Plant Hormones: The Auxins, Points for Understanding Their Actions and Use©

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INTRODUCTION

Whenever I travel to plant conferences — IPPS meetings and IPPS area meetings — I am inevitably asked: "Well what hormone do you use to root this particular plant?" While I might have a ready answer more often than not, I offer "well, it depends." This paper is an attempt to explain some of the things that fall under the category of "it depends."

From a commercial stand point auxins come to us in a variety of forms. There are auxins dissolved in an alcohol solvent to form a concentrate that we in turn dilute with water to the desired concentration. Some auxins come as a talc powder formulation that has a fixed dosage and in the last 10 years or so there are now auxin preparations that are completely water soluble and can be diluted to the desired concentration in the same manner as the alcohol concentrates but without the possible injury from the alcohol.

AUXINS

Natural Auxins. All plants produce natural auxins (Fig. 1) that they use for the regulation of growth, flower formation, fruit formation, fruit abscission and for the initiation of roots (Devlin, 1969; Salibury, 1955). The auxins, indole-acetic acid, indole-3-butyric acid, and indole-4-chloro-butyric acid have specific functions depending on the time of year and the physiological state of the plant. All are manufactured in the leaves and the apical buds and transported basipetally throughout the plant. The natural auxins are under the control of various feed-back and counter chemical relationships so that no particular auxin can get out of control. All indole auxins are under continual degradation by IAA-oxidase and IAA peroxidase enzymes, which breakdown the hormones after they have done their job and prevent an extraneous build up (Kenton, 1955).

In addition to the indole derivatives as auxins, a second class of auxins is found as ethylene gas (Devlin, 1969). It behaves in a similar manner as the indoles but has a different timing sequence and mode of action and a different degradation system. Think of indoles as a heavy truck and ethylene as sports car. Both move down the road but the similarity stops there as each has a different application.

All of the auxins can be thought of as a key that unlocks a particular activity in the cells of a plant.

When the key is inserted into the lock the membrane potential of the cell is changed and allows or forces the cell to start undergoing specific changes (Fig. 2) (Haissig, 1986).

The natural process of auxin action is held in place by regulatory enzymes and counter hormones in the plant such as the gibberellins, cytokinins, and abscisic acid (Jarvis, 1986).

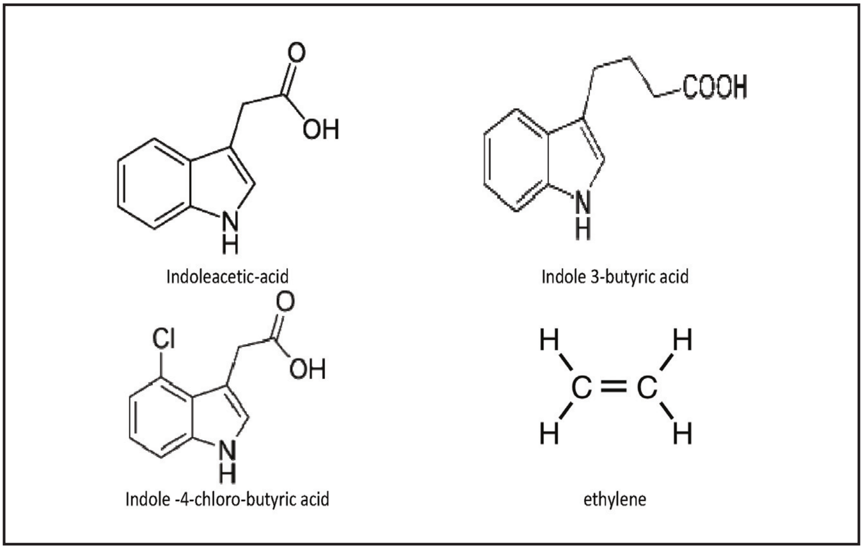

Figure 1. Various natural auxins and their respective chemical structures.

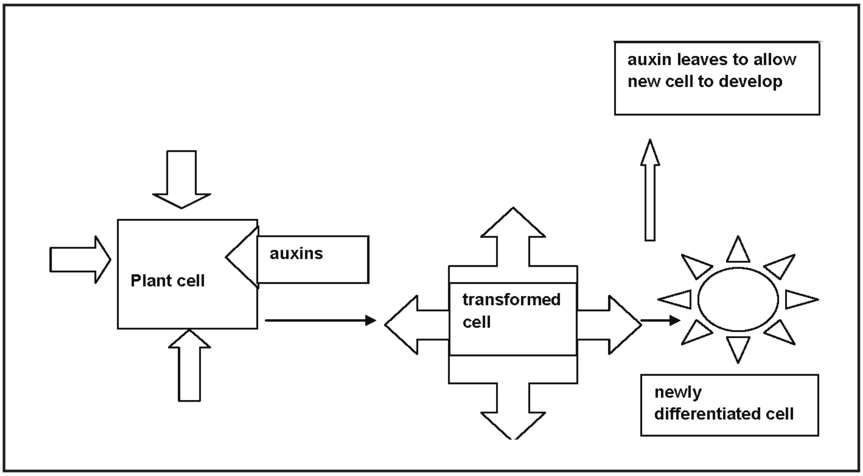

Figure 2. Sequence of auxin-induced events in a cell as it starts to undergo specific changes.

Synthetic Auxins. Synthetic auxins are not subject to many of the regulatory pathways in plants as the regulating auxin degredation/oxidase enzymes do not have an effect on the presence of a synthetic auxin. Accordingly it is much easier to overdose a cutting or tissue culture explant with auxin if a synthetic compound is used. The synthetic auxins with respect to the previous analogy of the lock and key will allow the key to turn the lock but then becomes jammed and will not allow for the normal processes to occur. This can lead to a range of problems. The most common of the synthetic auxins that mimic the indoles are α-naphthalyene acetic acid, followed by phenoxyacetic acid, 2,4,-dichlorophenoxyacetic acid, 2,4,5-trichlorophenoxyacetic acid, and dicamba (3,6-dichloro-2,methoxybenzoic acid) (Fig. 3). Synthetic auxins that mimic ethylene are acetylene, propylene, and carbon monoxide (Fig 3).

The mode of action of the synthetic auxins be they phenolic (NAA, 2,4-D, etc.) or aliphatic (gaseous) is based on the cells of a plant mistaking them for the natural forms based upon the similarity of the molecular structures. However, it is the alteration of the molecular structure that accounts for both their activity in the cell systems as well as their propensity to become toxic to the cellular mechanisms. They trick the lock into action but the key cannot be subsequently removed. A recent development in the creation of synthetic auxins is aminocyclopyrachlor-methyl ester. This chemical was released in 2010 as the herbicide (Imprelis™) by the DuPont Company. It is nontoxic to grasses but it is seriously toxic to conifers and has proven deadly to most of the common genera of conifers (Strachan, 2010).

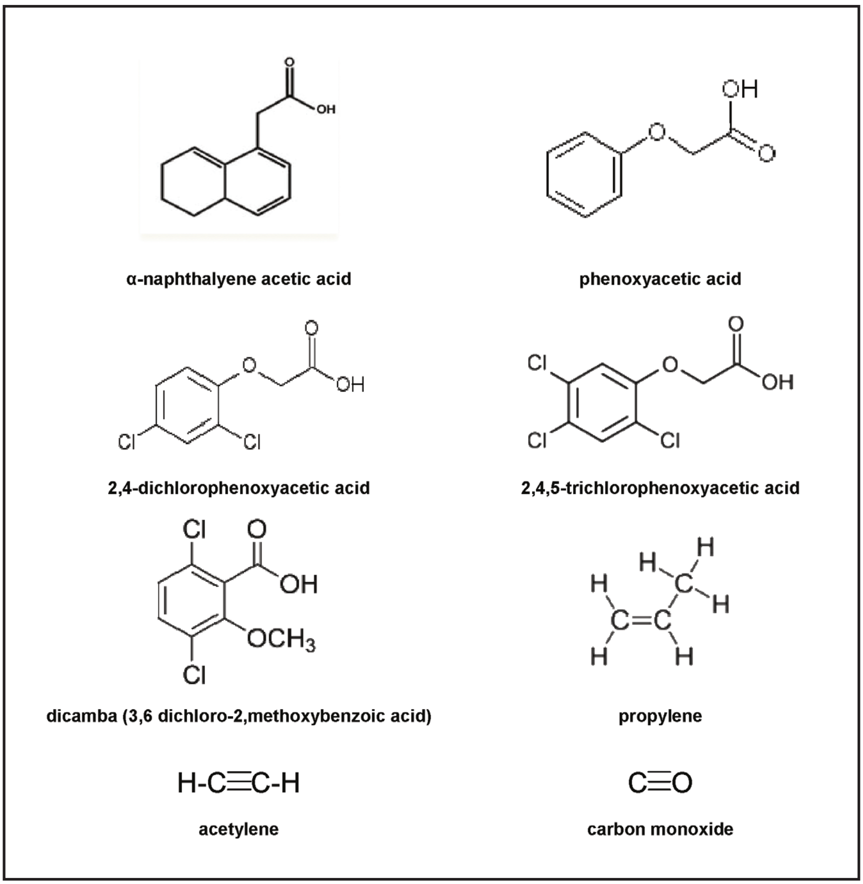

Figure 3. Synthetic auxins.

Commercial Availability of Auxins for Nursery Work. In the commercial world we commonly use IBA, α-NAA, and rarely but sometimes 2,4 D and ethylene. Indoleacetic acid is not used because of its tendency to be broken down before it has a positive effect on the rooting of cuttings. None of the other synthetic auxins are used because they have too great of an effect and cannot be easily administered in useable dosages although this property is exploited when they are used as commercial herbicides. None of the gaseous synthetic auxins are used as they cannot be used in a controlled manner and they all have a propensity to cause epinasty (abnormal leaf formation and development) and subsequent leaf abscission. Some authorities will suggest that auxins like 2,4-D cause plants to grow themselves to death. This is not the case, rather the synthetic auxins disrupt the cellar systems to such an extent that normal function is impaired and halted which results in toxic metabolites that in-turn kill the plant cells.

Commercially IBA and NAA can be found as a concentrate with ethyl alcohol as a solvent up to 10,000 ppm IBA and 5,000 ppm NAA. Dilutions from that point are made with water. The IBA is also available in the talc preparations at fixed rates such as 0.8% or 1.6% by weight. They generally cannot be altered to a lesser dosage. Potassium IBA (K-IBA) was used for a number of years for rooting cuttings but was removed from availability by the U.S. EPA because it was not registered for such use and it has been declared to be illegal to use K-IBA for the commercial rooting of cuttings in the U.S.A. Hortus Products (New York, New York) has a readily available alternative that is water soluble. Jones (2011) has suggested that in a comparison of K-IBA to the Hortus products that the Hortus material works better than K-IBA. The synthetic auxin, α-NAA, while available in the alcohol concentrates is not available as either a talc preparation nor as a water soluble formulation. It is available in the U.K. and presumably Europe but not in the U.S.A.

Other Uses for Auxins. Besides being used as root-inducing substances, auxins are used for a diverse applications such the formation of parthenocarpic fruit in plants such as *Capsicum*, chemical thinning of extra heavy fruit crops (the difference between fruit formation and fruit thinning is one of dosage, the same chemical can be used in either application), and for the suppression of suckering shoots on the rootstocks of grafted plants. It is interesting to note that the insecticide, Sevin (1-naphthyl-N-methylcarbamate), has been used as a chemical thinning agent for apples (Anonymous, 2011). The chemical structures found in Fig. 4 shows the similarity between the two chemicals and it is enough to fool the mechanisms in the plant.

Figure 4. Comparison of NAA and Sevin® (1-naphthyl methylcarbamate), note structural similarities.

Factors Associated with Auxin Use

A perfectly valid debate could be held as to whether to use an auxin or not use an auxin. Many plants will root acceptably without the addition of exogenous auxin and the rooting of plants prior to the commercial availability of auxins is well documented (Burbridge, 1876).

However the presence of an auxin does a number of things to hasten the rooting process:

- Will promote differentiation of tissues and speed up the rooting process.
- Will increase the total amounts of roots formed.
- Many times will increase rooting percentage but not always.
- Always remember that LESS is MORE, doing without is the best course.

The inevitable questions arise, I want to use an auxin but what concentration is the best dosage? This is not an easy answer because a range of factors can intervene and present a multitude of conditions.

Conditions that depend on:

- The plant itself, family, genus, and species, relationship within a kinship tribe.
- Stage of growth of the cuttings.
- Time of year.
- Stock in ground, container.
- Full sun, partial shade, shade.
- Nutrient status of the stock plant (Blazich, 1988).
- Primed or not primed, exposure to cold or other prompting environmental condition.
- Type of cutting, apical or basal.
- Wounded or not wounded.
- Liquid hormone or powder.

Some generalities:

- No auxin: cacti, sedums, sempervirens.
- Wounding without hormone, for easy-to-root tender things (*Impatiens*).
- 500–2,000 ppm IBA (NAA often used in conjunction to IBA at half rate), 5-sec dip for easy-to-root things such soft tips, *Lonicera, Weigela, Salvia.*
- 2,000–5,000 IBA, 5-sec dip, *Viburnum, Potentilla, Spiraea.*
- 5,000–7,000, IBA, 5-sec dip, *Syringa, Quercus, Prunus, Malus, Pyrus, Halesia.*
- 7,000–10,000, IBA, 5-sec dip, *Taxus*, *Juniperus*, *Picea.*

It should be remembered that even by following the obvious rules that not all groups of plants can be tarred with the same brush. In the maples (*Acer* species) for instance using quick dips:

1) *Acer tataricum* subsp. *ginnala,* 1,000 ppm IBA
2) *Acer rubrum,* 2,000 ppm IBA
3) *Acer palmatum*, 3,500 ppm IBA
4) *Acer griseum* × *A. maximowiczianum* (syn. *A. nikoense*), 5,000 ppm IBA

In general some approximations can be determined by following family patterns. A general rule of thumb for quick dips is offered by the following graph (Fig. 5).

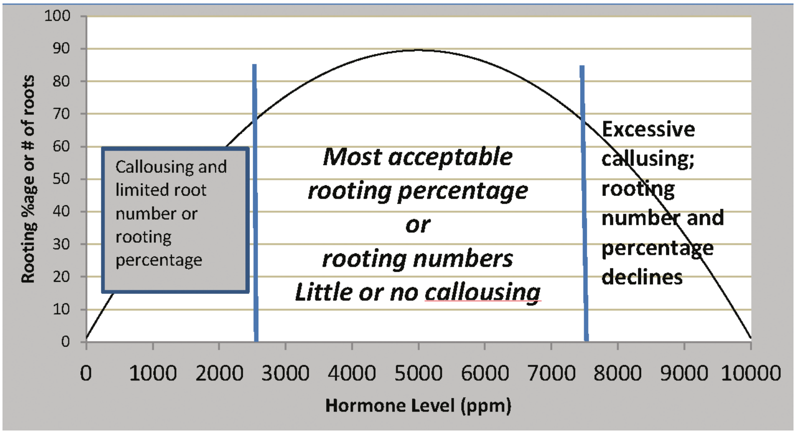

Figure 5. Cutting responses to variations in auxin concentrations.

SOURCES FOR DOSAGE RECOMMENDATIONS FOR QUICK DIPS

For Water Soluble Dips Go To:

- <http://www.hortus.com/Yoder/Yoder_recommendations_2004.pdf>.
- In general water soluble formulations use about 20% higher than acid formulations with alcohol.
- References such as: *Manual of Woody Landscape Plants* (Dirr, 2009), *Reference Manual of Woody Plant Propagation: From Seed to Tissue Culture*, (Dirr and Heuser, Jr., 2006); *Hartmann and Kester's Plant Propagation, Principals and Practices* (Hartmann et al., 2002).

Powder Formulations:

In many respects the use of rooting powders has diminished significantly. This is largely due to the fact that quick-dips are much more thorough to use and are more efficient. However, rooting powders do have a place in modern propagation. Some plants are ethanol sensitive and rooting powders can be used to overcome this difficulty although it should be noted that the water soluble quick-dips can also be used to circumvent the alcohol toxicity problems. So why use powders?

In some instances they are quite reliable and effective. They are somewhat cumbersome to use but they are not complicated. Many directions for using quick-dips suggest using xxxx ppm but the starting place for the alcohol dips is 1% IBA and 0.5% NAA. Some people have trouble going from % to ppm. To set the record straight 1% is 10,000 ppm. 0.5% is 5,000 ppm. However, people with limited English skills or folks just not familiar with the techniques might find powders to be that much more user friendly.

In general dosage requirements of powders follow the same pattern as quick-dips but with a different set of units. A dosage of 0.8% powder is equivalent to 2,500 ppm IBA quick dip. A dosage of 0.4% is approximately to 1,000 ppm IBA quick dip. Alternatively a 4% IBA powder has a rooting potential of a 10,000 ppm IBA quick dip. Older volumes of the Combined Proceedings of the IPPS offer the most reliable references to using powders, as the quick dip methods did not really become commercially available until the 1970s.

WHICH IS BETTER?

To effectively decide what to do, requires planning and an understanding of both the materials being used and of the plants being treated. Some of the pros and cons of the various formulations can be found in Table 1.

Table 1. Comparisons of various commercial auxin formulations.

Formulations	Pro	Con
Alcohol dips	Contains IBA and NAA	Alcohol toxicity
	Easily tailored to specific plants	Limits of solubility of both IBA and NAA 10,000 ppm, 5,000 ppm, respectively
		Not effective for all plants
		Fumes can be problematic
		Concentrate is flammable
Water soluble dips	Contain IBA	No alcohol toxicity
	Tailor made concentrations up to 20,000 ppm	Does not contain NAA
	No harmful fumes	Not effective on all plants
	Safe for many soft cuttings	Need about 20% more hormone than with alcohol dips
Talc preparations	Contain IBA	Do not contain NAA
	No alcohol toxicity	Limited effectiveness
	Safe on many types of plants	Cumbersome to use

Some Key Points for Consideration.

- Alcohol- and water-soluble formulations overlap in usage.
- Each method needs to be applied with respect to specific plant.
- Not all plants respond to either formulations, alternative formulations might be needed.
- Water-soluble formulations based on K-IBA reagent grade chemicals deemed illegal.
- Exact nature of new water-soluble forms not published.
- Barnes (1990) in unpublished work showed Rubidium salts of IBA just as effective as K-IBA, which indicates that the auxin is the majority player in the water-soluble formulations.
- Jones (2011) in a personal communication, says that Hortus products work better than K-IBA.
- Remember active ingredient is the auxin, not the solubility factor, unless alcohol solvents are involved.

Special Considerations with Auxins.

- Byrnes (2002) (pers. commun.) showed that IBA alone is preferable to IBA/NAA combinations for the rooting of *Quercus*.
- *Platanus* and some *Vaccinium* are generally rooted without auxins, because auxins will inhibit rooting in some taxa of these plants.
- Monocots: *Hemerocallis, Hosta*, Graminacae do not respond to auxins, but will root from cuttings.
- *Magnolia virginiana* and *M. grandiflora* show marked preferences for either IBA or NAA but not both in conjunction (Dirr, 2009; Martin and Ingram, 1989).
- Plants with high levels of manganese (Mn) are negatively affected with regards to rooting (Andersen, 1986).
- Boron at 2.5 ppm with auxins shown to be positive for rooting (Blazich, 1988; Haissig, 1986; Jarvis, 1986).
- Acidic pH for dipping solutions sometimes beneficial (Jarvis, 1986).
- Bottom heat and light shown to make significant contributions to the overall rooting success (Andersen, 1986; Burbridge, 1876).

CONCLUSION

Auxins are positive tools for the accomplished propagators. The variations in formulations and methods of applications can often spell success or failure. Other factors besides auxins can often contribute greatly to the overall effort. It is not prudent to assume that auxins alone will be sufficient to accomplish the largest amount of rooting that is possible for a given plant.

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