WHAT'S NEW IN GROWTH REGULATORS?

ROY M. SACHS
Department of Environmental Horticulture
University of California
Davis, California

In the past decade two kinds of research, one concerning naturally occurring growth regulators and the other synthetic substances discovered in screening programs, have yielded substantial advances in our ability to control plant development.

The work reviewed below is not necessarily "new", but, since there appears to be a 10-20 year lag between discovery and true application of growth regulators, it may be important to review the synthetic compounds made available over the past two decades. Present studies with naturally occurring compounds are more likely to sound "new" since they are still in the laboratory stage. However, they suggest outstanding opportunities for the development of additional chemicals of economic importance and will be discussed first.

A. *Naturally Occurring Compounds*

1. Abscisic acid (and related substances)

There is little question that the isolation of abscisic acid (ABA, abscisin II, dormin) from many different plants is having the same impact on our understanding of plant development as did the discovery of the gibberellins. Although ABA accelerates abscission of leaves and flowers in some species, its most significant effect is that at low levels it can inhibit meristematic activity without herbicidal side effects. It causes dormancy in many woody plants, inhibits seed germination without affecting viability, and may promote or inhibit flowering depending upon the species tested. Generally speaking, the effects of ABA on shoot systems parallel those of short day lengths, and are opposite to those of the gibberellins. Long days and chilling either reduce ABA concentration and/or cause an increase in gibberellin production which in turn overcomes the effects of ABA. Thus, ABA and some other physiologically related inhibitors appear to be the naturally occurring antagonists of gibberellins. ABA has been synthesized but its present cost prohibits widespread field testing. If wide spread applications are found, large-scale production could lower costs substantially. ABA could be used in many cases where it is desirable to extend dormancy in woody plants, seeds, and tubers, corms, bulbs, etc. In some instances the promotive effects upon flower initiation could also be exploited.

2. Gibberellins.

Continued research with gibberellic acid (GA, GA_3) and closely related compounds (there are now 20 known gibberellins) have revealed some new possibilities for growth regulation with these substances. Of great significance is the discovery that some gibberellins may promote stem elongation

with little effect on flowering, whereas others may have the reverse effects. There is some evidence that day length effects upon plants may be mediated by conversion of gibberellins from one type to the other, rather than by altering total gibberellin level. The promise for the future is that sufficient quantities of gibberellins having more specific effects upon flowering may be isolated. Chemical control of flowering is of such great import in all phases of agriculture that any compounds that can be produced economically will find immediate application.

B. *Synthetic Compounds.*

1. Growth retardants.

The growth retardants, such as Cycocel, Alar (B-9), and Phosfon, have been used for several years to reduce excessive stem elongation without at the same time inhibiting leaf and flower initiation or fruit development. In some plants (azalea, rhododendron, and bougainvillea) these compounds may be used primarily for causing earlier, more uniform and heavier flower initiation.

During certain phases of nursery propagation and when the plants are in the landscape the growth retardants may be used to hold a plant at the optimum size. A 0.5 to 1% foliar application of Alar at 30 day intervals applied shortly after bud break prevents excessive stem elongation in many shrub and tree species without harming the foliage or preventing leaf and flower initation.

2. Maleic hydrazide (MH)

Maleic hydrazide (formerly marketed as MH-30 and MH-30T but now called Slo-Gro; contains 30% maleic hydrazide as the diethanolamine salt) must be discussed apart from the retardants because it inhibits leaf and flower initiation as well as stem elongation. Because of its wide species range and effectiveness at relatively low levels it is presently the most useful growth regulator for preventing overgrowth in the landscape and nursery. Recent trials in northern and southern California have shown that repeated applications of MH at 30-45 day intervals, commencing shortly after bud break, can eliminate "within-growing-season" pruning in many evergreen shrubs. Furthermore, when used at low levels (i.e., at 0.1% or less of the marketed solution) there are few deleterious side effects although flower initiation is delayed or prevented. A single application of the high level recommended by the manufacturer (1% or more of the marketed solution) if applied after pruning stops growth for an entire season but also causes severe aberrations in leaf development including chlorosis. Such side effects are usually unacceptable in the nursery although they may go unnoticed in the landscape. The 1% solution is used with great effectiveness in preventing summer-shoot development in recently pruned trees. Many power companies employ MH on an annual basis. For deciduous trees it can be applied only after exfoliation; when appli-

ed too early, (just following bud break in the spring) leaf expansion may be delayed or prevented for the entire season. Applied when leaf expansion is nearly finished the only ill effect may be "tip die back" which can rarely be seen from the ground and then only by experts looking for damage. It is estimated that this use of MH can save power-companies 80% or more of the annual pruning costs; i. e., an annual spray with MH costs about 1/5 that of mechanical pruning.

3. Chemical pinching agents — the fatty acid esters.

In a certain sense the fatty acid esters are selective herbicides; i. e., they kill selectively the terminal shoot bud. The effect is to "release" axillary buds which then grow as normally as they would if the terminal bud had been removed by hand pinching. Although this practice has been successful on chrysanthemums, azaleas, and some other potplant species, there is no comparable published work for woody species. The few tests that I've seen have been relatively unsuccessful; nevertheless, in many shrub species, where axillary bud development is desirable during early stages of propagation, chemical pinching agents should find ready application. It should be kept in mind that effective techniques of application vary from species to species and from one locale to another.

4. New compounds requiring much additional work.

a. Morphactins. These substances are in some cases very effective growth inhibitors, but they invariably cause persistent foliar distortion. Major interest in these compounds may develop because all "dormant" axillary buds commence growing shortly after treatment.

b. Ethrel. This compound is reported to be an ethylene generator and an effective growth inhibitor for many ornamental shrubs. If indeed ethylene is the active component, we can expect undesirable foliar distortion; however, I have seen no photographs of treated plants.

C. Application timing, improved formulations, and the problems of penetration.

Several companies are testing growth regulating compounds that have been discovered in screening programs. Whether the materials will be registered is uncertain, but in the past most firms have been willing to bear the costs of limited registration required for ornamentals (no chronic toxicity tests necessary). Thus it appears probable that many chemicals will be released for use in the landscape and nursery without due attention paid to factors important to the horticulturist. This lack of intensive field and laboratory work prior to the release of a growth regulator accounts for the 10-20 year lag between discovery and true application of useful compounds. Maleic hydrazide has been available since 1949; only recently has timing of application and formulation been adjusted to account for differences in penetration. All studies with growth regulators must consider the problem of

penetration; this varies with the kind of tissue treated as well as the climatic conditions prevailing at the time of treatment. Our studies with MH and Alar have shown dramatically that timing after bud break is the most critical factor determining treatment effectiveness. One of the reasons is that penetration through the young tissues is considerably greater than through fully expanded leaves. Intervals between reapplication also depend upon initial penetration as well as metabolism of the compound in the plant.

Some formulations of the active growth regulator, e. g. as salts or esters, are often more effective than the free acid or base. The differences in activity may be due solely to increased penetration of the salt or ester.

The role of adjuvants (usually surface active agents) in improving effectiveness of growth regulators is receiving considerable attention in industrial and university laboratories. These "inert" ingredients are no longer believed to act only as wetting agents in causing increased coverage; new evidence suggests that some surface active compounds act as growth regulator penetrants, permitting co-solvency of the regulator in the waxy cuticular layer covering plant tissues.

In some of these areas of research new developments are likely to be as meaningful in determining the value of a growth regulator as was the initial discovery of the compound.

DICK MAIRE: Thank you, Wes. Are there questions from the audience?

UNIDENTIFIED SPEAKER: I have a question for Dr. Hackett. What can you tell us about the product put out by U. S. Borax called Maintain?

WESLEY HACKETT: Its active ingredient is one of a group of compounds called Morphactins. It is supposed to control the growth of turf grass but tests that have been run at U. C. Davis show that it turns turf brown before it controls growth.

UNIDENTIFIED SPEAKER: Do you know of any use on woody plants?

DICK MAIRE: We used Maintain on *Pinus radiata* in a Christmas tree plantation and got some very weird growth. We were using 100 to 200 parts per million and we got twisted, knarled, very unusual growth. The plants didn't grow for a year after the material was applied. We have also used Maintain in a chemical pinching trial on woody ornamental plants at San Gabriel Nursery. The material does stop the growth of plants fairly well at low rates, and it causes considerable axilliary bud break. We have to study this aspect a little more and find where it might fit into the picture.

UNIDENTIFIED SPEAKER: I have a question for Dr. Hackett. Where can I get Cycocel for some test purposes?

WESLEY HACKETT: Cycocel is a product of American Cyanimid Company. I am not sure, but I think Paul Ece, Jr. down in San Diego County is the West Coast distributor for it.