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ENTOMOLOGY

Annual Bluegrass Weevil
A Metropolitan Nightmare

By Dr. Patricia J. Vittum, University of Massachusetts

The annual bluegrass weevil, *Listronotus maculicollis*, is also often called the Hyperodes weevil because it was formerly assigned to the genus Hyperodes. The insect is a major pest of golf courses in the northeastern United States, particularly in the metropolitan New York area, including Long Island; the counties just north of New York City; southwestern Connecticut; and northern New Jersey. However, it has also been reported causing damage on golf courses throughout New England, upstate New York, central and eastern Pennsylvania and around Toronto, Ontario, Canada.

As its name suggests, the annual bluegrass weevil feeds primarily on annual bluegrass (*Poa annua*) and is particularly damaging on turf with low mowing heights. Damage is usually most severe on collars and approaches, tees, greens and fairways. The weevil can cause damage to fine turf wherever annual bluegrass grows in its perennial form. Since the multiple generations overlap, damage can occur any time from late May through early September. In the metropolitan New York area, the damage is usually most noticeable in early June and again in late July and early August.

Where Weevils Exist

The annual bluegrass weevil has been reported in more than 30 states, but so far is only a problem on fine turfgrass in the Northeast and Middle Atlantic states. It was first report-

Typical pattern of annual bluegrass weevil damage along the edge of a collar.

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ed as a turfgrass pest in Connecticut in 1931 and on Long Island in the late 1950s. Initially, turf managers blamed "spring die out" of annual bluegrass on the agronomics of the plant, specifically its inherent intolerance of summer temperatures. However, in many cases the obvious and rapid decline of annual bluegrass can be traced to weevil activity.

Weevil Description

The annual bluegrass weevil, like most weevils, is a beetle with a distinct snout (Figure 1). The adult is about 1/8 inch long, slightly smaller than most turf billbugs, and the thorax only occupies about 25% of the total body length. The snout is shorter and stouter than that of a billbug and the antennae are attached near the apex (far end) of the snout. Mature adults are dark brown or black with gray or yellow-brown hairs and scales on much of the thorax and hind wings. Teneral adults (recently emerged from pupae) are reddish brown.

Females usually lay two or three eggs at a time, lined up end to end inside the leaf sheath. Each annual bluegrass weevil egg is deposited between leaf sheaths. The egg is pale yellow when laid, but turns smoky gray as it matures. It is elliptical, about three times as long as it is wide.

The larva (Figure 2) is cream colored with a brown head capsule, sometimes with a slight gray coloration along the back. Larvae are legless but have several distinct "ridges" along the body and can move quite well through the thatch and upper part of the soil. They are somewhat elliptical, although the midsection is often slightly wider than the fore or hind end. Larvae are small (1/16-inch long when first emerging to 1/5-inch long just before pupating) and spend most of their development inside grass stems in their earlier developmental stages or near the crowns of plants as they mature.

The pupa has many adult characteristics, including the developing eyes, mandibles, antennae, legs and wings. Creamy white when it first develops, it later becomes reddish brown, just before the adult weevil emerges.

Life Cycle

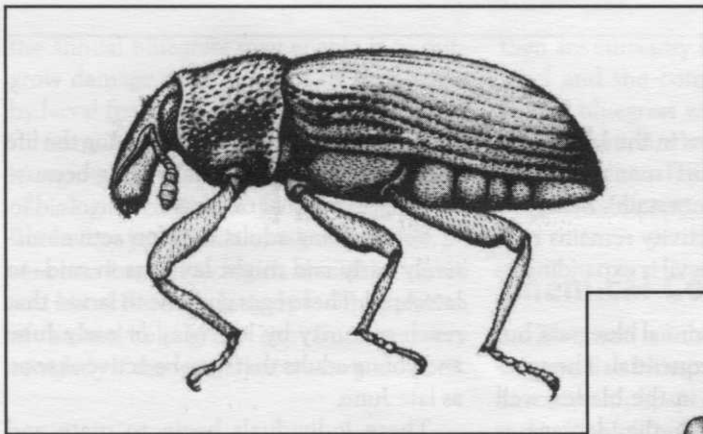
As with any insect, it is important to understand the life cycle and to know when the insect is vulnerable to control treatments. In the metropolitan New York area, the annual bluegrass weevil normally completes two or three generations per year.

The insect overwinters in the adult stage, usually in nearby woods (especially in the litter underneath white pines) or in tufts of high grass between the rough and woods. As temperatures warm, adults begin to migrate toward the short cuts of annual bluegrass. The earliest movement typically begins in late March, but many weevils do not begin migrating until early or mid-April.

Once the females reach the low-mown annual bluegrass (fairways or shorter), they begin to lay eggs inside the leaf sheath. This usually occurs in late April or early May. Eggs are reasonably well protected and take about a week to hatch into tiny larvae. The larvae are small enough that they can burrow inside the grass stem and feed as borers for about a week. Larvae molt once during this stage.

When the larvae grow large enough that they must leave the stem, they move down the outside of the stem to the crown of the plant and continue feeding. Larvae pass through a total of five larval instars (three or four of which are outside the stem), spending about five to seven days in each stage.

After the larvae have completed feeding, they pass through a "prepupal" stage, which resembles the larvae but is slightly longer. The prepupae carve out a little cell in the soil, just at the soil/thatch interface. (Often the tip of the larvae will "spin" in the soil when disturbed.) Each prepupa then transforms to a pupa, a quiescent stage during where the insect does not move or feed. Many changes occur internally during this stage, including the development of a reproductive system and muscles to power the wings and legs of the adult. The pupa stage lasts about five to seven days, after which



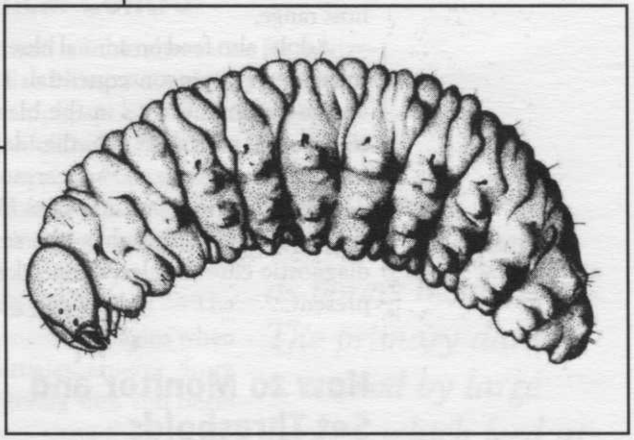


Figure 1. The annual bluegrass weevil adult is a dark brown or black beetle about 1/8 inch long with a short, distinct snout.

Figure 2. Larva are cream colored, legless and small (1/16 to 1/5 inch long). They have a brown head capsule with chewing mouthparts. Adapted from Cameron and Johnson, 1971.

young ("callow") adults emerge. These adults are reddish brown for a few days and the exoskeleton is not as hard as it will be once the insect matures fully. The callow adults tend to be more vulnerable to environmental extremes than the more mature "hardened" adults.

The completion of the first generation is marked by the emergence of adults the end of June or early in July. A second generation then develops, with egg laying possible only a week after the adults emerge. Each subsequent developmental stage occurs more quickly than in the spring generation because summer temperatures are higher and physiological activity is accelerated. So the large larvae of the second generation often are active by the end of July or early August. They then pupate and 2nd generation adults appear by mid August.

In unusually warm years, the development of each generation can be accelerated enough that second generation adults appear in *early* August, which allows a third generation to develop, resulting in larvae activity throughout August and into September.

Regardless of the number of generations that occur during the summer, only adults will survive the ensuing winter. We often find large larvae or pupae in the soil in late September or early October, but we never find these stages when we sample the same areas the following spring.

Look for Damage

Annual bluegrass weevil larvae, which have chewing mouthparts, can cause severe damage to turf. Young larvae feed as borers inside stems, sometimes depositing tan sawdust-like material inside the stems. However, the primary damage is caused by the large larvae which feed at the crown of the plant. Studies conducted in the 1970s demonstrated that an individual larva can sever 10 to 12 plants outright during its feeding (Cameron and Johnson 1971).

Damaged areas first appear as small yellow-brown spots. Small spots eventually coalesce into larger areas and take on a "water-soaked" appearance. Damage often coincides with, and can be confused with, anthracnose.

Damage from the larvae that are active in the spring is usually concentrated along the edges of fairways or on edges of greens, tees or collars. Damage later in the year can occur almost anywhere in the low-mown areas.

Larvae feed primarily on annual bluegrass, but we have been able to raise the larvae on perennial ryegrass in the laboratory. In addition, several turf managers have reported damage to certain bentgrass stands. Although this activity remains rare, it is possible that the weevil is expanding its host range.

Adults also feed on annual bluegrass, but their feeding is inconsequential. The weevils chew tiny notches in the blades, well above the meristem, so the damage is mowed off regularly and appears to have no detrimental effect on turf vigor. However, the characteristic notches can serve as a diagnostic clue that larvae are likely to be present.

How to Monitor and Set Thresholds

The easiest way to monitor for annual bluegrass weevil larvae is to cut a wedge of turf with a large knife. Any medium or large larvae that might be present will be clearly visible, with the cream color contrasting against the dark soil or thatch. Another method is to remove a cup cutter plug of turf, bring the core to the maintenance area, pull the turf apart gently, and look for larvae. Put all the loose turf and soil in a bucket or dish pan and fill the pan with luke warm water. Any larvae that were not found by visual inspection will float to the surface of the water.

Adult weevils can be flushed to the surface of the turf with a soapy flush — one or two tablespoons of lemon-scented dish detergent in one or two gallons of water poured over an area one or two feet on each side. The soapy solution irritates many insects and weevils will scramble to the surface within a couple minutes.

The tolerance level for annual bluegrass weevil larvae appears to be between 30 and 80 large larvae per square foot in the spring and around 20 to 40 larvae per square foot in the summer. The lower threshold is a direct function of the additional stresses the turf experiences during the summer months.

Turf managers who have dealt with the annual bluegrass weevil understand that sampling the insect and determining the life cycle is confusing and challenging because of the generational overlap.

Some spring adults become active relatively early and might lay eggs in mid- to late April. These eggs give rise to larvae that reach maturity by late May or early June and young adults that may be active as soon as late June.

These individuals begin to mate and reproduce almost immediately. In the same location, there may be spring adults that delay their movement so they do not reach short cuts of annual bluegrass until May and do not lay eggs until early to mid May. These give rise to larvae that mature in late June or even later.

The end result is that samples taken during the summer often reveal small larvae, medium sized larvae, large larvae and pupae, all in the same area at the same time. However, if a turf manager takes samples regularly (ideally weekly) and notes what proportion of the population is in each developmental stage on each date, the overall pattern can be discerned.

Cultural Control

Several aspects of the biology of the annual bluegrass weevil can be incorporated into turf management programs. First, the weevil overwinters in the adult stage, often in litter under white pine trees.

Anecdotal reports from turf managers in the metropolitan area indicate that removing pine needles in the autumn may remove some of the insulation the weevils need to survive the winter. While no scientific studies have been conducted, superintendents who have removed pine litter for three or more years feel the overall weevil population has declined in surrounding areas.

Adults lay most of their eggs in annual bluegrass and the larvae feed primarily on annual bluegrass. Therefore, any program that manages or reduces the amount of annual bluegrass on greens, tees, collars or fairways will ultimately result in a reduction in the weevil population. Alternatively, any program that enhances the vigor of the annual bluegrass may enable it to outgrow damage or at least not be devastated by larval feeding.

Some superintendents let the annual bluegrass weevil feed unimpeded as a form of biological control of the annual bluegrass. But before you decide to take that route, be sure you know how much annual bluegrass you have! Even a relatively low population of annual bluegrass can become very unsightly if the weevil becomes established.

Biological Control

There are a few biological control alternatives that bear further investigation. *Steinernema carpocapsae*, an entomopathogenic nematode, is effective against several species of weevils. Laboratory studies have indicated that the nematode has the potential to kill annual bluegrass weevil adults as well. However, attempts to use the nematode in field conditions have been disappointing or inconclusive.

One possible explanation for the poor performance may be the air and water temperatures at the time of application. Spring applications are typically made during late April, when water temperatures used to fill sprayers often are below 55°F. Such temperatures undoubtedly slow nematode activity. Summer applications are typically made in July, when air temperatures may exceed 80°F and nematodes are prone to desiccation.

Microctonus hyperodae is a parasitic wasp which is highly effective against the Argentine stem, a closely related weevil. Studies conducted in New Zealand in 1996 and 1997 indicate that the wasp is unlikely to be an effective parasitic agent against the annual bluegrass weevil. However, a closely related wasp (*Microctonus aethiopoides*) shows more promise and will be investigated in the future.

Spinosad is a naturally derived product from an actinomycete (a kind of bacterium), and is now available commercially as Conserve™. Studies with spinosad in 1996 (conducted as a series of experimental formulations), in the metropolitan New York area, indicated that spinosad reduced larval populations under field conditions. However, the application rates were much higher than are currently included on the product label and the company has not included annual bluegrass weevils on their label. So, at this point, further field work is necessary to determine whether Conserve will prove to be a viable option.

Chemical Control

The most reliable alternative for managing annual bluegrass weevil populations involves application of traditional insecticides. The following discussion will concentrate on spring and summer applications directed toward weevils in areas where two generations occur per year.

Young larvae feed as borers inside stems. The primary damage is caused by large larvae, which feed at the crown of the plant, severing as many as 12 plants in a feeding.

Spring generation — The spring generation begins when adult females emerge from overwintering sites and begin to lay eggs along the edges of fairways and other short-cut grasses. Therefore, insecticide applications should be concentrated along the edges. "Wall to wall" applications are not necessary.

Spring applications are most effective if they are directed toward adults just as they begin to arrive at the oviposition sites. This typically occurs between forsythia full bloom and dogwood (*Cornus florida*) full bloom (actually full color of the bracts) —usually between mid-April and early May in the metropolitan area. Applications should be watered in lightly (one or two passes of a sprinkler head).

Until recently, chlorpyrifos (Dursban™) was the material of choice but, in areas where annual bluegrass weevils have been present in damaging numbers for several years, turf managers feel the material has become less effective. In the last two years, superintendents have begun to use synthetic pyrethroids with generally good success. Our field trials have indicated there is little difference in efficacy between the pyrethroids, including bifenthrin (Talstar™), cyfluthrin (Tempo™), lambdacyhalothrin (Battle™, Scimitar™) and deltamethrin (Deltagard™), when used at their labelled rates. Note, however, that the labels vary — some include golf course turf and some do not and annual bluegrass weevil is not specifically mentioned on all the products.

Some superintendents have used tank mixes of a pyrethroid with imidacloprid (Merit™) or a pyre-throid with chlorpyrifos (Dursban). Again our field trials have found that tank mixes with Merit have been very effective, often providing more than 95% control. However, the difference between the tank mix and the pyrethroid alone is seldom statistically significant, so the tank mix might be providing an expensive form of "overkill." Merit alone is usually not particularly effective against annual bluegrass weevils. Several other insecticides are also labelled for annual bluegrass weevils and can be effective.

Concentrate on the areas where the "risk factors" are highest — for example, sites with substantial amounts of annual bluegrass near white pines.

The keys to the spring generation are to concentrate on the perimeters, time the application to coincide with appropriate plant phenology and water in the material lightly.

Summer generation — The second generation of weevils is less predictable in some ways, because there is so much overlap in development. However, in the metropolitan area, adult activity often peaks around July 4th.

We are in the process of developing a degree day model to predict weevil activity and hope to validate that model this year. In the meantime, July 4th provides a good initial target date. If larval damage was observed in early June, insecticide applications for the second generation probably should be made close to July 4th. If larval damage occurred in mid- to late-June, summer applications should be made about a week after July 4th.

Because adult activity will originate from where the larvae were present in the spring, the weevils may spread to virtually any part of the nearby fairways, tees or greens, so applications often should be made over a wider area. Insecticides should be watered in lightly to move the material off the blades and into the thatch.

Some formulations of pyrethroids are sensitive to high temperatures and Dursban can be sensitive to ultraviolet rays, so applications should be made as late in the day as possible — or, alternatively, as early in the morning as possible. The same materials that are effective in the spring should suppress populations in the summer as well.

Risk Factors

While some golf courses have had a history of annual bluegrass weevils and manage populations aggressively, many others only experience activity sporadically. Often spot treatment can be very effective. Concentrate on the areas where the "risk factors" are highest — for example, white pines nearby or substantial amounts of annual bluegrass.

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Back to Basics
How Turfgrasses Grow

By Dr. Richard J. Hull,
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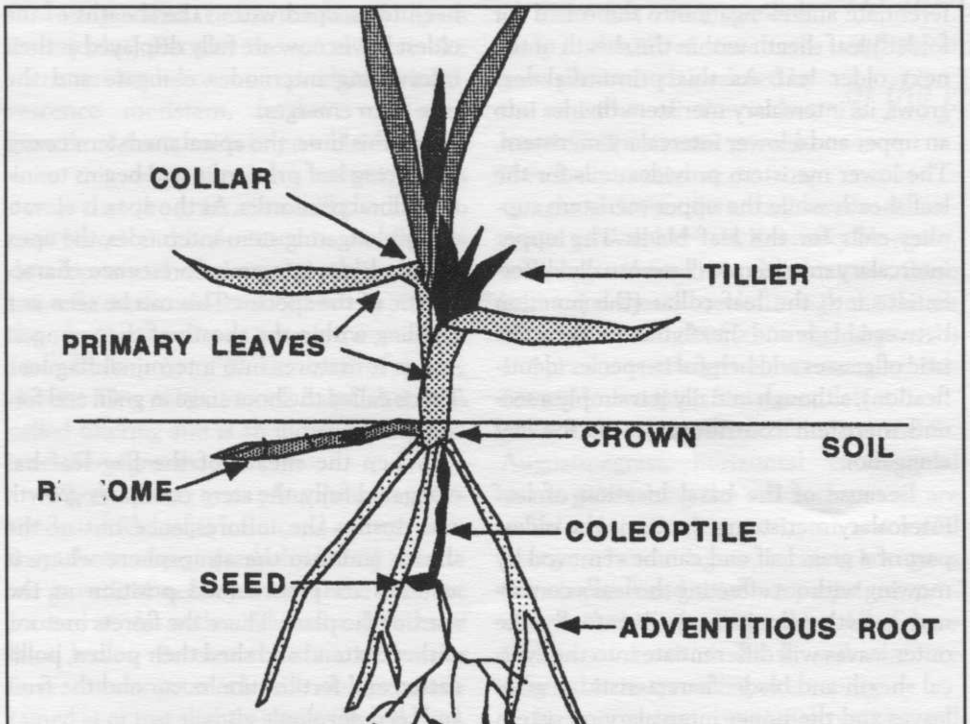
Turf managers see their grassed areas grow and respond by mowing. They observe some grasses flower in the spring. They note the recovery of divots and other mechanical injuries.

While they would be concerned if these manifestations of turfgrass growth failed to occur (maybe not the flowering), most managers give little thought as to exactly what grass growth entails. This ambivalence toward the growth process can be disastrous because the developmental characteristics of grasses place rather strict limitations on how these plants can be manipulated. This short discussion will try to review the process of turfgrass growth.



Growth structures of the turfgrass plant.

Leaf initiation and Growth: As in most seed producing plants, all primary leaves originate from a terminal meristem. When a grass caryopsis (dry fruit enclosing a single seed) germinates, the first organ to appear is the primary root called a radicle that, following gravitational cues, grows downward into the soil.

Shortly thereafter, the embryonic shoot emerges and, true to its antigravitational instructions, grows upward to where light should be found. The elongating shoot meristem and first leaf are protected as they pass through the soil by a closed sheath termed a coleoptile.

When the coleoptile breaks the soil surface and perceives light, it soon stops growing and its tip is ruptured by the first leaf which elongates and expands into the light. At the same time, the stem ceases elongating and the shoot apical meri-stem is positioned at, just above or just below the soil surface, depending on the grass species. At a predetermined distance behind the shoot meristem, a node develops in the embryonic stem from which adventitious roots emerge. These will develop into the permanent root system.

In a regularly mowed turf, the flowering process is cut short by mowing off the stem apex above the mower height, thus preventing all further growth of that stem.

Once the first leaf has emerged into the light, the apical meristem continues to differentiate nodes consisting of a leaf primordium that expands laterally and develops into a cowl-like, sheathing leaf. Just above the center of this sheathing leaf a bud develops. The leaves elongate as a roll enclosed within the first leaf sheath.

Leaf growth occurs from a basal intercalary meristem that produces cells that differentiate and elongate into the rolled (or folded) leaf sheath within the sheath of the next older leaf. As this primordial leaf grows, its intercalary meristem divides into an upper and a lower intercalary meristem. The lower meristem provides cells for the leaf sheath while the upper meristem supplies cells for the leaf blade. The upper intercalary meristem will eventually differentiate into the leaf collar (the junction between blade and sheath that is characteristic of grasses and helpful in species identification), although initially it is simply a second meristem contributing cells for leaf elongation.

Because of the basal location of leaf intercalary meristems, the tip is the oldest part of a grass leaf and can be removed by mowing without affecting the leaf's continued growth (elongation). Eventually the outer leaves will differentiate into the typical sheath and blade characteristic of grass leaves and the upper intercalary meristem will form a collar and cease to exist as a meristem. The lower intercalary meristem will continue to produce new cells and the leaf sheath might continue elongating for a while.

Inner leaves will not form a collar and their intercalary meristems continue producing cells that elongate and allow these leaves to maintain their growth within the sheaths of older leaves. This constitutes the vegetative phase of shoot growth in grasses. It is the growth desired by a turf manager because it produces the most uniformly textured turf.

Flower induction and stem elongation: For many turfgrasses, a cold period or the seasonal changes in day length (photoperiod) trigger the induction of reproductive growth: flowering. This initiates a profound change in the growth of a grass plant. Stem elongation, that had stopped when the seedling coleoptile emerged into the light, now resumes. Intercalary meristems at the base of each node produce cells that elongate and lift the apical meristem above the soil line eventually to assume a position at the apex of the plant. The leaves which had been telescoped within the sheaths of the oldest leaves now are fully displayed as their intervening internodes elongate and the true stem emerges.

At this time, the apical meristem ceases producing leaf primordia and begins to initiate floral primordia. As the apex is elevated by elongating stem internodes, the apex differentiates into an inflorescence characteristic of the species. This can be seen as a swelling within the sheath of the youngest leaf as it matures into a terminal flag leaf. This is called the boot stage in grain and forage grasses.

When the sheath of the flag leaf has elongated fully, the stem continues growth and pushes the inflorescence out of the sheath and into the atmosphere where it assumes its preordained position at the apex of the plant. There the florets mature, anthers extend and shed their pollen, pollination and fertilization occur and the fruit and seed develop.

In a regularly mowed turf, the flowering process is often literally cut short by mowing off the stem apex as the elongating stem lifts it above the mower height. Removing the apical meristem, and the developing leaves enclosed within the sheaths of older leaves, prevents all further growth of that stem.

Annual bluegrass, and some cultivars of Kentucky bluegrass, when maintained as a mowed turf, do not experience much stem internode elongation so the apical meristem and developing inflorescence are not removed by mowing until the inflorescence has fully emerged. This is why unsightly inflorescences (erroneously called seed heads) are often observed in turf containing these grasses during the flowering season.

Some weedy grasses, which assume a prostrate growth habit in turf, are able to develop inflorescences and produce mature seed because these organs remain below the mowing height. Crabgrass and goosegrass are notorious for this and are serious weeds, in part, because they have an extended flowering season which produces objectionable inflorescences throughout much of the summer.

Flowering triggers the death of a grass stem: A second undesirable feature of grass flowering is that it ends the life of a grass stem (culm). Because the apical vegetative meristem has become a reproductive inflorescence meristem, further vegetative growth of the stem is impossible even if it were not decapitated by mowing. This means that the grass stem will produce no new leaves and is destined to die. Such a developmental sequence would be disastrous for turf maintenance were it not for the plant's capacity to generate new stems from buds present at the base of young shoots. This initiation of basal shoots is called tillering and is an indispensable feature of turfgrasses.

When a young grass plant (seedling) initiates its fifth leaf, it has stored enough photosynthetic energy (carbohydrates) to initiate growth of axillary buds. These buds are located at the nodes inside the sheaths of basal leaves. Because the stem internodes have not elongated, these nodes are maintained at or just slightly above the soil level, protected from mowing injury.

Basal bud growth initially occurs within the enclosing sheath of the subtending leaf and does not break free until its elongating leaves rise above the level of the collar (intravaginal tillering). Because each primary leaf contains an axillary bud at the base of its sheath and these buds are all concentrated at the base of the stem, several tillers can emerge before the parent stem is induced to flower. When flower induction does occur, the internodes between nodes, from which tillers have emerged, are not stimulated to elongate so the tillers are not lifted from the soil during elongation of the parent culm. In fact the tillers become pretty much autonomous of their parent culm producing their own adventitious roots. They fail to senesce when the parent culm flowers and undergoes senescence.

Tillers can remain vegetative and not flower until the following growing season. As such, they serve as overwintering portions of the grass crown. In this way, an extensive crown re-gion composed of numerous tillers and culm bases constitutes the truly perennial portion of a turfgrass plant.

Tillers can remain vegetative and not flower until the following growing season. As such, they serve as overwintering portions of the grass crown.

Rhizomes and stolons: Early in the life of some turfgrass plants, buds enclosed by the sheaths of the oldest leaves will resume growth. However, instead of growing upright to form tillers, they assume a horizontal growth habit. In Kentucky bluegrass, creeping red fescue and bahiagrass, these horizontal shoots break through the sheath of the subtending leaf (extravaginal growth) and produce underground stems called rhizomes. In creeping bentgrass, velvet bentgrass, rough bluegrass, buffalograss and St. Augustinegrass, horizontal extravaginal stems grow along the soil surface and are called stolons. Some grasses, such as colonial bentgrass, bermudagrass, Japanese lawngrass (zoysiagrass) and seashore paspalum, produce both rhizomes and stolons. All of these turfgrasses form a dense sod and are referred to as spreading or creeping.

By comparison, perennial ryegrass, tall fescue, chewings fescue and some colonial bentgrass cultivars produce no horizontal basal shoots and are known as bunch-type grasses. These grasses depend on seeding rate to produce a thick turf and do not recover from mechanical injury as rapidly as the rhizomatous or stoloniferous grasses.

Rhizomes and stolons differ from tillers, not only in their direction of growth, but in the fact that they grow entirely as a result of stem elongation. Their apical meristem is covered by several layers of scale leaves and is thereby protected as it pushes through the soil or along the soil surface. The meristem produces nodes, each with a leaf primordium, bud and internodes, which elongate.

Rhizomes and stolons differ from tillers, not only in their direction of growth, but in the fact that they grow entirely as a result of stem elongation.

As a result, the horizontal stem differentiates into reasonably distinct nodes and internodes. At each node, the axillary bud is covered by a scale leaf. Nodes also produce adventitious roots and these extend the plant's root system to encompass a larger volume of soil.

Depending on the grass species and on environmental conditions, the tip of horizontal stems will turn upward and produce a new terminal shoot at some distance from the parent plant. When the tip turns upward, internodal elongation stops and the shoot that develops is like any other young grass plant; consisting mostly of telescoped leaf sheaths that overtop the shoot apex. The length of rhizomes and stolons varies with the species and environmental conditions.

The intervening axillary buds will probably not form shoots unless the apical meristem of the rhizome or stolon is injured, or the soil in which the horizontal stem is growing is largely free of other plants. Under such conditions, several shoots or branches can emerge from axillary buds along the horizontal stem.

In a dense sod, rhizome and stolon growth is limited. But, where bare soil is available, the growth of these horizontal stems is stimulated. In this way, turfgrasses that produce stolons or rhizomes can quickly invade disturbed sites and repair turf injury.

I have not been able to determine exactly what environmental or internal stimulus promotes horizontal stem initiation, but I suspect it has something to do with the plant's energy status. In cool-season grasses, rhizome and stolon growth occurs mostly in the spring and fall. Those are the times when such grasses experience their most favorable energy status. Even during the summer, grasses at the margins of turf areas will receive more solar radiation and are more likely to produce rhizomes or stolons.

Warm-season grasses experience their most favorable energy status during the summer. Their lack of photorespiration makes these grasses more photosynthetically efficient during the high light and elevated temperatures of summer. It is then that maximum rhizome or stolon growth occurs. Photoperiod and day/night temperature range might influence horizontal stem initiation, but I would bet on plant energy status being the primary trigger. Rhizomes are normally shorter and their apical bud turns upward to produce a new shoot closer to the parent plant in the fall than in the spring. This may be environmentally controlled.

Growth responses to adverse climates: Cold, heat and drought are climatic variables that will influence turfgrass growth. Cool-season grasses are generally stimulated to grow more vigorously when temperatures are cool and moisture is abundant. By contrast, warm-season grasses normally grow best under hot temperatures and adequate but not excessive water supplies.

As mentioned above, favorable growth conditions often stimulate tillering and horizontal stem growth in species that have the capacity for such growth. When the temperature drops to near freezing or below, warm-season grasses cease shoot growth and root growth is largely curtailed. These grasses essentially go dormant and will not resume growth until an extended period of warm weather is encountered.

Cool-season grasses do not go dormant under cold temperatures. Photosynthetic activity continues and nutrient absorption by roots persists at respectable rates. Aerial shoot growth (leaf elongation) pretty much stops, but rhizomes might continue to grow, if slowly. Root growth and cell divisions in root meristems have been observed in the heart of winter. In short, cool-season grasses continue growing under cold temperatures at a reduced rate. They do not become dormant and will resume growth quickly when temperatures warm.

Drought affects all turfgrasses in a similar way. The first response is a slowing of growth, although shoots are more affected than are roots. This reduces transpiration rates and helps conserve soil moisture. If dry conditions continue, growth stops altogether. Under high-light conditions, most grasses will suffer leaf damage and turn yellow or brown. An induced growth cessation occurs, which cannot be regarded as a true dormancy. When moisture is restored, most turfgrasses quickly resume growth and recovery can be rapid and complete.

Because warm-season grasses are more efficient users of water, under drought conditions they are able to divert carbohydrates to roots and stimulate deeper root penetration into the soil, thereby tapping a larger water supply. In this way, they can forestall serious drought injury. However, once subjected to drought, warm-season grasses are likely to sustain more injury than cool-season grasses.

Cool-season grasses have fewer energy reserves during periods of summer drought, which limits their capacity to avoid moisture stress through the stimulation of deeper root growth.Consequently, they may exhibit drought stress more quickly than warm-season grasses. However, cool-season grasses appear to be better able to recover from periods of prolonged drought than warm-season grasses. Soil conditions (depth, moisture holding capacity and aeration) will, of course, influence the timing and extent of grass responses to drought.

Root growth has been discussed above in the context of development and environmental conditions. In an earlier Back-To-Basics article, I concentrated on seasonal root growth as it influences nutrient absorption. It would be approriate to point out that seedling grasses develop two root systems, primary (seminal) roots that emerge from the seed (embryo) and adventitious roots that emerge from the coleoptile node which develops when the coleoptile breaks through the soil and experiences light.

The primary roots develop largely from seed reserves and also from current photosynthesis of the seedling. However, their growth is limited and their function is primarily to establish water contact between seedling and soil. Nutrient uptake will also occur but this function is soon taken over by the more rapidly developing adventitious root system. The primary roots may survive and make modest contributions to the plant during the first year but not thereafter. In some species, primary roots disintegrate within a month or two.

Cool-season grasses appear to be most resilient to periods of prolonged drought. Warm-season grasses can sustain more injury than cool-season but normally will also recover.

Adventitious roots emerge from the coleoptilar node and establish the base of the crown. This is set at the same depth within the soil regardless of how deeply the seed was planted. Because several adventitious roots normally emerge from the coleoptile node, and these branch freely, the grass root system always has a fibrous structure. Tiller bases produce additional adventitious roots, as do the nodes of horizontal stems, and these benefit the grass by extending its reach into unexplored soil.

This capacity for rapid root generation also allows grasses to reestablish a root system following stress induced root death or feeding by soil insects. Because such events are not uncommon during most growing seasons, cool-season turfgrasses often must regrow much of their root system during late summer and early fall. Warm-season grasses are able to support more rapid root growth during the summer and, therefore, enter the fall season with a more-or-less intact root system.

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nutrient use efficiency and photosynthate partitioning in turfgrasses and woody ornamentals.

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Refining Turf Management Practices

Understanding the patterns and timing of turfgrass growth can help refine turf management practices. Some ideas that emerge from the above discussion are listed below.

1. Because of their capacity to expand by horizontal stem growth, rhizometous and stoloniferous grasses need not be seeded as heavily as bunch-type grasses.
2. The ability to repair mechanical damage to turf makes the inclusion of sod-forming grasses in any turf seed mix a sound practice.
3. Because flowering and inflorescence production detract from turf uniformity and the flowering culms will die and introduce dead stems into the turf, selecting cultivars that are less likely to flower under turf management conditions would be desirable. Careful use of plant growth regulators can minimize this problem.
4. Close mowing or drastic changes in mowing height should be avoided because the apical meristem of grass shoots is near the soil surface and will tend to be elevated and damaged by mowing when grasses are allowed to grow too much between mowings.
5. Tillering of turfgrasses contributes to stand density and is encouraged by mowing but not by removing so much leaf tissue that insufficient energy is available to support tiller initiation and development.
6. Because root loss during the summer is to be expected in cool-season grasses, it is wise to raise the mowing height during summer to provide the photosynthetic products needed for adventitious root regeneration.
7. Turfgrasses respond to drought conditions by allocating more energy for root system expansion. Therefore, it is best to reduce mowing frequency during midsummer and allow more leaf surface to capture additional energy.
8. Because cool-season turfgrasses continue photosynthetic activity during the winter and root growth depends upon energy captured at that time, it is important to remove tree leaves promptly and avoid any unnecessary winter shading of the turf.
9. Turf growing in shaded locations will have less photosynthetic energy to support tillering and horizontal stem growth, so close mowing should be avoided.
10. Turf recovery from mechanical injury depends on tiller, rhizome and stolon growth which relies on photosynthetic energy. Such turf should be mowed as high as is compatible with its use and should be protected from shading even for short periods of time.

Speeding Transition
Of Overseeded Perennial Ryegrass

As the range of hybrid bermudagrasses expands and improved seeded bermudas gain acceptance, winter overseeding and spring transition are more important issues. During the winter, dormant bermudagrass is camouflaged and protected by overseeded ryegrass. But, when it's time for the bermuda to come back to life, lingering perennial ryegrass can be a problem.

To find out the approved ways to discourage ryegrass and encourage bermuda in the spring, *TurfGrass Trends* contacted two respected experts at Auburn University, Drs. Coleman Ward and Jeffrey Higgins.

Begin in the Fall

Successful spring transition starts with good bermudagrass management in the fall. Make sure your bermuda goes into the winter with healthy rhizomes and stolons. Several practices will insure that this happens.

Potassium — Apply potassium liberally, especially during the fall. Apply a fertilizer, such as a 10-5-20, 0-20-20, or 16-0-38, at a rate to supply 0.75 to 1.00 lb. of K_2O per 1,000 sq. ft. monthly from September through November.

Avoid scalping — Avoid scalping in the fall. When bermudagrass recovers from scalping, it consumes stored carbohydrates which are needed for spring regrowth. Mow low without scalping prior to overseeding.

Delay overseeding — Delay overseeding until the bermudagrass becomes less competitive. Observe the amount of clippings taken each mowing as fall progresses. When it decreases, overseed. By delaying the date of overseeding, less vertical mowing and aggressive preparation (penalty mowing) of the bermudagrass will be required to reduce its competitiveness with the germinating perennial ryegrass. Less scalping and vertical mowing means stronger bermudagrass.

Maintain irrigation — Do not let the rootzone dry out. Fall can be the driest season of the year despite cooler temperatures.

Apply fungicides — Apply systemic fungicides to the bermudagrass in September to prevent spring dead spot.

Cultural Practices

For many years, turf managers and researchers have sought a foolproof scheme to insure a smooth spring transition. There are several cultural practices recommended to remove the overseeded turfgrass while speeding recovery of the bermudagrass.

Delay core aerification — This idea is opposite to popular thought. The theory behind early core aerification is to stimulate the bermudagrass with warm air entering the soil through the aerification holes. In fact, cold air, which is heavier that warm air, is more likely to settle in the core holes. It is best to delay aerification until bermudagrass is actively growing so closure of the holes can occur as rapidly as possible.

Closer mowing — Close mowing of the perennial ryegrass should weaken the perennial ryegrass because it is a bunch grass. Almost all of the ryegrass' stored carbohydrates are above ground and will be removed by close mowing. However, for this practice to be effective, it must begin *and end* before the bermudagrass initiates spring growth. Removing any new leaves from the bermudagrass is extremely detrimental to its recovery from dormancy. Carbohydrate reserves in the bermudagrass' rhizomes and stolons are drastically depleted by the initiation of new growth. So, mow the ryegrass lower early in the spring and raise the cutting height as soon as you notice new bermuda growth.

Vertical mowing — Vertical mowing thins out perennial ryegrass and permits more light penetration to the bermudagrass. However, as described in relation to closer mowing, it is harmful to the bermudagrass once it starts growing again. Vertical mowing is more likely to be beneficial where perennial ryegrass was seeded at excessively high rates (more than 400 lbs. per acre). This practice could be more detrimental than beneficial when the bermudagrass has begun to grow.

Withholding irrigation — Since perennial ryegrass requires more water than bermudagrass, withholding irrigation should reduce its competitiveness and enhance the transition to bermudagrass. In practice, this theory has at least two flaws. First, spring is often the highest rainfall period of the year. And second, the turf area may be in use and irrigation might be needed to keep it playable.

The use of selective postemergence herbicides can compliment cultural practices to provide consistent spring transition.

Increase nitrogen fertilization — Applying high rates of nitrogen (more than 1.25 lbs. per 1,000 sq. ft. per month) causes an increase in the top growth of both perennial ryegrass and bermudagrass. However, increased nitrogen is more detrimental to the root growth of perennial ryegrass than bermudagrass.

Furthermore, bermudagrass responds favorably to much higher levels of nitrogen than does ryegrass. Increasing nitrogen is the one sure way, among the cultural practices listed, to favor bermudagrass during transition. This is especially true as night time temperatures exceed 62°F. The downside to this approach is late season frosts can damage the bermudagrass after it has been fertilized.

Making a Herbicide-Assisted Transition

Cultural practices alone are often a very uncertain way to remove perennial ryegrass and reduce its competition with the base bermudagrass. The use of selective postemergence-applied herbicides can compliment cultural practices to provide consistent spring transition. But before using a herbicide to remove perennial ryegrass and speed transition, turf managers should:

- Be sure base bermudagrass is alive.
- Check the activities calendar for events during the spring season.
- Consult long-range weather forecasts. You might need to hold the perennial ryegrass if cool, wet weather is forecast.
- Discuss spring transition options with users of the site to prevent surprises.

If an instant spring transition is desired and acceptable, then metribuzin (Sencor 75DF) can be applied in the spring at 0.67 lb. of product per acre. This will control the perennial ryegrass and allow the bermudagrass to grow. However, severe turf discoloration will result for a couple of weeks due to the removal of the ryegrass.

Napronamide (Kerb 50WP) can also be used to remove overseeded perennial ryegrass. Kerb should be applied at two pounds of product per acre in the spring. This treatment will not work as fast as Sencor. The addition of a nonionic surfactant at 0.25% volume to volume is recommended.

Seed Selection

Ward and Higgins believe that perennial ryegrass is the best choice for winter overseeding high-use turf. While other cool-season turfgrasses can be used, they believe perennial ryegrass has superior wear tolerance, establishes quickly, has excellent frost tolerance, requires less mowing than some varieties and the advanced cultivars provide better disease resistance. They report that more than 50 blends and cultivars of perennial ryegrass are currently available.

Some cultivars of perennial ryegrass, however, have demonstrated extraordinary heat and drought tolerance, which enables them to tolerate many of the cultural practices described. Avoid these ryegrasses when purchasing seed in the fall.

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We must be doing something right! Our paid subscriptions are at an all-time high and the staff of TurfGrass Trends would like to thank you for subscribing.

This brings me to my second point. The kind of material found in TurfGrass Trends is unique. There are probably many people in the industry — in academics as teachers or students and in the field who could benefit from each issue of TurfGrass Trends. If you know of other colleagues, students or researchers who would find TGT interesting, please let them know how they can subscribe.

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Sue Gibson

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- Gray Leaf Spot
- The Role of Humates
- Grub Identification
- Life Cycles of Nematodes
- Managing Saline Irrigation
- Soil Temperature's Impact

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