NEED FOR GROWTH REGULATORS ACCENTUATED BY RISING COSTS

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The concept of controlling plant growth with natural plant substances, such as auxins, was first developed in 1926-28 when F. W. Went identified and measured plant growth differences resulting from the application of very minute quantities of these natural plant hormones.

Auxins, as natural plant hormones, were thus able to stimulate plant growth. Eventually purely synthetic compounds were artificially made that could simulate their actions.

From this discovery followed the identification of natural organic substances in plants that could either inhibit or suppress various growth functions in plants. Some of these naturally occurring inhibitory functions we are familiar with include:

1. The maintenance of a dormant state in seeds of many plants until acceptable environmental conditions favorable for growth development.
2. Prevention of premature germination before adequate seed dispersal is attained.
3. Spreading germination over a long period, amounting to years in some cases, to assure the continuity of a species.
4. The ability of plants to compete in a mixed stand is also attributed, in some instances, to the release of an inhibitor by the plant that can prevent the development of other potentially competitive species. One example is that of a wheat-rye stand able to suppress growth of several competitive weeds.

The concept of chemically controlled growth inhibition for specific purposes developed. Initially this became most important as in the development of herbicides for the selective control of undesirable weed species. One of the earliest and most successful of these was the family of phenoxy herbicides of which 2.4-D was the most important. Since this discovery there has been a rapid increase in the introduction and use of plant growth regulators in agriculture, on recreational sites, and in horticulture. The many selective preemergent herbicides are an excellent example of growth inhibitors selectively controlling undesired species.

It is only recently that the concept of growth stimulation to increase crop yields in agriculture and growth regulation or growth suppression in horticultural and turf maintenance have been successfully applied on a large scale.

Increased yields in agriculture are now obtained with the application of synthetic plant hormones that can increase corn production, sugar content in sugar cane, and pineapple yields. It has been stated that the next major breakthrough in food production world wide will be through the use of plant growth regulators. The potential is there and only limited by the imagination.

Since we are now going to discuss growth regulators and their present day application in plant growth, the term should be defined. A growth regulator is a substance used for controlling or modifying plant growth processes without appreciable phytotoxic effect at the dosage applied.

In horticulture we now see the use of growth regulators to control height, as a substitution for cold treatment, for chemical disbudding, to hasten flowering, to produce longer lasting flowers, and for defoliation. (See "Growth Regulators Effective on Floricultural Crops" by R. D. Heins, R. E. Widmer, and H. F. Wilkins, Dept. of Horticultural Science and Landscape Architecture, University of Minnesota, St. Paul, MN for a complete list of compounds and uses). Fruit production is also enhanced by artificial thinning with these compounds. Uniformity of ripening in tomatoes with the use of ethylene has also been successful. There are many other examples to demonstrate the usefulness of these compounds. These early success stories are impressive, yet the industry is only in the early stages of development.

The controlled growth of turfgrass species also demonstrates the practicality of this controlled growth concept. Today with high labor costs and fuel shortages, and the continued increase in fuel costs, the need for effective growth regulators is accentuated. A recent example, for the first time in 1979 the Indiana State Highway Department used a growth regulator when there were no acceptable mowing contracts submitted. In turf growth control, as in other fields, there remains a great potential and need for more effective compounds.

One of the first plant growth regulators sold in the United States was maleic hydrazide (M.H.) introduced in 1950. By 1965 more than three million pounds of growth regulators were sold in the U.S.

Height of unmowed Merlon bluegrass next to treated bluegrass four weeks after application.

M.H. accounted for approximately 90%. By 1972 the quantity used increased to six million pounds, with M.H. comprising 70%. By 1975, newer growth regulators were estimated to have accounted for more than 50% of the total market.

There are two primary methods by which growth regulators control plant growth functions.

1. **Terminal growth inhibition.** Some of the effective growth inhibitors now available, including maleic hydrazide, the flurenols, and ethylene releasing compounds act by inhibiting terminal bud growth. These growth inhibiting compounds usually alter geotropic responses, cause axillary bud break or induce early leaf loss, and reduce stem elongation in some plants. Inhibitors such as M.H., the flurenols, and ethylene, that disturb terminal bud growth activity cannot, generally, be used where normal leaf and flower initiation and development are necessary.
2. **Internode elongation inhibition.** These are compounds which inhibit internode elongation without disrupting terminal bud development. Retardants such as CCC (Cycocel®), ancymidol (A-Rest®), etc. are usually recommended to reduce plant height in potted plants, nursery crops and fruit trees since leaf and flower initiation are not severely delayed.

Some of the existing growth regulatory compounds would include:

1. Ancymidol (A-Rest®)
2. CBBP (Phosphon-D®)
3. CCC (Cycocel®)
4. Chlorflurenol (Maintain CF125®), (Po-San®)
5. Mefluidide (Embark®)
6. Ethephon (Ethrel®), (Cepha®), (Florel®)
7. Maleic hydrazide (Slo-Gro®), (Royal Slo-Gro®)
8. Daminozide (Alar-87®), (B-Nine SP®)
9. Gibberellic acids (GA^3, GB^4, 6A^7)

The choice of inhibitor will depend on the objective. In turf the selection of a compound to control plant height often depends to a great extent on the degree of plant discoloration on thinning that can be tolerated and whether only seedhead prevention is desired. The M.H., flurenols, mefluidide (Embark®) and ethephon can all control excessive plant height. There are situations, however, where high temperatures, excess drought, insect or disease activity can cause turf thinning and discoloration since the turf is unable to recover rapidly due to the growth regulator activity. There are sites where these conditions can be tolerated and where these compounds have a very important place. This would be true for plants viewed from some distance, such as from moving vehicles. Thus the phytotoxic side effects of some compounds can be tolerated.

M.H., the flurenols, and now Embark have successfully reduced the need for mowing grassy areas in the United States and Europe. Reduced blade and sheath elongation are beneficial effects. The reduced length of the seed stalk and reduction of seedhead formation are major factors in the use of these products for roadside maintenance.

For most lawn turf, inhibition of the plant stem and leaf blade elongation is all that is desired. Complete prolonged inhibition of new leaf formation, tillering, rhizome, and root formation is undesirable and will eventually lead to a reduction in turf density as the existing plant parts die and there is not adequate regrowth for recovery.

The M.H., flurenols and Embark, though effective growth regulators, cause a general reduction in quality of good turfs of Kentucky bluegrass, bentgrass, and bermudagrass. This reduction in quality is especially severe under either pest or environmental stress.

Maleic hydrazide at 4 lbs. ai/A restricts stem and leaf growth and inhibits seedhead development. It is best on minimum use turfgrass sites such as roadsides, steep slopes, pond or stream banks, along fence rows and around trees where trimming costs are excessive. Root and rhizome growth may be restricted. Repeat applications, without a turf recovery period, can result in additional thinning.

Flurenols used at 1-3 lbs. ai/A give good shoot growth retardation as well as inhibition of apical bud formation. Leaf color is enhanced. They are most effective when used in combination with the maleic hydrazide.

Embark 2-S at 0.12 to 1 lb. ai/A on cool season grasses and 0.5 lb. to 1 lb. ai/A on the warm season grasses offers good turfgrass growth inhibition and suppression of seedheads. The leaf has a darker green color than that of untreated grasses. There is also some evidence of root growth stimulation. It has some herbicidal activity and therefore can be toxic if rates are not carefully controlled. The compound successfully inhibits fine turf, but here again, under environmental and/or pest incidence stress thinning results.

Another growth regulator that has some potential for the turf market is ethephon. When used at 4-6 lbs. ai/A moderate to good growth inhibition of perennial bluegrass is observed. Green leaf color is enhanced. There is also some evidence of tiller stimulation although with some inhibition of rhizome development. There is an increase in leaf numbers per plant. The leaves are shortened with slightly elongated internodes. This tends to dwarf the plant and thus results in the necessary growth reduction. Therefore, the plant, although dwarfed, continues to grow and offers some protection from environmental stress and pest damage.

The efficacy of these growth regulators can be seen in the data from Purdue 1976 presented in Table 1.

The potential of some existing experimental growth regulators is encouraging. Growth regulators are able to change the bluegrass plant form by shortening the leaf and lengthen the internode, to stimulate rhizome bud formation on perennial bluegrass, and to enhanced tiller formation as rates increase.

The ideal turfgrass growth regulator is one that will reduce leaf and stem height and produce many small leaves to maintain surface density and

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Growth Regulators *from page 26*

Table 1. Reduction in Kentucky Bluegrass Growth

	ai/A lbs.	20 days	Growth Reduction 49 days	89 days	Effects on plant
		%	%	%	
Control	—	normal	normal	normal	—
Ethephon	6	50	54	32	darker green
M. H.	4	50	73	22	slight chlorosis
Embark	0.5	56	65	33	darker green
Sustar	4	61	35	23	darker green

color and permit continued growth or stimulation of tiller, rhizome and root formation, thus reducing mowing requirements yet maintaining the plant in a vigorous growth state to enable it to overcome the environmental or pest incidence stresses.

Application of growth inhibitors may be as foliar sprays, fogs, and as soil drenches. Inhibitors such as M.H. flurenols, Embark, and ethephon are generally applied as foliage sprays. Adequate moisture is essential at application to assure proper entry into the plant.

M.H. and the flurenols have been applied as a soil drench to effectively reduce shoot growth. Some of the phytotoxic side effects of foliar applied M.H. are minimized by soil applications. However, labels should be checked for rates and application procedures. Soil applications to shrubs and other ornamentals for growth retardation have not been successful due to rooting depths of the plants.

The effectiveness of foliar sprays may be increased by reducing the average droplet size and using more concentrated solutions. Fogging applications may be useful for foliar applied compounds, especially in enclosed or isolated areas where drift is not a problem. The finer mist offers greater potential for chemical effectiveness because both the upper and lower leaf surfaces are covered offering greater potential for plant uptake.

Adjuvants which aid in surface wetting and thus absorption of the active ingredient can be combined with growth regulators. There is general agreement that the action of surfactants in improving foliar absorption is complex involving more

Test plots show seedhead suppression and growth retardation six weeks after treatment to Kentucky bluegrass. Photo courtesy J. A. Jagschitz, Virginia Polytechnic Institute.

than the increase in surface wetting. M. H. has recently been formulated with a special surfactant (Royal Slo-Gro formulation) that further enhances the activity on a limited number of species. Foliar absorption of M.H. is reduced after the droplet has dried.

Cumulative phytotoxicity caused by applications of growth regulators has not generally been reported. M.H., flurenols, Embark, and ethephon however, appear to have a residual effect on some species.

Solutions of 0.3 to 0.4% M.H. are normally applied annually to tops of trees under power lines. M.H. is applied only to trees in which bud break and leaf growth were normal the previous spring. For this reason, cumulative phytotoxicity has not been observed. Some regrowth is necessary before growth regulator applications are repeated.

As yet there is no method of predicting sensitivity of a species to a compound. One species may respond to a compound when another does not. This may be due, in part, to differences in absorption, transport or metabolism of the compound.

Finally, the growth regulators available to date, though effective, have some limitations. These may be due either to phytotoxicity, thinning, excess or inadequate inhibition, or due to short or a prolonged residual inhibition period. Continued investigations will produce newer compounds that will permit the chemical manipulation of plant growth in specific directions. There is no reason why drought resistance and winter hardiness, rhizome, tiller and root formation with vertical leaf growth suppression should not be obtained by chemical treatment, thus permitting the agriculturalist to modify plant growth to meet local conditions or needs, and expand and introduce plant species in areas that have so far been nonproductive. There is little doubt that the future of chemically controlled plant growth offers great potential for satisfying the increasing needs of mankind.

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