treated stock plants yield cuttings that root normally. These cuttings develop into higher quality liners with more new shoots than cuttings removed from untreated stock plants. In addition, azalea stock plants treated with Atrinal develop more new shoots than untreated stock plants. As a result, more shoots are available for propagation. This can also be an aid in the rapid development of azalea stock blocks.

The price of Atrinal is $89 per liter. When applied at a recommended rate of 1¼ ounces per gal, it costs $3.34 to prepare a gallon of spray.

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AUXINS OTHER THAN INDOLEBUTYRIC ACID WHICH CAN EFFECTIVELY BE USED TO STIMULATE ROOTING

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The chemical identification and elucidation in 1934-35 of the role of auxin [indoleacetic acid (IAA)] in promoting adventitious root initiation was a landmark in the history of plant propagation (8,9). This advancement led to auxin treatment of cuttings to stimulate rooting and made it possible to consistently root large quantities of cuttings from difficult-to-root plants.

Following the discovery that IAA promoted adventitious root initiation, the search began for other naturally-occurring auxins. Also, chemicals with structures similar and dissimilar to IAA

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were examined for root-promoting properties. The former studies, conducted for many years, were unsuccessful. Currently, it is generally agreed that IAA is the only naturally-occurring auxin found in plants. The latter studies were more successful and, in 1935, appeared the first report indicating the synthetic auxins, indolebutyric acid (IBA) and naphthaleneacetic acid (NAA), had strong root-promoting properties (14). Reports of additional synthetic compounds also classified as auxins and having root-promoting activity appeared in 1942 (5,13). These compounds included 2,4-dichlorophenoxyacetic acid (2,4-D) which, in later years, would be extensively utilized as a herbicide.

Since 1942 additional compounds, both naturally-occurring and synthetic, have been reported to stimulate root initiation in cuttings. However, commercial use has been limited to the auxins IAA, IBA, NAA, and to a limited extent, several of the phenoxy compounds When used to treat cuttings, these materials have been utilized alone or in combination. Sometimes when used in combination they are more effective than when used alone (4).

An interesting sidelight to the discovery of the role of auxin in root initiation occurred in 1933. At that time reports appeared demonstrating that certain gases such as acetylene, carbon monoxide, ethylene and propylene could promote rooting in cuttings of various plants (11,12). In herbaceous cuttings the response consisted of stimulation of root initiation and/or root development. For woody cuttings the response was merely development of existing root primordia (12). Little of this information has ever been used commercially by propagators. The role of ethylene in regulating certain plant physiological processes has received much attention in recent years. This is due to the natural production of ethylene by plants and its effects on such processes as fruit-ripening and abscission of leaves and fruit.

With the knowledge that cuttings could be treated with auxins to promote rooting, techniques were developed for treating cuttings with root-promoting compounds (3). These techniques included the application of auxin-talcum powder mixtures, the concentrated-solution-dip method (quick-dip method) and the dilute solution soaking method.

Initially, propagators prepared rooting formulations from reagent grade chemicals. Soon, a number of companies offered for sale, various commercial rooting formulations, under a variety of trade names. These commercial formulations consisted of two general types: one in which a particular concentration of auxin or several auxins were dispersed in talcum powder and a second in which one or more auxins were dissolved in a solvent. The solutions were usually concentrated and had to be diluted by the user before treatment of cuttings.

Of the two commercial rooting formulations the auxin-talcum powder mixtures have remained popular as evidenced by wide use and the numerous trade names under which these formulations are sold. Despite availability of commercial formulations, many propagators preferred to purchase the reagent grade of a particular auxin or auxins and prepare their own rooting formulations. This had the advantage of being more economical than purchasing commercial products It also allowed propagators greater flexibility in terms of the concentrations of formulations they could prepare. For those individuals who chose to prepare their own rooting formulations, the auxin most often purchased was reagent grade IBA. For a number of reasons IBA was the auxin of choice, one of which was its effectiveness in comparison to IAA and NAA (3,14). Through the years IBA could be purchased from several chemical supply houses in the United States. However, action taken by the United States Environmental Protection Agency (EPA) in early 1978 has alarmed propagators who purchase and utilize reagent grade IBA.

STATUS OF THE AVAILABILITY OF IBA IN THE UNITED STATES

Although clarification on this point has been difficult, it "appears" with the exception of propagators in California and scientists throughout the country that the purchase of reagent grade IBA by propagators from producers has been halted by the EPA (1). This has resulted since an EPA registration number has never been granted for its use. Until recently, federal registration of reagent grade IBA had never been sought. Reagent grade IBA can be sold by producers to commercial formulators who hold valid EPA registration numbers on the IBA-containing rooting preparations which they formulate and offer for sale This explains why IBA-containing rooting preparations are still readily available.

Several trade organizations and chemical companies are in the process of acquiring national registration of technical grade IBA (1). Thus far, no valid registration has been granted. Meanwhile, propagators who use IBA are concerned because their remaining supplies are dwindling or exhausted and they cannot reorder. Hopefully, the halt on the sale of reagent grade IBA to propagators will be rescinded. However, before this happens, what alternatives, if any, does a propagator have? Are there any other compounds which an individual might use to stimulate rooting with results comparable to IBA? Let us consider some alternatives.

ALTERNATIVES TO BE USED IN PLACE OF IBA

In the past, if a propagator purchased reagent grade IBA, the individual was undoubtedly preparing rooting formulations of desired concentrations. With reagent grade IBA now unavailable, a propagator has one of two choices; either purchase commercial rooting formulations or find a suitable substitute for IBA. Numerous possibilities exist for the first choice, and further explanation is unnecessary. Finding substitutes is not as obvious.

Any substitute for IBA should be an auxin. Although plant hormones other than auxins and chemical compounds not classified as growth regulators have been reported to stimulate adventitious root initiation in cuttings, auxins are generally the most effective compounds for achieving this goal. If one considers the reasons for treating cuttings with root-promoting compounds the auxins will out-perform all other materials (2). Before considering other auxins it should be kept in mind that a stimulatory response to auxin is not always possible. When treated with auxin, cuttings of many species show a stimulatory response while cuttings of other species do not. In summary, a stimulatory response to auxin is not universal.

Indoleacetic Acid (IAA). As an alternative to IBA one could consider IAA, the only naturally-occurring auxin. Use of IAA has not been widespread commercially because it is not as effective as IBA or NAA in promoting rooting (3,14). A possible explanation for the reduced root-promoting activity of IAA when applied to cuttings is that plant tissues possess several metabolic mechanisms which function for removal of IAA from the growth regulating system (6). In simple terms, plants possess mechanisms which operate to reduce and/or eliminate the effectiveness of IAA. There are also other problems associated with the use of IAA. Unsterilized solutions of IAA are rapidly destroyed by microorganisms (2) Similarly, strong sunlight also destroys IAA solutions (2,7)

IAA could be used as a substitute for IBA but there are problems associated with its use; one being that it is not as effective as IBA There are better choices.

Naphthaleneacetic Acid (NAA). NAA appears to be the best alternative to IBA This auxin has been shown to promote rooting in cuttings from a wide range of species. Effectiveness is further illustrated by its use in Rootone and the use of some closely related compounds, including naphthaleneacetamide, in several well-known commercial auxin-talcum powder formulations.

Though effective in stimulating rooting, reagent grade NAA has never been used extensively by propagators, probably due to an early report indicating it was not as effective as IBA in promoting rooting (3). This same report showed NAA was more effective than IAA.

In comparison to IBA, NAA is more toxic over a wide range of concentrations. Often the NAA concentration which promotes optimum rooting is close to a toxic concentration which leaves little margin for error. If a propagator decides to use NAA, studies should be conducted to determine optimum rooting concentrations. Despite the somewhat narrow concentration ranges over which this material may be used there are other factors which favor its use in comparison to some of the other auxins such as IAA. NAA is more resistant to microbial destruction than IAA and is light-stable (2). NAA would be a suitable alternative to IBA in addition to being more economical than IBA.

Phenoxy Compounds. A third alternative to IBA might be the phenoxy compounds such as 2,4-D, 2,4,5-trichlorophenoxyacetic acid (2,4,5-TP). These compounds, classified as auxins and used primarily as herbicides, promote rooting in cuttings from many species when used at extremely low concentrations. Though relatively light-stable and resistant to microbial decomposition they have not been used extensively for propagation (2). There are several reasons for this, one being that following rooting these materials inhibit shoot formation (2). Inhibition of shoot formation has been attributed to translocation of these compounds to the buds (10)

Phenoxy compounds when used to treat cuttings often stimulate callus-like growth on the bases of cuttings. This growth is usually associated with numerous short roots which appear bent, thick and stub-like in appearance. It is not unusual to observe masses of these short roots in which the individual roots are fused together. This type of root system is in direct contrast to strong fibrous root systems produced by IBA. Roots produced by the phenoxy compounds often develop slowly which, in turn, affects overall growth of the cuttings. Another problem is that the concentration which promotes rooting often causes necrosis of hte portion of basal stem treated. If the concentration used is greater than the optimum rooting concentration, severe injury or death of the cuttings may result. Thus, this illustrates the very narrow range of concentrations in which these compounds may be safely used.

A possible procedure of utilizing the phenoxy compounds might be to use a small quantity in combination with another auxin such as NAA. One report indicated that when this technique was used, greater stimulation of rooting was observed in comparison to using a phenoxy compound alone (5)

CONCLUSIONS

Until reagent grade IBA again becomes available to propagators, alternatives must be considered. For propagators who desire to prepare their own rooting formulations the best alternative appears to be some of the other auxins, particularly NAA. This auxin is readily available from several chemical supply houses in the United States and is cheaper than IBA. Other possibilities include IAA and the phenoxy compounds although problems are associated with their use.

Alternatives should be considered carefully. This includes conducting empirical trials to determine optimum rooting concentrations. Such trials will be necessary because reports in the literature concerning optimum auxin concentrations for stimulating rooting deal primarily with IBA.

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