Propagation of Cuttings Using Foliar-Applied Indolebutyric Acid in Aqueous Solutions at or After Sticking©

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INTRODUCTION

When propagating plants from cuttings, plant hormones called auxins can be applied to induce root formation. The auxin most used in plant propagation is indolebutyric acid (IBA). Basal application of auxins, done all year, has been done at the time of sticking using dry powders or solutions. Foliar application of auxin in aqueous solutions has been done in the growing season on leafy plant cuttings either before or after sticking. The applied auxin enters the plant's vascular system through open stomata. The auxin solutions travel with the natural auxin indole-3-acetic acid (IAA), by polar transport, to the basal end of cuttings where they can induce root formation.

The present study is to find out if there is a difference in root numbers on cuttings of the annual plant *Begonia* 'Red Wing', if an indole-3-butyric acid (IBA) in aqueous solution is foliar applied at time of sticking or several days later. Commercially, Aris Green Leaf Plants, on perennials, and Bailey Nurseries, on woody ornamentals, both recommend an IBA in aqueous solution foliar treatment within the day after sticking. Using foliar applied IBA in aqueous solutions on the woody plant *Ficus pumila* (creeping ficus) by Dr. Fred T. Davies, all treated cuttings (both mature and juvenile), had higher root numbers than untreated cuttings.

The current study found IBA in aqueous solution foliar treatment to be effective on annual cuttings. Application can be done at time of sticking and up to several days after sticking. Higher root numbers occurred on cuttings when treatment was near the time of sticking. Root numbers diminished when treatment was done on later days.

FOLIAR APPLIED ROOTING HORMONES TO INDUCE ROOT FORMATION ON CUTTINGS

Since the late 1800s, scientists, including Charles Darwin, believed substances produced in the leaves of the plants regulated other parts of the plant (Darwin, 1880). "In 1893 (Julius) Sachs' suggestion was that special stimulating and constructive substances are formed in the metabolic processes in leaves" (Reynolds-Green, 1909). In 1934 Thimann and Went identified this substance as IAA. Produced in the leaves during growth, they called it an "auxin" or "plant hormone." They also identified the bio-simulators of IAA, IBA, and nathaleneacetic acid (NAA), more stable then IAA yet producing similar effects. In their book, *Phytohormones*, they define "a hormone is a substance which, being produced in any one part of the organism, is transferred to another part and thereby influences physiological responses." They found application of auxin to the leaves of plants had a positive effect on basal root formation. They also identified the route of the auxin, from leaves to the basal end of cuttings, as polar (one way) transport (Thimann and Went, 1937).

Auxins in aqueous solution can be applied to the foliage of plants in the growing season. They can enter through open stomata where the leaves capture the

solutions under the stomata's guard cells in air spaces. After, they are polar transported to the basal end (Sargent, 1965; Franke, 1967). At the basal end the auxins are stored then regulated by the plant to stimulate root initiation (Thimann and Went, 1937; Epstein and Ludwig-Muller, 1993).

Fred T. Davies foliar applied IBA in aqueous solutions in his rooting trials on cuttings of the woody plant *Ficus pumila*. In one of his trials, application was one time at the time of sticking. Foliar treated cuttings all had higher root numbers compared to untreated control cuttings. Cuttings treated at the time of sticking had the highest numbers. Juvenile cuttings had higher root numbers than mature cuttings. (Davies and Joiner, 1980; Davies et al., 1982; Davies, 1984).

In Holland, Kees Eigenraam, the Senior Researcher of Rhizopon, in 1985 found that foliar applied IBA in aqueous solution improved root formation on chrysanthemum cuttings. Working with the growers at the Dutch company Lyraflor, their greenhouses began using robotic sprayers to apply IBA in aqueous solutions to cuttings soon after sticking (Eigenraam, 2010).

In 1994, Kees Eigenraam and I visited the Yoder Brothers chrysanthemum propagation facilities in Florida, introducing foliar applied IBA in aqueous solution. Since they had large homogenous plant lots, we suggested that they use the total immerse method. By 1996, Yoder (now Aris) Green Leaf Plants greenhouses in Pennsylvania began using foliar application on perennials. They have small production lots; the spray drip down method was more suitable since they did not want to have cross-contamination between lots. They recommend: "apply hormone within 24 h of stick for best results" (Green Leaf, 2010). After 2002, Bailey Nurseries began using foliar applied IBA in aqueous solution on their woody ornamental plant cuttings. "Our results have shown when making these applications within 24 h of sticking is critical for our success" (Drahn, 2007). Dr. Davis said "We would typically apply at dusk at Gainesville, Florida, with the mist turned off for the evening" (Davies, Pers. commun.).

Kees Eigenraam and I have refined two methods to foliar apply auxin in aqueous solutions to leafy cuttings in the growing season. We call these the Spray Drip Down and Total Immerse methods. Rates of application are similar. Application is to be done when the temperature permits stomata to be open. If application is made in cold or hot temperature the stomata would be closed and will not accept the solution. When day temperatures are high then treatment is done early, on cool mornings. Some plants, such as clematis, have their stomata on the bottom of leaves. To assure adequate treatment we found it is best to spray the solution on both sides of the leaves or use the Total Immerse method.

Spray Drip Down Method. The spray drip down method is used after sticking. The solution is used one time resulting in no cross contamination between plant lots. The solution is kept in a tank that does not have cuttings dipped in it. Foliar treatments can be made one time or many times on the same lot. Secondary application can be done on cuttings that had a primary treatment by any other basal or foliar method such as quick dip, basal long soak, or dry dip.

- Stick the cuttings
- Spray leaves of cutting with the solution until drip down
- After treatment, they can resume misting within 30–45 min

Total Immerse Method. The total immerse method is used one time on cuttings before sticking. The cuttings are dipped in a production tank where multiple lots

can be processed. It is suitable where cuttings come from a homogenous lot where cross contamination of a used solution is not a problem. The method is useful when getting good coverage of leaves by spray is difficult, such as treating large leaves.

- Totally immerse the cuttings in the solution for about 5 sec then drain
- Stick the cuttings
- After treatment, misting can be resumed within 30–45 min

Plants Can Be Divided into Three Relative Foliar Rate Groups.

A) Annual like plant cuttings: at 80–50 ppm IBA
B) Perennial-like plant cuttings: at 250–1500 ppm IBA
C) Woody ornamental like plant cuttings: at 500–1500 ppm IBA

Growers have asked me if a surfactant (wetting agent) should or could be used with foliar applied solutions made with Hortus IBA Water Soluble Salts. I have never heard of any commercial growers that have added them. In Dr. Davies' studies he added a surfactant to his solutions. It could be the Hortus IBA Water Soluble Salts solution does not need a surfactant due to the composition of the salts. I plan to do a study to find out if surface tension of IBA aqueous solutions is a critical factor in root formation. I want to find out if droplets have a low enough surface tension to enter open stomata.

PRESENT STUDY

The present study was conducted on cuttings of the annual plant *Begonia* 'Red Wing'. IBA in aqueous solutions was foliar applied by the Spray Drip Down Method. The study was to find out differences in root number formed between untreated and one treatment at time of sticking, at the 3rd, 5th, or 7th day after sticking.

Methods and Materials. Annual plant *B.* 'Red Wing' cuttings were used. All cuttings were taken from one mother plant kept in bright daylight for several days. Stem cuttings had 3–5 full leaves. The medium was perlite and peat (1 : 1, v/v). Treatment was by the spray drip down method. The solution was 200 ppm IBA in aqueous solution using Hortus IBA Water Soluble Salts (1.0 g salts per liter water). Fifteen cuttings were in each of five blocks: un-treated control cuttings, treated 1 h after sticking, or at 3, 5, or 7 days after sticking. Application was made at 80 °F to assure the stomata were open to accept the solution. Cuttings were kept in a propagation tunnel at close to 100% humidity for the trial period. Bright sunlight was supplemented with artificial light for 16 h.

After 24 Days (Table 1).

- Compared with the un-treated control cuttings, all cuttings treated with foliar applied IBA in aqueous solution had higher root numbers.
- Cuttings treated 1 h after sticking had the best side root formation.
- Both the untreated control cuttings and those treated 1h after sticking had new leaf shoot formation; untreated controls had more shoots then those treated after sticking.
- Cuttings treated at 3, 5, or 7 days had some leaf loss and no new leaf shoot formation.
- The numbers of rooted cuttings in blocks varied from 92% to 95% (not statistically significant).

Table 1. Number of roots formed on cuttings by Day 24.

Plant: Begonia 'Red Wing'.
Treatment: The spray drip down method.
Solution: At 200 ppm IBA in aqueous solution using Hortus IBA Water Soluble Salts (1.0 g salts/liter water).

	Number of roots formed (averages)					
	Average per cutting	Average at basal cut	Average at sides	Average at nodes	Root quality	Observation
Untreated control	* 18.9	12.3	4.1	2.5	Good	New leaf shoots.
Treat at 1 h	† 27.2	3.9	19.7	3.6	Good	New leaf shoots.
Treat at 3 days	20.7	5.5	8.3	6.9	Poor	Original leaf loss. No new leaf shoots.
Treat at 5 days	22.0	12.4	2.9	6.7	Poor	Original leaf loss. No new leaf shoots.
Treat at 7 days	22.1	6.0	12.4	3.7	Poor	Original leaf loss. No new leaf shoots.

Note: Begonias form new roots on various parts of the cutting. How counts were made for the average number of roots:

Average at basal cut: roots formed at the cut line of the basal end.

Average at sides: roots formed on the stem between basal cut and nodes or between nodes.

Average at nodes: roots formed directly over a node.

* = Lowest value in column.

† = Highest value in column.

Basic Findings. The present study found that auxins applied to leaves translocated to the basal end at the expense of leaf formation. The untreated control cuttings had more leaf shoot formation compared with cuttings treated within an hour. For the untreated control cuttings this was at the expense of root formation. The study found an advantage to treat within the first hour after sticking and perhaps within the same day (Table 1).

DISCUSSION

Rate Determination. Begonia's require very low foliar rates, usually 80–200 ppm IBA. A higher rate on tender annual cuttings may cause leaf curl or leaf spotting where the liquid touches the leaves. Despite these problems, the cuttings develop a good root system with new normal leaves. I have observed the new leaf growth to be normal and the cuttings develop a strong rooting system. The *F. pumila* in Dr. Davies' trials used a high rate, 1,000 ppm IBA for juvenile and 3,000 ppm for mature cuttings. For this specific selection Davies said: "Optimum concentrations for the juvenile and mature *Ficus* were, respectively, 1,000–1,500, and 2,000–3,000 ppm K-IBA" (Pers. commun.). Other ficus family taxa require other rates. In our trials on *F. benjamina*, found 500 ppm IBA to be suitable. I had never heard of other plants that had useful rates higher than 1,500 ppm IBA.

Rooting Quality. The present study, on annual begonias, showed the best root quality are on cuttings treated soon after foliar treatment. The Davies' studies had similar results.

Effects of High Rate. Occasionally I have seen cuttings, such as maples and rhododendrons, that have received too high a foliar treatment rate. Woody plant cuttings may accumulate the auxin at the basal end. The auxins, having no place to go, accumulate at the basal end. This may cause heavier than normal callus formation, and may inhibit root initiation. Growers made the problem more severe when they made a second or third application at the same high rate.

Third Day Observations. I cannot identify why in all the trials there was a slight decrease in root number formation on cuttings treated on the 3rd day after sticking. These cuttings still had more root numbers then the un-treated controls. The root numbers increased on 5th day treated cuttings. I had seen this effect in prior trials using cuttings from the same *B.* 'Red Wing' mother plant and on *F. benjamina*. My initial response was that there were problems with the experiments on the 3rd day. Apparently the trials were accurate.

Secondary Treatment. In another study, Dr. Davies did two foliar applications on *F. pumila*. All treated cuttings were given a treatment at time of sticking. The second application was given on one of several days. The two rates were the same. Juvenile cuttings had more root formation when treated on the 3rd day, for mature cuttings on the 9th day. His study suggests a first application at the time of sticking with a second application a few days later give improved root numbers and quality (Davies, 1980).

Kees Eigenraam did research at Dutch commercial growers of herbaceous plants. He found using a foliar application of rooting solution at the time of sticking, then a second application a week or so later, gave improved root formation. For the grower, the crop is leveled; it may reduce the need for grading (Eigenraam, pers. commun.).

Juvenility. Juvenile cuttings appear to benefit most from foliar application. Dr. Davies found juvenile cuttings of *F. pumila* had higher root numbers than mature cuttings. Growers like Yoder, in commercial propagation of perennials and crops like chrysanthemums, regenerate their stock plants, by taking cuttings from cuttings to make new stock plants. These juvenile cuttings root well when using foliar applied IBA in aqueous solutions.

Timing. Commercial growers must plan their production day to take into account the time of sticking and the time of treatment. The total immerse method has treatment in line with sticking. The spray down method can be done at time of sticking or at a later time. Yoder and Bailey say they have best results when they treat within the day after sticking. To accommodate scheduling, the present study and the Davies studies suggest that after sticking, treatment after a few days produces positive root formation. In addition, rooting numbers are best when treatment is made soon after sticking. I intend to do future studies narrowing the treatment to half days in the first 5 days after sticking. (Tables 1, 2; Fig. 1).

Discussing his *F. pumila* trials, Dr. Davies said: "In terms of our aqueous applications of IBA on juvenile and mature *F. pumila*, the earlier we applied the auxin, the better the response. Auxins were applied at days 3, 5, and 7 for the juvenile and

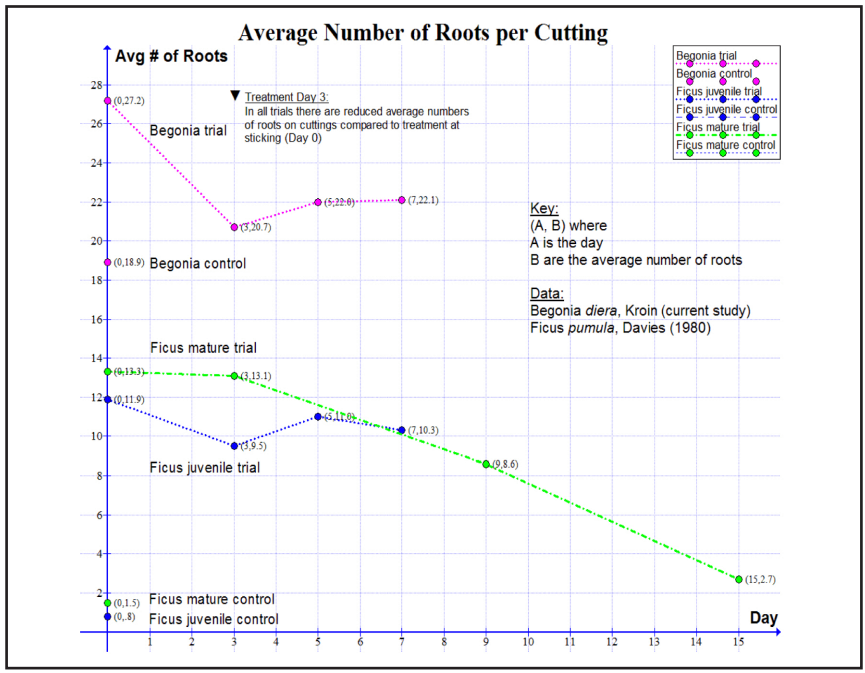

Figure 1. Study comparison: Average number of roots per cutting by day of application. Foliar auxin sprays for rooting of *Begonia* 'Red Wing' and *Ficus pumila* cuttings.

Plants: Present study Begonia 'Red Wing'
Davies studies: *Ficus pumila*
Treatment: The Spray Drip Down Method
Solution: IBA (ppm) in aqueous solution

Table 2. Study comparison: Timing of foliar auxin sprays for rooting of *Begonia* 'Red Wing' and *Ficus pumila* cuttings.

Plants: Present study *Begonia* 'Red Wing'
Fred Davie's studies: *Ficus pumila*
Treatment: The spray drip down method
Solution: IBA (ppm) in aqueous solution

	Begonia 'Red Wing' (Davies)		*Ficus pumila* study (Davies and Joiner, 1980)				
	200 ppm IBA		Juvenile 1000 ppm IBA		Mature 3000 ppm IBA		
Treatment	Average (no.) of roots formed per cutting	Root quality	Average (no.) of roots formed per cutting	Root quality	Day treated	Average (no.) of roots formed per cutting	Root quality
Untreated Control	* 18.9	Good	* 0.8	Poor	Untreated control	* 1.5	Poor
Treat at sticking	† 27.2	Good	† 11.9	Good	Treat at sticking	† 13.3	Good
Treat at 3 days	20.7	Poor	9.5	Good	Treat at 3 days	13.1	Good
Treat at 5 days	22.0	Poor	11.0	Good	Treat at 9 days	8.6	Good
Treat at 7 days	22.1	Poor	10.3	Good	Treat at 15 days	2.7	Poor (See Note 2 below)

Notes:

* Lowest value in the column

† Highest value in the column

Root quality note:

1) For root quality, in this table I have given a subjective value. Dr. Davies gives a numeric value where I have assigned: 1 = poor, 2 = fair, 3 = good.
2) "Application at Day 15 was beyond the "optimum application window", and there was a deterioration of percentage rooting, root numbers, root length, and root quality." (Davies, Pers. commun.)

Days 3, 9, and 15 for the mature since the process of adventitious root formation occurs more rapidly in the juvenile material. When we delayed applying IBA to the easier-to-root juvenile *Ficus* from Days 3, 5, or 7, there was no significant difference in adventitious root formation, including root quality. When we delayed applying IBA to the more-difficult-to-root mature *Ficus* from days 3, 9, to 15, there was no significant difference in adventitious root formation, including root quality at Day 3 or 9, but there was a significant reduction in Day 15" (Davies, pers. commun.).

CONCLUSION

Auxins, natural substances produced primarily in plant leaves, translocate to the basal part of cuttings to induce root formation. Indolebutyric acid, a bio-simulator of the natural auxin, when applied in an aqueous solution by foliar means can be used to propagate plants from leafy plant cuttings in the growing season. The applied auxin solution enters the leaf's stomata and translocates with the natural auxin to the basal end. The plant self regulates auxin use to produce new roots. Application can be done on annual, perennial, and woody plant cuttings. One time application can be done by the total immerse method. One time, or multiple time applications, can be done by the spray drip down method. Studies used IBA in aqueous solutions. Woody plant *Ficus* studies found, compared with untreated control cuttings, juvenile cuttings develop the highest root numbers followed by mature cuttings. The present study on *Begonia*, an annual plant, compared untreated control cuttings with foliar treated cuttings. The highest root numbers were on cuttings treated close to the time of sticking. Positive root numbers were on cuttings treated 3, 5 and 7 days after sticking. Other studies, by Davies, on slower-to-root cuttings have shown positive root numbers when treated beyond 7 days after sticking. Auxins accumulate at the basal end. Root formation is at the expense of leaf formation. Leaf growth resumes after root formation. Cuttings that are foliar treated with IBA in aqueous solution anytime in the trial period have higher root numbers than untreated control cuttings.

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