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What to Expect from a Nitrogen Fertilizer

by
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The comment is made often that in using nitrogen fertilizers it is best to base rate and frequency of application on experience with the specific grass involved and not strictly on manufacturers directions. Because of the wide variation in plant response that can result from the use of nitrogen fertilizer it is important to know what to expect when various materials are used.

Facts of Life About Nitrogen

There are several key facts about nitrogen that must be understood before it can be effectively used in turfgrass fertilization.

First, nitrogen is the most important element in turfgrass production. Turf responds more to the presence or absence of nitrogen than to any other element. Too much nitrogen can be as detrimental to the turf as too little. Also, the nitrogen level within the plant often determines what effect other climatic factors will have on turf production.

Second, there are three different types of nitrogen fertilizers; i.e., inorganic, natural organic, and synthetic organic, but only two categories as far as use is concerned; i.e., fast acting soluble materials and slow acting insoluble materials. In general the fast acting soluble inorganics and certain synthetic organics must be applied in small amounts at frequent intervals. The slow acting insoluble natural organics and certain synthetic organics may be applied in large amounts at less frequent intervals.

Third, in soil, nitrogen is changed from the form in which it was applied to the nitrate form. Turfgrass may absorb some nitrogen in other forms, however, for the most part nitrogen nutrition involves nitrate nitrogen.

Fourth, turfgrass gets only the nitrogen that is left over after soil microorganisms get theirs. Usually a soil which is not microbiologically active does not produce high quality turf. It is important to recognize the value of soil born organisms and to realize that they utilize minerals from the soil and to this extent compete with the grass for,some plant food.

Fifth, nitrogen response of turf is controlled by the type of nitrogen used and by how it is used. There are 17 different turfgrass growth responses that have been studied in research projects at Iowa State University during the past five years. Results of these investigations provide a rather complete picture of nitrogen effects on turf. They should help to make clear what can be expected from the use of a nitrogen fertilizer.

Nitrogen and Chemical Iniuries

Fast acting soluble nitrogen fertilizers whether applied as liquids or as solids may severely burn foliage of turf if applied at rates in excess of 1 pound of nitrogen per 1000 sq. ft. These materials should be applied to dry foliage and watered in following treatment. Care should be taken to obtain even distribution of fertilizer. Avoid overlaps and adjust spreaders so that material is deflected and scattered before it hits the ground. The whirlwind type spreader scatters the fertilizer so that it is uniformly distributed. Use of this type spreader eliminates the possibility of streams of material running out in rows on the turf and permits the safe application of fast acting nitrogen sources which are otherwise difficult to spread. It is often desirable to drag fertilized areas which cannot be watered so that materials lodged between leaves and on the foliage will be brushed to the soil surface. Where particles remain on foliage overnight they may dissolve in a heavy dew and cause foliar burn.

Nitrogen and Growth Stimulation

When temperatures are cool, light intensity is adequate, and moisture is readily available, nitrogen stimulates foliar production (Table 1). Some minor differences in response are noted from time to time between varying nitrogen sources. For the most part these differences are due to the fast or slow acting properties of the fertilizer.

Nitrogen and Wilt

Nitrogen has a pronounced effect on both the rate of foliar growth and on total production of leaf tissue. Where grass receives excess nitrogen and where soil moisture and temperature are favorable for plant growth, the foliage that develops may become soft and succulent (filled with too much water for the amount of dry matter produced). Such foliage is susceptible to wilt any time the rate of water loss from the leaves is greater than water uptake from the roots. Soft succulent foliage wilts quickly and injury to the turf can be severe. Poa annua is particularly susceptible to wilt under these conditions. In order to avoid an increase in wilt from use of nitrogen fertilizers keep track of the total nitrogen being applied to greens throughout the season and avoid the accumulation of large amounts of slowly available synthetic nitrogen sources during warm weather. These nitrogen sources have been noted to breakdown and release nitrogen faster than desired during periods of hot humid weather. In general less nitrogen should be applied during the summer months than during spring and fall.

TABLE I

Evaluation of Washington Creeping Bentgrass Putting Green Turf For Growth and Color of Foliage

TREATMENT	RATE OF APPLICATION*	TURFGRASS QUALITY IN JUNE#
No Fertilizer	- - -	3.8
Natural Organic	10	1.1
Natural Organic	5	1.9
Natural Organic'	10	2.1
Natural Organic'	5	2.9
Ureaform	10	1.9
Ureaform	5	3.1
Sodium Nitrate	10	1.0
Sodium Nitrate	5	2.5
Ammonium Nitrate	10	1.0
Ammonium Nitrate	5	2.3
Ammonium Sulfate	10	1.0
Ammonium Sulfate	5	2.4
Urea	10	1.1
Urea	5	2.6

l-Milorganite 2-Agrinite 3-Nitroform
* -Pounds of Nitrogen per 1000 sq. ft. per season
#-l-best 4-poorest

Nitrogen and Thatch

Grasses vary in their tendencies to form thatch. Those that are most likely to become thatched are especially vigorous growers and usually are very responsive to nitrogen fertilization. To keep thatch from developing at a faster rate than it can be removed fertilization must be carefully regulated. Growth rates should be stimuIated by nitrogen only to the point where the turf has sufficient vigor to heal in quickIy following injury and sufficient capacity to produce new foliage for proper play. Other elements such as iron can be used to provide improved color if this is all that's lacking.

Once thatch has formed nitrogen is required by the microorganisms to decompose it. Topdressing thatched greens with soil to which fast acting nitrogen has been added should help to decompose these organic thatch deposits. Turf should be opened up by use of a verticle mower so that the topdressing can filter down into the thatch.

Nitrogen and High Temperature Effects

It has been noted that when temperatures are cool (65° to 80°F) nitrogen fertilizer stimulates growth of foliage; however, when it is hot (80 to 95°F), nitrogen reduces growth of foliage and weakens turfgrass stands. During hot weather high phosphorus added to high nitrogen further reduces the vigor of fine turf, but high levels of potassium help to harden off the tissue and thus increase turf vigor. Because of these relationships between nitrogen and high temperature, it is important not to use too much nitrogen during warm weather.

Nitrogen and Nutrient Balance in Turfgrass

Nitrogen is absorbed by grasses in larger amounts than any of the other mineral nutrients. Once nitrogen is absorbed and is inside the grass plant it must be assimilated or used in order to have a beneficial effect on plant growth. The use of nitrogen within the grass plant depends on the presence of other mutrients in the proper proportion one to the other and on several other physiological or growth factors.

When nitrogen is deficient for a period of time while other nutrients are readily available, the plant becomes unbalanced with respect to its mineral nutrition. It absorbs more of some nutrients than can be used because of the lack of others. If adequate nitrogen is applied to a turf which has become unbalanced because of the lack of nitrogen, the grass will quickly absorb the added nitrogen. This nitrogen accumulates in the tissue and is slow to be used because the unbalanced nutrient condition is slow to adjust. Our studies at Iowa State University have shown that bluegrass turf can be produced with 4.5 to 5% nitrogen in the foliage and with other essential elements applied in adequate quantities to prevent the formation of deficiency symptoms, but not applied in the proper balance. The result has been the development of yellow, chlorotic foliage because although ample nitrogen was available to the plant, it could not be utilized. Nutrient unbalance prevented this nitrogen utilization.

Nitrogen Effects on Root Development

Turfgrass which is clipped high; i.e., above 1 1/2 inches produces increased root systems under low nitrogen. In this instance the lower nitrogen level reduces the rate of foliar growth so that organic energy sources within the plant can be diverted to increased root development. As the clipping height is lowered and leaf surfaces available for photosynthetic processes are reduced, the amount of organic energy sources becomes less. Nitrogen is needed under these conditions to stimulate foliar growth so that the amount of these energy sources may be increased for root growth. In general, any time nitrogen increases foliar growth past the point needed to supply a base level of organic energy sources for foliar and root growth, the turf will produce excess foliage at the expense of the root system.

Nitrogen and Moisture Stress Effects on Foliage

Turfgrass grown under conditions of moisture deficiency is generally susceptible to extremes of other growth factors in the environment. For example, growth of turfgrass foliage is reduced by lack of available moisture when grown under medium levels of nitrogen; however, growth is further reduced when nitrogen levels are either low or high. Since fairways and tees may often suffer from a lack of moisture it is important to keep these turf areas well fertilized, but not over fertilized. Since greens are more likely to be over watered than under watered this growth response is not believed to be important in these areas.

Nitrogen and Moisture Stress Effects on Roots

Nitrogen fertilization also effects root growth under moisture stress. Where medium to high rates of nitrogen are used root growth remains unchanged as moisture becomes less available. Where nitrogen is kept low root growth increases as moisture levels become lower. Apparently a lack of available moisture in some way stimulates root development as long as nitrogen is not readily available to stimulate foliar growth processes. In the fall foliar growth rates are relatively slow and under these conditions the level of nitrogen appears to be less critical.

Nitrogen and Winter Desication

Cold dry winds blowing over the surface of a green that is not protected by a cover of snow often cause severe drying out or desication of the turf. Use of nitrogen fertilizer in the fall helps to produce deeper grass roots that can draw water from a larger volume of soil. Where greens are fertilized with slow acting nitrogen sources growth continues as long as soils remain warm enough for microbiological breakdown of the nitrogen carrier. Since days are shorter at this time of year than in the spring and since light intensity is usually less the turf has a better chance to utilize the added plant food in root production rather than in foliar growth. The development of a sturdy root system not only helps protect against winter desication, but also permits the grass to make a faster start in the spring.

Nitrogen and Rust Disease on Merion Bluegrass

Rust caused by the fungus *Puccinia spp.* can be serious on Merion bluegrass. Field studies have shown that when Merion bluegrass is watered well and fertilized with plenty of nitrogen, rust infection is substantially reduced. It has been theorized that the increased growth rate resulting from use of adequate water and nitrogen permits the turf to replace diseased tissue faster than the disease can spread. The net effect is that the grass outgrows the infection. Close observation of Merion bluegrass turf has shown that some plant parts do not make rapid growth even though the turf is watered and fertilized. These parts do not become as heavily infected with rust as similar plant parts on under watered and fertilized turf. This suggests that the level of moisture and nitrogen effect internal growth processes which help to render the turf more resistant to disease.

Nitrogen and Leaf Spot Disease on Bluegrasses

Leaf spot caused by the fungus *Helminthosporium spp.* is the most damaging disease which attacks bluegrass. Both field and greenhouse studies have shown that where moisture levels are high and where nitrogen supply is plentiful bluegrass is more susceptible to leaf spot. Under these conditions not only are there more lesions per leaf, but the average size of the lesions is greater. During the period in late spring and early summer when climatic conditions are favorable for the development of this disease, nitrogen levels should be reduced and water applications made with care.

Nitrogen and Disease Complexes on Bluegrass

Often disease causing fungi attack turfgrass as a group. Resulting disease complexes are usually quite lethal. *Helminthosporium, Curvularia, and Altemaria* have been noted to infect bluegrass turf during periods of hot humid weather in late summer. The disease develops in saucer shaped patches that result in near 100% kill of the grass. Nitrogen fertilizer studies have been conducted in areas where this disease complex has been common. Results indicate that under high nitrogen treatments diseased patches were reduced by 80% in comparison with low nitrogen treatments. In addition the diseased grass found under high nitrogen treatments was not completely killed and recovered quickly during favorable fall growth condi-

TABLE 2

Number of Dollar Spot Scars per Square Foot in Washington Bentgrass Putting Green Turf

TREATMENT	RATE OF APPLICATION*	AVERAGE NUMBER OF SCARS PER SQUARE FOOT FROM 8 REPLICATES
No Fertilizer	- - -	17.2
Natural Organic [1]	10	1.1
Natural Organic [1]	5	8.3
Natural Organic [2]	10	3.7
Natural Organic [2]	5	6.6
Ureaform [3]	10	8.5
Ureaform [3]	5	11.2
Sodium Nitrate	10	3.3
Sodium Nitrate	5	6.2
Ammonium Nitrate	10	4.6
Ammonium Nitrate	5	6.1
Ammonium Sulfate	10	3.9
Ammonium Sulfate	5	9.7
Urea	10	2.9
Urea	5	5.4

1 -Milorganite, 2-Agrinite, 3-Nitroform

* Pounds of Nitrogen per 1000 sq. ft. per season

tions. Diseased grass in the low nitrogen treated plots was completely killed and spots were slow to fill in. All disease complexes do not respond to nitrogen fertilization in this way; however, this response is typical of the pronounced effect that nitrogen has on resistance of turfgrass to infection by disease complexes.

Nitrogen and Dollar Spot Disease on Bentgrass

Dollar spot disease is caused by the fungus *Sclerotinia homoeocarpa*. This disease is much more pronounced under low levels of nitrogen than under high nitrogen fertilization. Differences in nitrogen source have also been noted (Table 2). Where 10 lbs. of nitrogen was applied per 1000 sq. ft. per season all nitrogen sources resulted in three or more dollar spot scars per square foot except the natural organic fertilizer Milorganite which had only one scar per square foot. At a 5 lb. rate of nitrogen per 1000 sq. ft. the number of scars varied from about 5 to 11 per square foot. Where turf was not fertilized with nitrogen 17 scars were noted per square foot. More research information is needed to determine why these differences occur. It is assumed at this point that the nitrogen level within the plant in some way affects the infective nature of the fungus.

Nitrogen and Brown Patch Disease on Bentgrass

Brown patch disease on putting greens is caused by fungus *Rhizoctonia solani*. This disease is often more serious where greens are heavily fertilized than where they receive only moderate levels of nitrogen. In this instance the nitrogen-disease relationship is not clear cut. Our studies at Iowa State University have not shown disease incidence to be increased under high nitrogen treatments.

Nitrogen and Weed Infestation

Nitrogen fertilization of lawn turf increases the competitive nature of the grass so that weed infestations are less severe. Since two objects cannot occupy the same place at the same time a healthy vigorous grass plant can prevent the establishment of a weed. Where turf is thin and weak because of lack of nitrogen weeds quickly crowd out the grass.

Studies at Iowa State University have shown that both seedbed and maintenance nitrogen treatments are helpful in preventing weed infestations (Table 3). With both Merion bluegrass and a Kentucky bluegrass-Creeping red fescue mixture more crabgrass developed under low seedbed nitrogen treatments than under high seedbed treatments. Merion bluegrass has a higher nitrogen requirement than Kentucky bluegrass and creeping red fescue, thus more crabgrass came into Merion turf under low nitrogen than came into the Kentucky bluegrass-red fescue turf. Also under high nitrogen the Merion was more competitive than the Kentucky-red fescue turf and thus the amount of crabgrass that became established was less.

Maintenance nitrogen treatments at the high level helped reduce crabgrass infestations when seedbed nitrogen treatments were high. It is likely that the combination of high seedbed nitrogen plus high maintenance nitrogen provided excess available nitrogen which weakened the turf stand and allowed slightly more crabgrass to become established. A weakening of turf fertilized with high rates of nitrogen when temperatures are high is quite common.

TABLE 3

Effect of Fertilization on Crabgrass Establishment in Merion Bluegrass and Kentucky Bluegrass-Red Fescue Turf

	Crabgrass-Grams Dry Weight/l 000 sq. ft.			
	Low Nitrogen Seedbed#		High Nitrogen Seedbed#	
	Low Nitrogen*	High Nitrogen*	Low Nitrogen*	High Nitrogen*
100% Merion	20.4	5.6	1.7	3.1
50% Kentuky 50% Red Fescue	8.5	6.9	3.9	6.2

#Low Nitrogen - 2 lbs. Ammonium Nitrate Nitrogen./1000 sq. ft.
High Nitrogen-20 Ibs. Ureaform Nitrogen/1000 sq. ft.

*Low Nitrogen-O lbs. Nitrogen/1000 sq. ft. per season
High Nitrogen-10 lbs. Ureaform Nitrogen/1000 sq. ft. per season.

Nitrogen and Plant Population Shifts

Just as nitrogen level affects competition between basic turf grasses and weeds, it also affects competition between various varieties and strains of basic grasses. The exact percentage of various bluegrasses and red fescues in a seed mixture is not particularly important in the long run since maintenance treatments on the established turf will determine to a large extent which of the grasses will predominate.

Studies at Iowa State University have shown that high nitrogen levels favor bluegrasses over red fescues, and that only when nitrogen levels are low does red fescue have much of a chance to spread in a bluegrass-red fescue mixture (Table 4).

TABLE 4

Effect of Fertilization on Bud Counts of Bluegrass and Creeping Red Fescue Seeded in Equal Proportions

Original Seed Mixture	Buds per Square Inch (June)							
	Low Nitrogen Seedbed#				High Nitrogen Seedbed#			
	Low Nitrogen*		High Nitrogen*		Low Nitrogen*		High Nitrogen*	
	Blue-grass	Fes-cue	Blue-grass	Fes-cue	Blue-grass	Fes-cue	Blue-grass	Fes-cue
50% Merion 50% Red Fescue	5	11	13	1	11	5	17	0.5
50% Kentucky 50% Red Fescue	7	6	9	2	9	3	11	1

#Low Nitrogen — 2 lbs. Ammonium Nitrate Nitrogen/1000 sq. ft.
High Nitrogen - 20 lbs. Ureaform Nitrogen/l000 sq. ft.

*Low Nitrogen - 0 lbs. Nitrogen/1000 sq. ft. per season
High Nitrogen - 10 Ibs. Ureaform Nitrogen/1000 sq. ft. per season.

SUMMARY

What should you expect from a Nitrogen fertilizer?

1. Expect fast acting nitrogen sources to burn turf foliage if not carefully applied.

2. Expect nitrogen to increase foliar growth when temperatures are cool, light intensity is adequate, and moisture is readily available.

3. Expect turf fertilized with too much nitrogen to be more susceptible to wilt during hot weather.

4. Expect nitrogen fertilization to increase the rate of thatch formation in those grasses which become thatched readily.

5. Expect nitrogen fertilization of thatched greens to help break down these organic thatch deposits.

6. Expect nitrogen fertilization just prior to and during hot weather to reduce foliar growth and plant vigor.

7. Expect poor nitrogen response in turf that is unbalanced in respect to the presence of other essential nutrient elements.

8. Expect increasing levels of nitrogen to reduce root development at high clipping heights, but have little effect on root growth as the height of cut is lowered.

9. Expect too little or too much nitrogen to produce poorer foliage under moisture stress than a medium nitrogen level.

10. Expect medium and high levels of nitrogen to increase rate of foliar production during cool weather so that normal stimulation of root development by increasing moisture deficiency will not be noted.

11. Expect the turf to develop a deeper root system following fall fertilization with nitrogen.

12. Expect to increase resistance of Merion bluegrass to rust by use of nitrogen fertilizer.

13. Expect to decrease resistance of bluegrasses to leaf spot by heavy watering and use of large amounts of nitrogen fertilizer.

14. Expect nitrogen fertilizer to have a pronounced effect on the degree of infection and turf injury caused by disease complexes.

15. Expect well fertilized greens to be more resistant to dollar spot disease.

16. Expect variation in the effect of nitrogen on Brown Patch infection of bentgrass greens.

17. Expect nitrogen fertilizer to be effective in preventing weed problems in lawns.

18. Expect nitrogen fertilizers to encourage bluegrasses at the expense of red fescues in lawn mixtures.

Growth Retardants

by Roy M. Sachs
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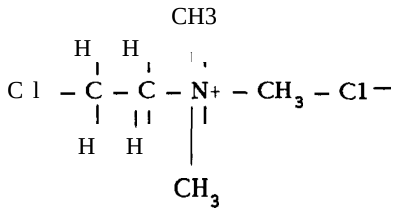
Horticulturists have been searching for 3 to 4 centuries, and this accounts for the written record only, for ways of curtailing the growth of plants. Seed and nursery catalogs list relatively great numbers of "dwarfed" species (woody and herbaceous, perennial and annual), providing indisputable evidence for inheritable growth retarding mechanisms. In the past decade, however, chemical-control of plant size has become a possibility -- thus, the growth rate of inherently tall, or rapidly growing, species may be sharply reduced to the level of dwarf species by application of the appropriate compound. It is not yet clear that chemical control of growth is the best or most economical method available. The purpose of this paper is to review what we know about growth retardants, provide some basis for selection of the compounds available, and to indicate what future research is likely to reveal. At the outset, however, one should avoid the necessity for chemical control of growth by advocating (1) the "right plant for the right place" and (2) the elementary principles of pruning. Chemical control should be the last resort; in the long run it will prove more costly than replanting with the right species.

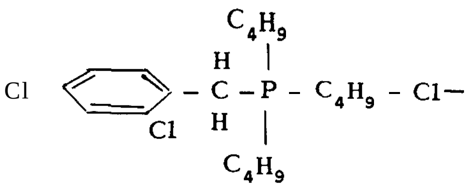
Nevertheless, the growth retardants are useful to horticulturists. Indeed, they will be expanded in number, perfected in application, and become even more useful -- not only for control of plant size but also for control of flowering and evapotranspiration.

What is a growth retardant? There is no simple definition, but generally the term is applied to chemicals that inhibit stem elongation without similarly inhibiting leaf and flower initiation and development. Also, and very important for understanding their mode of action, their effects are usually completely reversed by applied gibberellin (to date, gibberellic acid (GA_3) has been used almost exclusively). Some of the most active, commercially available growth retardants are:

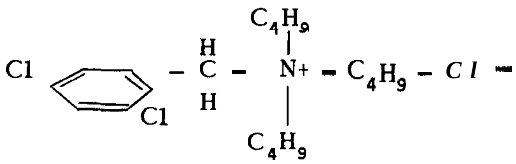
I. (2-chlotoethyl) trimethyl ammonium chloride; called CCC or Cycocel (manufactured by American Cyanimid Co.)



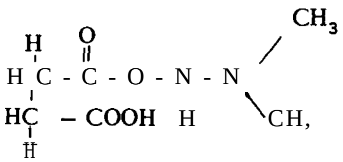
2. a. 2,4-dichlorobenzyl – tributyl phosphonium chloride; called Phosfon-D (manufactured by Virginia-Carolina Chemical Co.)



b. 2,4-dichlorobenzyl – tributylammonium chloride; called Phosfon-S (manufactured by Virginia-Carolina Chemical Co.)



3. N-dimethylamino succinamic acid; called B-9 (manufactured by U.S. Rubber Co.)



Obviously there are great structural differences among the three types of compounds. In most cases small deviations in structure drastically reduce the growth-inhibiting activity; it is not yet clearly known for each substance what parts of the molecule are necessary for biological activity. B-9, CCC, and some other experimental compounds not cited above, inhibit gibberellin synthesis in the fungus *Gibberella fujikorii,* and it seems likely that their effect on stem elongation in higher plants is also the result of reduced gibberellin synthesis. For this reason one would expect exogenous gibberellin applications to prevent or reverse the effects of the retardants, whereas other growth promoting substances (such as the auxins or Kinins) would be entirely inactive. The growth retardants have other effects upon plant tissues, which may be quite important in explaining their phytotoxic (even herbicidal) action, but our interests for the present concern stem elongation only.

Stem elongation is the result of cell expansion and division in the subapical meristematic tissues which extend 1-4 cm below the apical meristem. The latter tissue is the site of leaf and flower initiation and ultimately the source of all cells of the aerial shoot, but most of the cells of the elongate stem are formed and grow to mature size in the subapical tissues. Thus, the control of stem elongation is the result of effects upon cell expansion and division in the subapical tissues. Dwarfism, whatever its cause, and the transition from long-shoot to short-shoot or from rosette to caulescent growth are special cases of stem elongation in which subapical meristematic activity alone is affected. In fact, apical meristematic activity is usually the same in dwarf and tall species and, thus, the number of leaves initiated is usually the same in both instances.

It is not surprising that the inhibition of stem elongation by growth retarding chemicals is the result of their effect upon subapical, not apical, meristematic activity. For this reason, leaf and flower initiation are not affected even though stem elongation is nearly completely inhibited. Some of the growth retardants affect leaf and flower initiation, but this is probably the result of phytotoxic side-effects of the application of very high levels of the compound in question. The prevailing hypotheses accounting for the greater sensitivity of the subapical as compared to the apical meristematic tissues are:

1. Gibberellins are required for cell division and expansion in the subapical, but not in the apical, meristem. (Remember, the retardants inhibit gibberellin synthesis.)

2. The gibberellins are synthesized in greater quantities in the apical then in the subapical tissues; therefore, lower (non-phytotoxic) concentrations of the retardants are effective in the subapical meristematic regions.

Whatever the explanation, the fact of continued apical meristematic function, simultaneous with impaired subapical activities, in the presence of growth retardants makes the latter extremely valuable compounds. For the first time we have attained inhibition of one plant activity without at the same time reducing all other physiological manifestations of life.

There is another, gloomier side to the essentially bright picture that has been painted. The spectrum of action of a growth retardant is limited; that is, field tests have shown that not all plants respond to one or more of the above-cited chemicals. Perhaps as serious is the fact that the concentration and mode of application of retardants must be determined on empirical rather than theoretical grounds; thus adding to the cost of the field tests.

Perhaps these areas of ignorance will be eliminated by future research. Nine gibberellins have been isolated from higher plants, and each must have specific steps regulating its synthesis. Some of the steps have been shown to be inhibited by the retardants. Are there potentially nine kinds of retardants, one for each stage of synthesis? Or do some of the retardants block the same stage of synthesis? Naturally occurring retardants have been isolated; how do they work? How many of them will we identify? Answers to such questions will be difficult to find, yet other questions appear to involve far more complex phenomena. For example, do the retardants penetrate at equal rates, are they translocated at equal rates, and are they metabolized at equal rates in all plants? Is the active form of the retardant the same as that applied or must it be converted into another substance? (The latter appears to be true for gibberellic acid applied to dwarf bean seedlings).

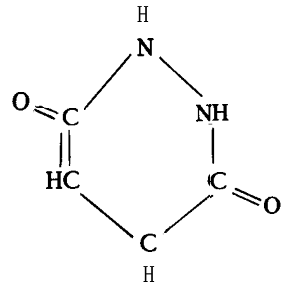
With so many basic questions unanswered, all of which are of some importance to horticulturists, great advances in growth retardant technology should result from future laboratory (or basic) research. Field research should make possible extended use of the available compounds into areas of horticulture previously beyond our control.

Perhaps the most important area to be explored is that of retardant-induced control of flowering in woody plants. For centuries we have known that rootstock-induced dwarfing, espaliering, and other elongation-restricting practices have been accompanied by precocious flowering. Thus, apple trees on Malling rootstocks flower and bear fruit several years earlier than seedling trees. In other species slow-growing adult forms flower, whereas the fast-growing, juvenile stages do not. There are many such instances of the apparent inverse relationship between vegetative growth and reproductive development. Stuart found that Phosfon, CCC, and B-9 treated *Rhododendron* (Azalea) species initiate more flowers earlier than control plants. He found that the response does not depend upon minimum age or size of the plant, but Kohl has extended these observations and demonstrated that varieties differ widely in their response to retardants. Accelerated flower initiation has also been observed in *Camellia japonica* and *Ilex comuta* and several varieties of apples and cherries. It seems likely that this list will be extended by field research now in progress throughout the United States and elsewhere (U.S. Rubber Co., Naugatuck Division, is preparing a summary of research discussed at Boulder, Colorado, August, 1964). All horticulturists recognize the potential value of regulating flowering initiation in woody plants, but few of us comprehend the complexity and great number of interactions of the plant with its environment that may influence flower initiation and development. Such interactions undoubtedly affect the horticultural use of growth retardants. Before making recommendations, the very least we should take into consideration is 1) the normal time of year of flower initiation, 2) the possibility that adverse temperatures may dictate against out-of-season initiation and development, 3) that low temperatures may be required to insure breaking of bud dormancy (regardless of initiation), and 4)that early and heavy flowering and fruiting one year may reduce flower number the following year. Thus, field tests must be extensive.

Next in line of potentially important applications of the retardants is that of reducing evapotranspiration, thereby making plants more tolerant to saline, or arid or other adverse environmental conditions. It seems likely that applications of retardants in the spring will permit transplanting during the hot, dry summer months. In part, the reason for retardant-induced hardiness is the result of increased cuticular and vascular development in the leaves and stems, respectively. Although no information is available, the osmotic concentration of the cell sap may be increased (lowering the freezing point and decreasing the vapor pressure of the cytoplasm) in trtardant-treated plants, thereby providing the necessary attributes of hardiness characteristic of plants subjected to high salinity, drought and low temperature conditions.

Maleic hydrazide

Special consideration must be given to maleic hydrazide (usually sold by U.S. Rubber Co. as the diethanolamine salt of 6-hydroxy-+(2H)-pyrida zinone, called MH-30).



Rather than a growth retardant, it is an inhibitor which interferes with nucleic acid metabolism. For this reason it is an excellent herbicide, completely inhibiting cell division in all tissues of the plant. However, by selecting certain low concentrations it is possible to avoid tissue death, merely delaying plant development. It must be understood that MH-30 affects all aspects of plant development, not only stem elongation. Thus, leaf and flower initiation are inhibited to the same extent as stem elongation. There are many reports of successful application of MH-30 to mature plants, but it is difficult to imagine that this chemical can be useful in cases where new leaves and annual flowering are essential or prized.

Pruning Responses of Mature Trees

by Richard W. Ham's
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Much has been written and said about pruning mature landscape trees. The desirability of drop crotching or thinning out has been stressed in contrast to heading back or stubbing. However, just the opposite is usually practiced.

Let's be sure we are familiar with these pruning terms. The types of pruning cuts they describe can be visualized as well as the tree's response to them.

Heading back is cutting to a stub, a lateral bud or a lateral branch so small that the new growth usually comes from buds near the cut and is vigorous while the lower buds remain latent. ***Stubbing*** is heading back a large branch to a stub. If the heading back is severe, buds throughout the tree may be forced into growth.

Thinning out is the removal of lateral branches at their point of origin or reducing the length or height of a branch by cutting to a lateral large enough that it tends to assume the terminal role and new growth is modified accordingly. ***Drop crotching*** is a severe thinning out of the top of a tree to reduce its height by cutting to a large lateral branch or branches lower in the tree.

The response to heading back is opposite to that characteristic of thinning out. Heading back usually results in dense, vigorous, upright growth, while thinning out retains the natural shape of the tree with a more open, airy appearance. The new growth forced by severe heading back is usually weakly attached. Its main attachment is the thin layer of new wood laid down below the stub.

Unfortunately, thinning out type of pruning requires greater skill and more time of the pruner. Thinning out is appreciated by most people because they cannot see that the tree has been pruned, even though a truck load of brush may be hauled away.

Few trials have been conducted to compare the response of mature trees to these two types of pruning. And for good reason, we found out. It is next to impossible to find enough trees of uniform size and vigor to assure some reliability of the results. When such plantings are found, for some reason their owners are somewhat reluctant to have their trees pruned alternately in “Mutt and Jeff” fashion, even in the interests of science. In addition, pruning such trees is not an easy task, nor are the measurement and evaluation of the responses simple.

In spite of these handicaps, through the urging and generous assistance of Keith Davey and his able representative in this area, Hershel Hawkins, we undertook to push back the frontiers of arboricultural science.

The experiment was set up to determine the response of mature trees to these two types of pruning -- heading back and thinning out -- done at three different times during the year. These times of pruning were (1) in February while the tree was dormant, (2) in May during the period of active spring growth, and (3) in late July after terminal growth had ceased.

Four species of trees were selected. However, for a number of reasons, the responses could be determined reliably only on the Northern California Black Walnut, *Juglans hindsii*.

The trees were growing along a country road near Davis. They were 28 to 32 feet high with a diameter at breast height, DBH, of 15 to 18 inches. Three trees each were either headed back or thinned out at each of the three times of pruning. Eighteen trees were used in the trial.

The trees were pruned so that about the same amount of wood was removed by each type of pruning. About one-third to one-half of the tree was pruned out. The major cuts were made about the same distance from the top of the trees in both types of pruning so that the thinned trees ended up about 4 feet taller than those headed. The highest major cuts were about 10 feet below the original tops of the trees.

Each tree was photographed before pruning and each year after pruning. The trees were pruned in 1960 and the growth of the following four seasons recorded. Interpretation of the results is not clear-cut because the difference in pruning treatments made measurement of the actual response to thinning out somewhat arbitrary. Regrowth was determined by averaging the increase in height of new growth at the top of each tree.

Certain observations can be made about the results of this pruning trial with Northern California Black Walnut:

1. Four years after pruning, the trees had almost regained their original height that they had at the beginning of the experiment, except for the July-headed trees. The trees headed in July were about *3* feet below their original height.

2. Over the 4-year period, there was little difference in the length of regrowth of trees headed back compared to those thinned out, except for the July-headed trees which made less growth.

3. The influence of the time of pruning was quite marked the first season on those trees headed back. The growth, the season after pruning, was about 5.5, 2.0, and 0 feet respectively for the February, May and July dates. However, the reverse was true the following year with the growth averaging 1.4, 1.7, and 2.6 feet.

4. The influence of the time of pruning was slight on those trees thinned out. This was somewhat masked by the nature of the pruning treatment.

5. Following the July pruning, no measurable shoot growth took place that season. However, the July-headed trees made longer shoot growth each of the following three seasons than did those trees headed in February or May.

6. The trees were not adversely affected by the season in which they were pruned, although the July-headed trees could be considered somewhat unsightly following pruning for about seven months until growth resumed the next spring.

7. The regrowth of the headed trees was more upright and dense than that of the thinned trees.

By the very nature of the experiment and other inherent difficulties, the results are not as neat as desired. However, the results underline the fact that we do not know enough about the effects of pruning on mature trees. We hope to study this subject in more detail in the future.

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