A historical perspective of annual bluegrass control

Fighting Poa annua *has kept researchers and superintendents gainfully employed through more than eight decades.*

Nick Christians, Ph.D.

Over the past 85 years, annual bluegrass has endured and thrived on golf courses despite one attempt after another to conquer this weedy turfgrass. Each time a new weapon has come along, word has spread quickly that *Poa annua* has finally been defeated. Unfortunately, these dispatches from the war zone are always premature.

Golf courses the world over are theaters of operations in this war. The only areas where annual bluegrass isn't a problem are some warm, remote tropical island courses where *Poa annua* hasn't thrived and some cool-region golf courses where superintendents have nearly achieved peaceful coexistence with the intruder.

The weapons against *Poa annua* have included herbicides, growth regulators, management practices and even natural biological controls. But some of the most effective weapons against *Poa annua* have proven too hazardous to the human combatants and have been banned. Other weapons have inhibited or killed only certain types of *Poa annua*, and left alive surviving types that produced legions of seeds to replace the weakened troops.

Annual bluegrass is such an aggressive invader of turf, I used to jokingly tell students that it could infest artificial turf. Then I found an artificial-turf practice tee on a Florida driving range that had annual bluegrass growing in fibers where sand had accumulated. Of course, selective control in artificial turf would be no problem, but history tells us that selective removal of annual bluegrass from living perennial turf is difficult indeed.

Winter annual

Poa annua readily produces solid stands of turf. But it generates profuse seed heads in spring that create an untidy playing surface, particularly on golf greens. And in the heat of summer, the species typically dies off completely, leaving gaps in the turf until it grows back from seed weeks later.

No superintendent appreciates dead greens or fairways in midsummer, but when annual bluegrass dies on the golf course during heat stress, it's doing exactly what it's supposed to do as a winter annual. Winter

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Photo by Nick Christians

It's not a joke anymore: Annual bluegrass can *invade artificial turf.*

annuals' seeds germinate in late summer and fall. The plants mature in the fall and live through the winter. In the spring, winter annuals produce their seed crops and die soon thereafter.

Poa annua's winter-annual life cycle is a natural survival mechanism that allows this seemingly fragile species to simply avoid the stress of summer by producing a seed crop and dying. Unfortunately, this is a big problem for the game of golf, and this mechanism of survival is one of the reasons this species has been so hard to control.

Some researchers have argued that annual bluegrass, with a reputation for weakness because it dies so easily in stress periods, is actually a much better competitor than creeping bentgrass in many situations (25). In fact, if an area is seeded to creeping bentgrass and everything possible is done to maintain that species, annual bluegrass still finds a way to infest the area. It may be susceptible to stress, but it's one of the most competitive species golf course superintendents deal with when conditions are right for its growth. Even so, annual bluegrass also is quite susceptible to winter damage and may be killed by direct freezing of the crown (2) and by extended periods under ice cover.

Annual bluegrass invades any opening in the turf. Although classified as a winter annual, its seed may germinate almost anytime soil temperatures and moisture levels are right. Dormant seed can remain viable in the soil for six years or longer (18). Whenever a divot, ball mark or similar opportunity presents itself, annual bluegrass seed is there to fill in the open area. Although most seed heads are formed in the spring, some seed heads can usually be found anytime annual bluegrass is actively growing. This species is also known for its ability to produce seed at very low mowing heights — as low as 1/10 inch.

Photo by David Minner

While other golf course grasses rarely grow tall enough to produce play-disrupting seed heads, annual bluegrass cannot be mowed short enough to eliminate its seed heads. Here, Poa annua's *light-colored seed heads mar a putting green.*

Not just one *Poa annua*

The grass that is known as annual bluegrass is really a highly diverse group of different biotypes with varying characteristics. There are annual bluegrasses that act as true winter annuals. They live through the fall and winter, produce a seed crop in the spring and die no matter how they are managed. These types are termed *Poa annua annua* (3).

There are also types that act as weak perennials. After they produce a flush of seed heads in the spring, these "annual" bluegrass plants can be kept alive through summer by minimizing stress conditions. These types are known as *Poa annua reptans* (22). Between these two extremes are hundreds or perhaps thousands of biotypes, some closer to the *annua* types and some closer to the *reptans*. In the United States, perennial types are most common in northern regions, and the annual types are more common in southern regions. It's typical to find a mixture of biotypes on the same golf course. Superintendents often report variations in color, texture, date of seed-head production and other visual characteristics among annual bluegrass patches found on their course.

Over the past 17 years, it has become clear that certain biotypes will segregate based on the conditions under which they are managed. On older courses, it is not unusual to find distinct biotypes that are common to fairways, others that are common to greens, and yet other to tees. It is also possible to find variable types within each area (17, 27). This helps explain the variations in response to chemical applications that are often observed from one location to another on the same course.

Mechanical control

One of the earliest references to control of annual bluegrass was published in 1922, before selective herbicides had been developed. Published in *Bulletin of the Green Section of the USGA* (1), the article recommends mechanical control by removing annual bluegrass with a knife whenever it begins to invade the turf.

This article reports that W.A. Alexander, superintendent at Old Elm

Photo by Nick Christians

Annual bluegrass easily dies of summer heat stress, then vigorously regrows from seed, only to die again the following summer. The result can be large dead patches on the golf course during the playing season.

Club, had successfully removed annual bluegrass from his greens over a 10-year period (note that he started his control program in 1912). Mr. Alexander said, "*Poa annua* is all about us in every direction. All of the golf courses in our locality have *Poa annua* on one-half to all of their greens. Some of the courses have nothing but *Poa annua* on their greens, and of course have relatively poor greens for a month or two at least."

Mechanical control is by no means outdated, and it may even be making a comeback in popularity. Many superintendents who begin with new greens — or who have killed off *Poa annua* seeds in their greens through methyl bromide fumigation — attempt to remove every invading plant as it appears. While this can be practiced successfully for a time, annual bluegrass usually wins the final battle.

Arsenates

The first selective controls for annual weeds, the arsenates, were developed in the late 1920s. Their use for annual bluegrass began experimentally in 1930 (21). These arsenic-containing materials included arsenic pentoxide, lead arsenate and calcium arsenate. Interestingly, these first herbicides were some of the most effective controls ever developed for annual bluegrass.

Arsenic is chemically very close to phosphorus, an essential nutrient element known for its immobility in the soil and for its importance at the time of establishment. Arsenic is so similar to phosphorus that the root system of a germinating plant will take it up. Although arsenic is similar to phosphorus, it cannot function like phosphorus in the plant. Instead it's a deadly poison that quickly kills the seedlings and mature plants at higher rates. Because it's immobile, arsenic remains near the surface after it's applied. Established grasses with a well-developed root system, such as creeping bentgrass on a fairway, will obtain phosphorus from the underlying soil, while the germinating seedlings of annual bluegrass are killed at the surface by arsenic.

Proper use of arsenic took a great deal of management skill (9). The selectivity is based on concentration. If the level is too high, it will kill the perennial grasses, as well as the weeds. The tricalcium arsenate was particularly phytotoxic in low areas and in anaerobic conditions. Arsenic is an element and doesn't break down into nontoxic materials as do modern organic herbicides. If mistakes in application were made, damage to the perennial turf would last for years. I visited an Ohio golf course in 1975, 10 years after calcium arsenate had been mistakenly applied at 10 times the prescribed rate. Damage to the grass could still be seen during stress periods of late summer.

It wasn't the potential of turf damage that eventually removed these materials from the market; it was the risk of human exposure. Arsenic is extremely toxic to humans and was removed from the market in the early '70s. It made a brief comeback in the early '80s (13), but restrictions made it difficult to use. Arsenic is no longer available in the United States for control of annual bluegrass, although a few courses may still have supplies that were purchased before the material was removed from the market.

Organic preemergence herbicides

The next answer to the annual bluegrass problem was the organic preemergence herbicides that began to reach the market in the '60s (16, 23). These materials, such as bensulide (sold as Betasan and Pre-San), DCPA (Dacthal) and pronamide (Kerb, for warm-season grasses) would selectively kill germinating seedlings of annuals while doing little damage to established perennial turf. They were safer than the arsenicals for the turf and were safer for humans to use. The solution seemed simple. This is an annual species. If you could

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selectively kill the germinating seedling, eventually annual bluegrass would be eliminated.

Thirty years later, annual bluegrass is with us still, even though these chemicals are good at killing *Poa annua* seedlings if levels of active ingredient are high enough. The problem is that not all annual bluegrass is a true winter annual. There are many perennial types that produce seed but do not have to come back from seed each year. Preemergence herbicides have no affect on mature plants because they kill only at the time of germination.

A second problem is that these organic materials break down in the soil. Their period of efficacy is 30 to 60 days, depending on weather conditions. The primary period for annual bluegrass germination is in late summer, but it may germinate anytime there is an opening in the turf. It's not feasible to keep the level of these materials high enough throughout the season to prevent germination into divots, ball marks and other openings. This was the big advantage of the arsenates. Their efficacy period could be maintained all season because they were inorganic and wouldn't break down.

The search for new and better preemergence herbicides continues today. Dithiopyr (under the brand name Dimension) has recently been labeled as an annual bluegrass control, and it has been shown to be effective in some situations. There will be others in the future, but it is evident that preemergence herbicides will not be the final answer to the problem.

Growth regulators

The '60s also brought the first appearance of growth regulators to control *Poa annua,* in which they were used to inhibit seed formation. These materials made another appearance in the '80s when they were used to selectively phase out annual bluegrass.

Growth-regulating compounds such as maleic hydrazide (a component of Po-San) and mefluidide (sold as Embark) are good seed-head inhibitors. Theoretically, if seed production could be stopped, the seed source would be eliminated and eventually the annual bluegrass would disappear.

It sounded good, but unfortunately it didn't work. There were two problems. First, there are many perennial biotypes of annual bluegrass, and a simple elimination of the seed source for a season or two had little impact on these grasses. The other problem was the almost inexhaustible supply of annual bluegrass seed that already exists in the soil beneath older turfgrass stands. This seed can remain alive for years, awaiting an opportunity to germinate.

In the '80s, mefluidide made a brief comeback with a slightly different approach. It was promoted as a seed-head inhibitor, but this time the idea was to nurture the annual bluegrass as turf. The goal was to allow the plant to use the energy that would normally go into seed-head production to enhance its likelihood of survival during the stress periods of midsummer. This was a good idea and showed some promise of success. The problem was timing. Mefluidide had to be applied at just the right time to be effective. It quickly became apparent that the timing was different for a south-facing slope than for a north-facing slope. The different biotypes of annual bluegrass also varied over several weeks in their seed-head production.

Mefluidide also has been used in recent years to prevent seed-head formation on annual bluegrass in the spring to improve putting quality on golf course greens. The label for this use is somewhat unclear, however. The label on the product sold as Embark Lite doesn't restrict its use on golf greens, unlike the label on other Embark formulations. Some turf discoloration can occur from mefluidide, and label recommendations should be followed closely.

Endothal could either be classified as a growth regulator or as a herbicide. It has growth-regulating characteristics at low rates of application. At the higher rates used for annual bluegrass control, it works as a herbicide that kills the living plant. It was used as a postemergence control for annual bluegrass in both Kentucky bluegrass and creeping bentgrass in the early '70s (23). At higher temperatures endothal tended to kill desirable perennial grasses. Some annual bluegrass biotypes were extremely sensitive to it, while others were tolerant. Researcher A.J. Turgeon, Ph.D. says it also worked well on sandy soils, but required high levels on organic soils. Endothal was available in the Pacific Northwest for annual bluegrass control into the '90s. While it's no longer being sold there, remaining stocks can be used, and there are some golf courses still using it.

Fenarimol, a growth-regulating compound that was released as the systemic fungicide Rubigan, was labeled as a control for annual bluegrass in the '80s (24). Selective inhibition of *Poa annua* by this chemical reportedly allowed perennial grasses to eventually crowd it out. This phenomenon proved to work on only certain biotypes, and annual bluegrass control was eventually deleted from the label, although fenarimol is still used in the southern United States for selective preemergence control of the annual biotypes in dormant warm-season turf.

Gibberellic acid inhibitors

Flurprimidol (Cutless), paclobutrazol (TGR) and trinexapac-ethyl (Primo) represent the next step in the use of growth-regulating compounds to phase out annual bluegrass. These compounds suppress growth by interrupting the plants' ability to synthesize the hormone gibberellic acid. Their use began in the '80s and continues to the present. These gibberellic-acid inhibitors slow the growth of annual bluegrass, but have less affect on com-

peting cool-season, perennial grasses such as creeping bentgrass. The net result is a slow conversion away from annual bluegrass to the desirable species (26).

Trinexapac-ethyl is the newest of the three materials. In a 2-year test on fairways on two golf courses in Wisconsin, researcher Frank Rossi, Ph.D, observed a 8.5-percent to 18.7-percent reduction in annual bluegrass with trinexapac-ethyl over a 2-year period (19). Gibberellic-acid inhibitors do not act as herbicides but as growth regulators that slowly phase out the annual bluegrass. They tend to work better at fairway height than at green height. Management techniques unfavorable to *Poa annua* are an important part of the process.

The gibberellic-acid inhibitors can play a role in an integrated program to reduce annual bluegrass, but they should be tested first in a side-by-side trial with an untreated area to be sure that they are providing the desired result on the annual bluegrass biotypes in the environmental conditions that exist on your site. Turf response to growth-regulating compounds can vary with soil type, climatic conditions, moisture levels, time of application and a variety of other factors (7). It's also very likely that the different biotypes of annual bluegrass vary in their responses to these materials. They may work on the course down the road but not on your course. One other word of caution: Rate of application is extremely important. Follow the label carefully. This is one of those situations where more is definitely not better.

Postemergence herbicides

Over the past 30 years, several herbicide labels have promised annual-bluegrass control on golf course turf. Many of those products have since disappeared from the market, and others have simply not proven effective on annual bluegrass in perennial turf.

Linuron was labeled in the late '70s and was used for a period of time with some success (14). Inconsistency of plant response led to its removal from the market a few years later.

Triazine herbicides are known for their ability to selectively kill cool-season grasses in warm-season turf. This should be a perfect mechanism for eliminating the cool-season annual bluegrass from bermudagrass, a warm-season grass. These materials have been used with some success, but again the old problem of resistant biotypes has limited their effectiveness. Research in 1983 revealed that some biotypes can tolerate high rates of triazine applications (10). Triazines also affect the success of winter overseeding with cool-season species.

Glyphosate (sold as Roundup, Hoedown and Avail) is a nonselective, systemic, postemergence herbicide that will kill annual bluegrass and almost any other grass it comes into

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Characteristics of *Poa annua*

Photo courtesy of Crop Science Society of America

Annual bluegrass is a winter annual, cool-season grass. Its boat-shaped leaf tip and folded vernation distinguish it from creeping bentgrass, which has a pointed leaf tip and rolled vernation. It can be distinguished from Kentucky bluegrass — which also has a boat-shaped leaf tip and folded vernation — by its long, membranous ligule. Bermudagrass, with its pointed leaf tip and hairy ligule, is easily distinguished from annual bluegrass.

Annual bluegrass is generally a bunch grass, but some biotypes may have short stolons. Colonies may have a lighter color than surrounding turf, although that is not always the case. The species generally produces seed heads, although some biotypes produce few, if any. Many biotypes persist as weak perennials, not true winter annuals.

contact with. It's often used in renovation of areas infested with weeds before re-establishment of a new grass cover. It has no soil activity, however, and will not prevent germination of annual bluegrass seed in the soil. A common complaint of superintendents using this product is that they end up with just as much annual bluegrass as they started with.

Glyphosate is quite effective for selectively killing annual bluegrass during winter in dormant bermudagrass and zoysiagrass, although you must avoid treatments as the warm-season grasses emerge from dormancy.

Ethofumesate (sold as Prograss) is labeled for annual bluegrass control and is getting a lot of attention. It provides excellent postemergence and some preemergence control. It's particularly useful in perennial ryegrass because of the species' tolerance of ethofumesate, even in the seedling stage. In parts of the country where the climate is suitable for perennial ryegrass on fairways and tees, the existing turf can be killed with glyphosate, re-established to rye and then treated with ethofumesate to keep the annual bluegrass from becoming re-established (4).

Ethofumesate is also labeled for dormant bermudagrass overseeded with perennial ryegrass (6), although it may delay the bermudagrass' spring green-up. Creeping bentgrass and Kentucky bluegrass are more sensitive to ethofumesate, but it can be used where these species are maintained at higher mowing heights, such as fairways. Consult the label for warnings about its use on bentgrass cultivars. It's not labeled for creeping bentgrass greens, although some superintendents have been experimenting with it. Some of our tests on Penncross creeping bentgrass greens at the Veenker Memorial golf course here at Iowa State University have been promising. Other tests have produced damage to the bentgrass. One thing we learned the hard way: Never apply ethofumesate to bentgrass greens that have also been treated with the growth regulator paclobutrazol. The Prograss label states that ethofumesate should not be applied within eight weeks following the application of growth regulators. This material is relatively new, and whether the old problem of biotype resistance will recur is still open to speculation.

Photo courtesy of Nick Christians

The lighter color on the left side of this practice green reveals a high annual bluegrass population. The right side has been treated with the growth regulator paclobutrazol.

Methyl bromide is a nonselective herbicide that is applied as a gas under plastic covers placed over the turf. The covers are left on the turf for a minimum of 48 hours. The gas filters down into the soil, and the material will kill not only mature tissue, but also the seed lying dormant in the soil. Methyl bromide, if used properly, represents the one sure way of killing mature annual bluegrass and of preventing its reinfestation from seed (8).

This material is difficult to use and must be applied by specialists with the proper equipment and know-how. Special certification is required for its use. All grass is killed and complete re-establishment is required, which means that the treated area will likely be out of play for months.

Methyl bromide is also expensive, with the application of the gas currently running 8 to 14 cents per square foot, and total renovation costing up to $1,000 per green. Golf course use had been traditionally limited to greens and tees. As methods have developed for treating larger areas, however, its use has expanded to fairways. Superintendents generally seem quite pleased with the results of methyl bromide fumigation. Minor infestations of annual bluegrass may persist in a few areas where the gas is not uniformly distributed, but on most areas the control is usually complete. Vigilance is key to success following methyl bromide fumigation. The process of reinfestation from surrounding areas will begin almost immediately, and you must remove every invading annual bluegrass plant to prevent the problem from returning.

There's political pressure to ban the use of methyl bromide nationwide because of suspected damage to the atmosphere's ozone layer. It will be available through at least 2001 as the evaluation process continues.

Experimentation

Several experimental herbicides with potential for controlling *Poa annua* were dropped from consideration after they were widely tested. In the mid-'80s, I worked with a product that appeared to have great potential for selectively removing annual bluegrass from both Kentucky bluegrass and creeping bentgrass turf. After conducting some successful tests on a local golf course, I moved to another course 50 miles away that had a different biotype of annual bluegrass. There, 12 times the effective herbicide rate didn't even discolor the local biotype.

The perfect herbicide

What characteristics would define the perfect herbicide for control of annual bluegrass? It would have both postemergence and preemergence activity on annual bluegrass. It would be universally effective on all biotypes. It would do no damage to creeping bentgrass, Kentucky bluegrass, perennial ryegrass, bermudagrass or any other desirable turfgrass species. It would be nontoxic to humans and would carry no risk to groundwater or surface-water resources. It's highly unlikely that such a material will ever be developed. The biggest barrier is the tremendous genetic diversity that exists within the species we call *Poa annua*. If something were developed that would eliminate 99 percent of it, the remaining 1 percent would reinfest the area in a few short years, and we would have to look for a new solution.

Making friends with *Poa annua*

The next attempts to deal with annual bluegrass reflect an "if you can't beat it, join it" philosophy. The '50s and '60s were times of optimism. New discoveries were being made every year, and the release of new herbicides led to the belief that the end of the annual bluegrass problem was just around the corner. By the end of the '60s and the early '70s, though, some doubts were beginning to emerge. Country club members were growing a little weary of the extreme treatments used to eliminate this troublesome grass, such as these efforts in 1967 at the Knickerbocker Country Club in Tenafly, N.J. (20): "The nearly 100 percent *Poa annua* fairways were treated with MCPP (mecoprop) at the highest recommended rate, then treated twice with sodium arsenate and thatched. The fairways were then scorched and seeded with a bentgrass mixture at 100 pounds per acre."

By the early '70s, strategies emerged for maintaining annual bluegrass in the best possible condition for play (28). Annual bluegrass is not totally objectionable. At some times of the year, it can provide a high-quality playing surface. Its biggest problems are the seed heads, particularly in the spring, and the fact that it tends to die in stress periods.

The careful use of growth-regulating compounds can help with the seed-head problem, but keeping annual bluegrass alive can be a little more difficult. Climate is the key. In the cooler regions of the northern United States and in some microclimates such as mountain areas, coastal areas and the foothills of the Rockies, this approach can be successful. In the Great Plains and the transition zone, where heat and drought are common, annual bluegrass management may not be successful.

The rules of managing annual bluegrass as a turf species are simple: Take everything you know about proper management to prevent annual-weed infestation and do the opposite. Irrigation frequency, for example, can either encourage or discourage annual species. Annuals rely on germination of seed on the soil's surface for survival, while deep-rooted perennials receive their moisture from the underlying soil. To encourage an annual, keep the surface wet.

Fertilization can also play a role. Nitrogen levels should be maintained on the high side, as should phosphorus, which is particularly important in seedling establishment (5). One management step that discourages annual weeds is to keep low phosphorus fertilization levels on the surface and allow the mature turf to take its phosphorus from the underlying soil. A soil test will reveal whether the underlying soil has sufficient phosphorus.

Spoon feeding should be used in spring, just after seed heads have formed, to strengthen the turf for the summer-stress period. Spoon feeding should also be used in the summer to just meet the needs of the turf. Heavier fertilization can be used in fall when annual bluegrass is thriving.

The timing of cultivation can also favor annual bluegrass. To discourage a weed crop, cultivation is timed to avoid peak seed germination. For crabgrass control, for instance, the spring germination period is avoided, and aerification is instead timed in late summer or fall. The peak germination period for annual bluegrass in most regions is late summer and fall. If the goal is to encourage annual bluegrass, aerification in mid- to late August will bring seed to the surface for germination.

Some mowing practices can encourage annual bluegrass. Lightweight mowing equipment and clipping removal are not helpful to the species, but lower mowing heights favor *Poa annua*, particularly the extremely low mowing heights used on greens.

The preventive fungicide program requires materials nontoxic to annual bluegrass. Fenarimol, which is known to have some activity on annual bluegrass, would not be a good choice for encouraging annual bluegrass survival. Also avoid growth regulators that inhibit gibberellic acid. Insect control will likely be necessary. Black

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turfgrass ataneius should be given close attention if annual bluegrass is the primary turf.

Integrating controls

One of the ultimate challenges for a superintendent is to combine all the accumulated knowledge about annual bluegrass into an integrated program to discourage *Poa annua* and encourage perennial turf. While this approach began in earnest in the '80s, its origin dates back much earlier (9, 12, 16). This requires a great deal of knowledge and skill.

Creeping bentgrass fairways are the primary turf on which this method is used, but the basic principles would apply to any type of perennial turf system with an annual bluegrass infestation. It has become popular in the midwestern and northeastern regions of the United States, particularly in areas where the high temperature and humidity of summer make annual bluegrass maintenance impractical. In this case, management practices are used to eliminate the annual bluegrass, not to encourage it.

Irrigation again plays an important role, only this time it's going to be less frequent to allow drying on the surface. This practice favors the relatively deep-rooted perennial grasses and helps select against the annual bluegrass. Syringing — the application of small amounts of water during midday high temperatures to cool the grass and wash sugars and amino acids that have formed on the cuticle — is critical in summer. Nitrogen and phosphorus are maintained at moderate levels to just meet the requirements of the perennial grass without promoting competing weeds.

Mowing is a critical part of the program. Experience has shown that lightweight mowers tend to help with the conversion process by favoring perennials such as creeping bentgrass, whereas heavier mowing equipment tends to favor annual bluegrass. Clipping removal is also an important part of the process (11, 29). This is likely due in part to the removal of seed produced by the annual bluegrass, although this can't explain all of the benefits observed when clippings are removed.

Cultivating strategically to discriminate against annual bluegrass is a little more difficult. Compaction favors annual bluegrass, and aerification will allow the perennial turf to be more competitive. However, aerification also brings annual bluegrass seed to the surface and can encourage a weed problem. Trying to avoid the primary times of seed germination would be the obvious solution. That is difficult to do, however, because this also happens to be the best time to aerify. Disruption of play may also be a factor, and the timing of aerification to the best advantage may be difficult. It's clear that late summer is a time that favors winter annuals and should be avoided. There is too much stress in midsummer. Although annual bluegrass seed will also germinate in the spring if conditions are right, spring and fall aerification with the proper use of preemergence herbicides are probably the best alternatives in most situations. Spiking may also play an important role. Spiking severs stolons, resulting in rooting from the nodes. This provides a competitive advantage for perennial turf.

More and more turf managers are overseeding perennial turf as part of their annual bluegrass control program. Particularly where creeping bentgrass is the desired species, seed-

Methods used over the years to solve the annual bluegrass problem in golf course turf

1. Mechanical removal — early 1900s to present
2. Arsenates — '40s to early '70s with brief revival in the '80s
3. Preemergence herbicides — '60s to present
4. Growth regulators for seedheads — '60s
5. Postemergence herbicides — '50s to present
6. Management techniques to keep annual bluegrass alive — '70s to present
7. Growth regulators for gradual removal of annual bluegrass — '80s to present
8. Management techniques to eliminate annual bluegrass — '80s to present
9. Biological control — experimental

ing can help thicken the turf and may help overcome annual bluegrass' competitive advantage in seed production.

Growth regulators and herbicides may also be an important part of the process. They must be used in accordance with sound management techniques, but they may give the perennial turf the edge it needs to outcompete the *Poa annua*.

Biological control

The concept of biological control is relatively new, but it may well develop into a common part of pest management in the future. It may involve biological pests that selectively kill annual bluegrass without damaging perennial turf. One such material is a bacteria named *Xanthomonas campestris* (30). While early tests on *Poa annua annua* types are showing some promise, the bacteria has been less effective on perennial biotypes.

What the future holds

There was a time when I had a great deal of hope that science would find an answer to the annual bluegrass problem. For me, that time has passed. There will be advances and improvements in technology, but I am betting that this aggressive, highly diverse species will find a way around every one of them.

Years before I was born, golf course superintendents were holding meetings to discuss this problem. All through my career it has been one of the primary focuses of attention in the golf industry. If I had to predict the future, I would bet that 50 years after this generation has passed, *Poa annua* will still be a problem.

That may not, however, be as bad as it sounds. If a country club's membership wants to see playing condition deteriorate quickly, it simply needs to replace an experienced superintendent with someone less skilled in annual bluegrass management.

If a "magic bullet" were developed tomorrow that would kill all annual bluegrass, superintendents' lives would be easier, but their skills and knowledge would become less valuable. This old enemy may be more of a friend than we realize. □

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