in older established primordia which was deleterious to root formation.

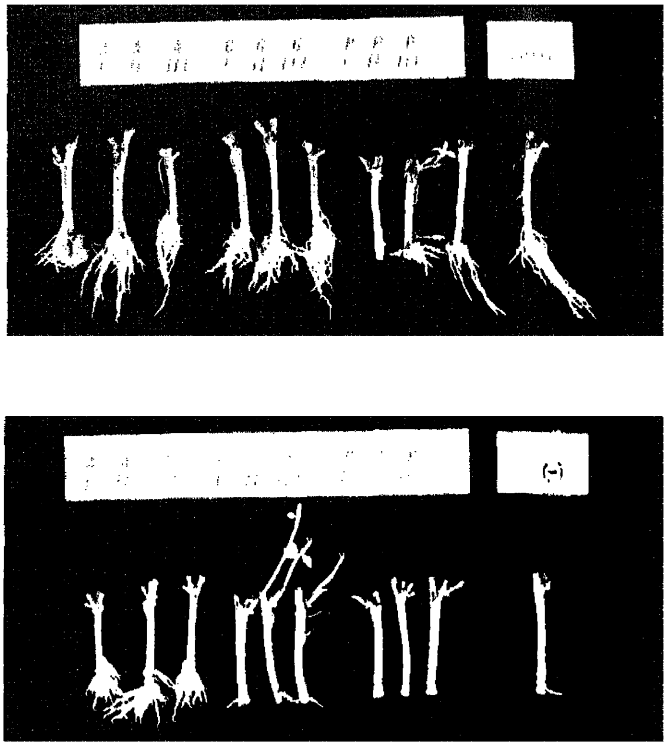

Fig. 5. Effect of IBA, GA_3 and PBA on adventitious root formation when applied at 3 time intervals to juvenile leaf bud cuttings. (top) Pretreated with (IBA). (bottom) No pretreatment with IBA.

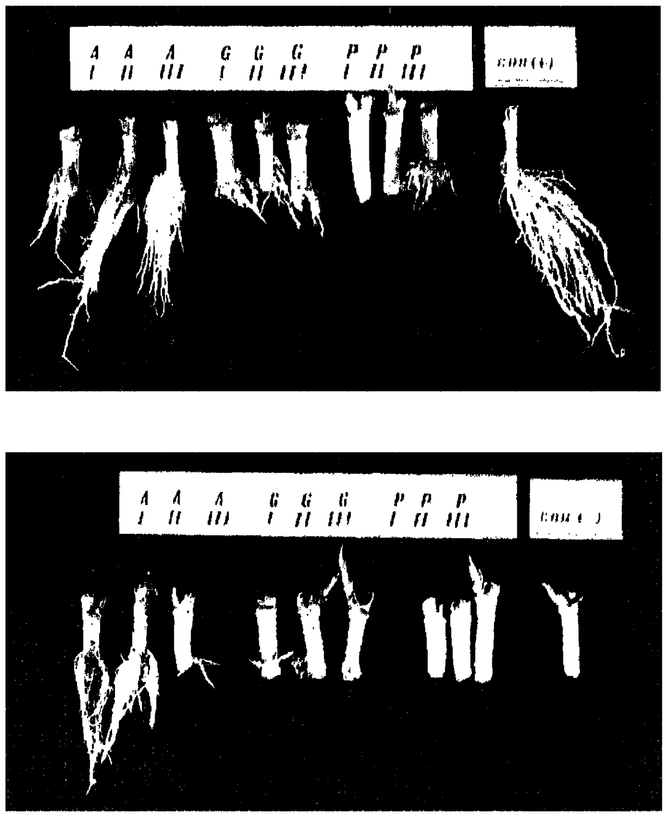

Fig. 6. Effect of IBA, GA_3 and PBA on adventitious root formation when applied at 3 time intervals to mature leaf bud cuttings. (top) Pretreated with IBA. (bottom) No pretreatment with IBA.

Table 3. Stage of adventitious root formation of juvenile leaf bud cuttings of *Ficus pumila* at 3 time intervals.

Treatment	Increased cambial activity	Root initials	Root primordia	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
IBA pretreatment at (1000 mg/liter)							
day 3	yes	none	none	0	0	0	1.0
day 5	yes	yes	yes	0	0	0	1.0
day 7	yes	yes	yes	50	6.2	0.7	1.6
No IBA pretreatment							
day 3	none	none	none	0	0	0	1.0
day 5	yes	none	none	0	0	0	1.0
day 7	yes	yes	yes	20	0.4	0.5	1.2

[z]Root quality scale ranged from 1 to 4 with 1 = no root system, 2 = poor root system, 3 = intermediate root system and 4 = extensive root system.

Table 4. Stage of adventitious root formation of mature leaf bud cuttings of *Ficus pumila* at 3 time intervals.

Treatment	Increased cambial activity	Root initials	Root primordia	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
IBA pretreatment at (3000 mg/liter)							
day 3	none	none	none	0	0	0	1.0
day 9	yes	none	none	0	0	0	1.0
day 15	yes	yes	yes	20	1.7	0.5	1.2
No IBA pretreatment							
day 3	none	none	none	0	0	0	1.0
day 5	none	none	none	0	0	0	1.0
day 15	yes	none	none	0	0	0	1.0

[z]Root quality scale ranged from 1 to 4 with 1 = no root system, 2 = poor root system, 3 = intermediate root system and 4 = extensive root system.

The rooting inhibition of PBA on juvenile and mature *F. pumila* concur with reports that cytokinins inhibit preinduction phases of rooting (12) with a loss of inhibitory effect at later stages (6).

Differences in adventitious rooting between juvenile and mature cuttings may be partially attributed to endogenous auxin levels, since lower IBA levels were required for optimal rooting in juvenile compared to mature LBC. However, other factors such as auxin/cytokinin and auxin/GA_3 ratios, cofactors and inhibitors may be involved, since exogenous IBA applications did not overcome root formation differences between IBA-pretreated juvenile vs. mature tissue.

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Foliar applications of rooting hormone at Decker Nursery

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Foliar applications of rooting hormone at Decker Nurserv©

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INTRODUCTION

Decker Nursery currently uses only over-spray methods to apply rooting hormones on softwood and dormant hardwood cuttings of woody ornamentals. We have been evolving down this path away from liquid dip and powder application methods for the last 4 years. In this presentation, I will attempt to review the history of this evolution, our current methods of application, a summary of our observations, and the current status of research on the over-spray method.

HISTORY AND EVOLUTION OF HORMONE SPRAY APPLICATION

In the 50 propagation seasons in which I have participated in my career I have used rooting hormone powders and liquid dips for the majority of those years. I have seen people covered up to their elbows in talc rooting powders, cuttings coated with dry powders 1/8 of an inch thick due to a wet stems, spilled cups of rooting liquid dripping all over the propagation table and the laps of any person unfortunate enough to be downhill of the spill, cuttings hanging outside of the container of liquid hormone as the person dipping the handful of cuttings joyfully discusses the details of last night's adventures, and rooting results, either good or bad, that defied explanation and were not able to be repeated.

Sometime back about 2010 I first heard about IBA water soluble salts offered by the company Hortus (Figure 1). Initially I was very skeptical about this method as I saw multiple pitfalls:

- Sprayer application uniformity.
- Hormone storage in a sprayer once mixed.
- Inaccurate application from one day to the next.
- Basic resistance to change.

Figure 1. Hortus IBA Water Soluble Salts & Rhizopon AA Water Soluble Tablets used to make K-IBA rooting solutions

We did request information and were supplied some hormone tablets that could be used to make a standard liquid dip solution. Casual testing showed the dips rooted plants successfully compared to other hormone solutions on the market but we did not try the over-spray method.

On an IPPS Eastern Region annual conference tour we happened to visit a perennial grower whose propagator made an offhand demonstration of using an electronic sprayer to

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apply Hortus IBA over some perennial cuttings. I noticed that this expensive sprayer did atomize the solution much like mist from a cutting mist system. I had now found a tool that could be counted on to apply hormone in very small droplet size with excellent coverage on both the top and bottom of the foliage. I photographed the sprayer and had one purchased when I returned from the conference (Figure 2). At this time, we also purchased a quality electronic scale to measure out grams and our first purchase of the Hortus IBA water soluble salts.

Figure 2. Electronic sprayer BP-4 by Dramm.

In our first year we primarily used hand dipped cuttings during the winter hardwood propagation season. We tried to find information on how the overspray would work on dormant cuttings on species such as *Thuja, Juniperus, Taxus, Buxus, Chamaecyparis, Ilex, Picea*, and others but no information was available. I was under the impression that the belief was that the auxin entered the plant through stomata. I used logic to make assumptions. Fresh cuttings gathered cold from outdoors in a dormant state probably did not have open stomata. We discussed things and since it took a day for the cuttings to warm up on the heated greenhouse concrete floor, we would spray three times beginning the day after the cuttings were stuck. As to rates, we decided, due to the multiple applications, to use a rate about half of the hand dipped rate (generally about 1000 ppm).

As this first winter season progressed we noticed excellent callus formation on the cuttings and that the progress of the crops as a whole seemed more uniform than the dipped cuttings. If I recall, I believe we eventually did an overspray on some of the dipped cuttings that seemed to be lagging behind. This was our first off the cuff post sticking over-spray that has eventually evolved to a standard practice for slow to root plants.

Our next summer of softwood cuttings was more dramatic. Due to the success we had the previous winter we over-sprayed our first house of cuttings for three consecutive days. We saw rooting activity quickly and at a very consistent rate. We did not have to do any post-sticking applications as most of the softwood cuttings rooted too quickly and uniformly to require this step. All things considered this summer season was a success but we did notice that we had significant losses in some certain crops.

One significant difference from a nursery like ours and a science based University style experiment is that we often change multiple environmental factors such as plug design, rooting medium recipe, hormone application method, and then try to guess which factors most likely had an effect on success or failure. We just sort of assume we are smart enough to guess correctly. In our convoluted logic to use three applications of hormone but at a lower rate to save money and attempt to avoid hormone toxicity, we neglected to take into account that some species might just need a higher rate of hormone to successfully root. Combine this with other environmental changes and I can tell you stories about how Decker Nursery could not successfully root a cutting of *Euonymus alatus* 'Compacta' for about 3 years; but that is a story for around the bar later in this conference.

CURRENT METHODS OF APPLICATION

Over time we have developed some basic protocols for the use of this product. These are based on experience and results, not on scientific documentation. That research still does not exist at this time.

Dormant hardwood winter cuttings are generally gathered, processed, and stuck within 10 days, and placed in a heated floor Dutch style propagation tent. After sticking they are sprayed at a rate of 1500-2500 ppm based on the species for three consecutive sprays. After about 2 weeks, they are re-spayed with IBA lightly at 2 week intervals (Figure 3). We have noticed once the cuttings progress enough to see signs of rooting that we see a jump in this rooting activity about 2 days after one of these re-applications of hormone. Spray protocols for IBA spray application are shown below.

Figure 3. Hormone application through windows of a rooting tent.

- We use only distilled water for the solution to avoid any contamination or hard water deposits in the spray nozzles.
- Each day's spray is marked by a small different colored flag so that the applicator can easily see how far back to spray on the 3-day rotation.
- We measure our hormone to mix with 1 gal of water to achieve desired rates. For instance, 1 gal of water and 30 g of Hortus IBA will yield close to 1500 ppm. Keep it simple!
- Unused hormone is stored in the sprayer and used the following day.
- All applications occur in the early morning prior to any sun related stress on the cuttings that might result in closed stomata.

Our summer softwood cuttings receive 3 days of hormone application after they are first stuck. Easy to root items might be at 500 ppm while cuttings with early dormancy, such as *E. alatus* 'Compacta', *Viburnum*, or *Rhus aromatica* 'Gro-low' might get 1500 ppm treatments (Figure 4). Any cuttings that are slow to root might get a re-application about 10 days after initial sticking. In reality, Dave Graff, one of our Senior Propagators, will roam the houses and spot target crops that he has observed to need a little helping hand (Figure 5).

Figure 4. Burning bush an example of a plant that requires higher rates of IBA in the summer.

Figure 5. Spot treating with IBA spray.

SUMMARY OF OBSERVATIONS

In the years that we have been using the over-spray hormone we have come up to some conclusions based on our observations:

- This method greatly improves worker safety. I come from a generation where I was instructed, by a State Nursery Inspector, to stick my bare arm into a 30-gal spray tank full of pesticides to stir the batch before spraying nursery stock when I was 16 years of age. I have watched propagation staff with white talc all over their hands or fingers dripping in hormone dip. In recent times, we were spending hundreds of dollars per year on latex gloves to protect the staff. Post-sticking hormone application limits exposure to one person who is wearing the proper protective gear. There is no longer any need to provide gloves to the staff. We have had five successful pregnancies amongst the staff of the Propagation Department in recent years all to give birth to healthy children. As I have somehow to date survived all these sins of my past, I have come to realize how important it is to error on the side of worker safety whenever possible.
- Over-spray of hormone, especially with multiple applications, removes almost 100% of the variables that could contribute to lack of uniform application of hormone. With an electronic sprayer, a mist is generated that rolls over, under, and through the cuttings. We immediately noticed, after switching to this method, significant reduction in variation in rooting.
- We have seen, especially in *Buxus* and *Juniperus*, cuttings that had rotted below the soil line, root at that point downward into the medium. Obviously there was some sort of stress on the cuttings that caused the damage but the hormone re-application allowed the problem to eventually become a successful cutting (Figure 6).
- We believe that overall production is faster due to skipping the step of reaching to dip a handful of cuttings. I would estimate a 20% increase in daily production. This is easily balanced by a couple of minutes spent the next day spraying hormone over tens of thousands of cuttings.

Figure 6. A winter cutting good callus and root formation.

STATUS OF FUTURE RESEARCH

I know that as a propagator I would dread going back to hand dipping of cuttings. I would however like to see some research to clarify some of the unknowns about how these rooting hormones work.

- Are multiple hormone applications at time of sticking required?
- What are the most effective rates?
- Does time of day of application have an effect?
- What is the process or interval that is most effective for re-application of Hormone?
- Is toxicity a problem with multiple applications? We believe there may be an issue in this regard with certain *Thuja* cultivars.

Recently there has been an interest shown by Joel Kroin of Hortus to recruit researchers who might be interested in doing research at multiple Universities to try and nail down the science behind the observations.

Plant Propagation from Cuttings Using Single & Multiple Foliar Applied Hortus IBA Water Soluble Salts® K-IBA Rooting Solutions by the Spray Drip Down® Method

Osteospermum "sweet yellow"

Treatments: Foliar **Spray Drip Down® Method** using aqueous **K-IBA rooting solutions** made with **Hortus IBA Water Soluble Salts®**
Stick cuttings then spray the solution onto the leaves until drip down

Photos were taken 21 days after sticking

0X **Control,** *no treatment*
1X **One foliar treatment at time of sticking**
2X **One foliar treatment at time of sticking** *and*
One foliar treatment 10 days after sticking
The same rate was used for two foliar treatments

NO treatment

CONTROL
No Treatment

treatment @ 200 ppm K-IBA

treatment @ 400 ppm K-IBA

* treatment @ 600 ppm K-IBA *

treatment @ 1200 ppm K-IBA

ONE TREATMENT
at time of sticking

treatment @ 200 ppm K-IBA

treatment @ 400 ppm K-IBA

* treatment @ 600 ppm K-IBA *

treatment @ 1200 ppm K-IBA

TWO TREATMENTS
first at time of sticking
second at 10 days after sticking

Study and photos courtesy of Dr. P. Allen Hammer
Presented by Hortus USA Corp rootinghormones.com support@hortus.com