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Turfgrass Seedling Establishment

Frank S. Rossi
Cornell University

Establishing turfgrass from seed as part of a new installation or renovation represents the most important stage in the life of the stand. Mistakes made during establishment evolve into chronic problems that often require additional inputs of water, fertilizer or pesticides to maintain an adequate stand. Many times, the mistakes made at establishment are a result of less than ideal conditions.

A clear understanding of the logistical considerations involved in establishing a healthy stand of turf is vital, such as; assessing site conditions, timing, soil preparation, selecting an adapted species or cultivar, seed rate, mulching, interval to traffic, etc. Optimizing each consideration to maximize establishment success, however, is often constrained as a result of construction, economic, scheduling issues, or environmental concerns associated with erodable soils. Each constraint then moves the manager further from the ideal. Without additional resources, will result in a less healthy stand more reliant on energy intensive inputs.

The establishment of a turfgrass stand from seed involves a myriad of decisions rooted in the basic principles of soil science, seed physiology, ecology, and pathology. Utilizing information based on these disciplines will lead to a healthier stand.

Soil Testing and Preparation

Improper soil preparation is a common reason for establishment failure. Soil preparation includes physical and chemical characteristics. Traditionally, soil nutrient testing has been recommended to ensure success, with particular emphasis on pH and phosphorus (P) levels. The soil reaction or pH is vital for determining nutrient availability and adequate P levels necessary for the energetic processes required during germination (see Hull, Turfgrass Trends Vol. 6 No. 5).

Recently, with the increasing use of modified rootzones, soil physical testing is becoming a standard practice. The increasing costs of modified root zones and the well publicized failures have lead to the establishment of an accredi-

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Editor, William E. Knoop, Ph.D.
903-860-2239; 903-860-3877 (fax)
knoop@mt-vernon.com

Production Manager
Linda O'Hara
218-723-9129; 218-723-9576 (fax)
lohara@advanstar.com

Circulation Manager
Karen Edgerton
218-723-9280

Layout & Production
Bruce F. Shank, BioCOM
805-274-0321

Group Editor
Vern Henry

Group Publisher, John D. Payne
440-891-2786; 216-891-2675 (fax)
jpayne@advanstar.com

CORPORATE OFFICE
7500 Old Oak Blvd.
Cleveland, OH 44130-3369

EDITORIAL OFFICE
P.O. Box 1637
Mt Vernon, TX 75457

Abstracts: *800-466-8443*
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tation program organized by the United States Golf Association (USGA) and implemented by the American Association for Laboratory Accreditation (A2LA). Soil physical testing provides valuable insights on the particle size distribution and functional performance. This information should be used to ensure an adequate balance between water holding and drainage. Obviously, water holding is essential for successful seedling establishment. However, excessive moisture can limit oxygen as well as increase the potential for seed rot.

Amending Problem Soils

The process of amending a soil to enhance its physical or chemical attributes has been an important aspect of successful establishment for many years. For example, organic amendments have been the cornerstone of the modified root zone mixtures for putting greens over the last 30 years. Still, inorganic amendments such as calcined clay, diatomaceous earth, fly ash, and natural zeolites are gaining in popularity. In each case, amendments are incorporated to enhance the nutrient and hydrologic properties of the growing medium.

In the last few years, investigations have been conducted on the use of organic composts for amending heavy clay soils. These studies, as well as ones conducted at Penn State University have identified key characteristics of composts such as C/N ratio, particle size, pH, metals, and soluble salt content that could determine their benefit. Results indicated that seedling establishment was significantly enhanced on compost amended soils compared to topsoil and no amendment. In addition, infiltration on the heavy clay soils was increased ten fold in some plots. Not only does this serve a valuable purpose in soil preparation, it contributes to the sustainability of the turf system.

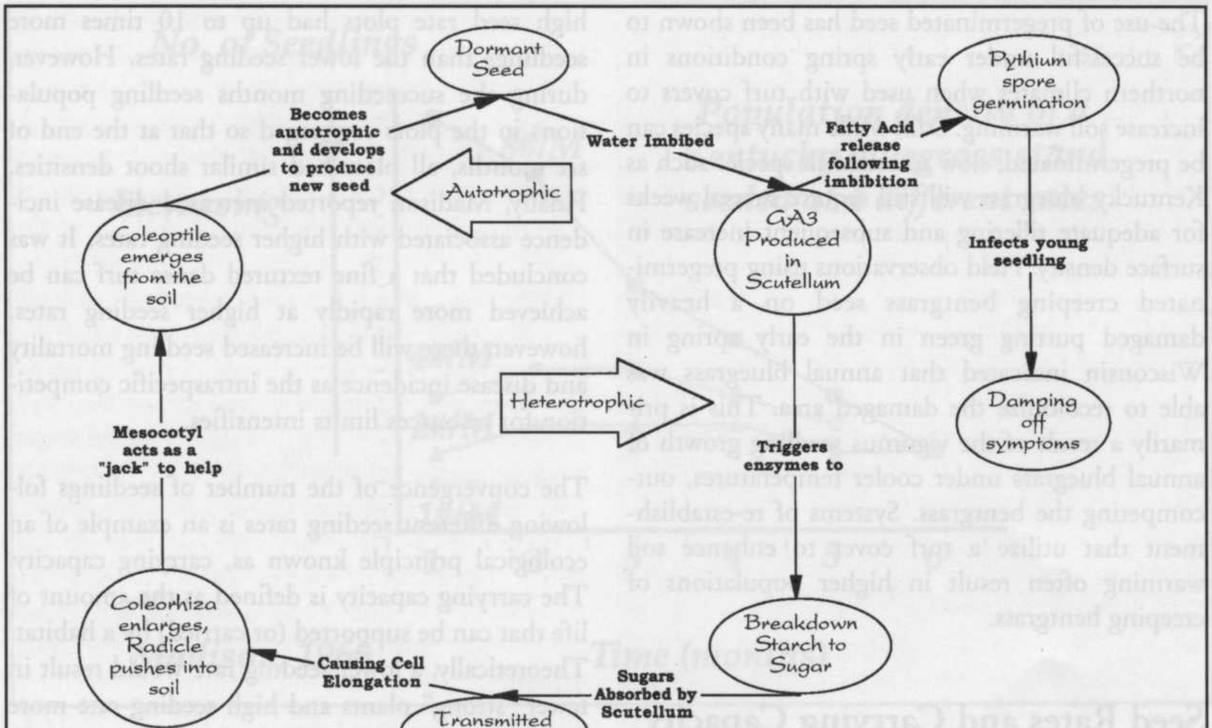
Seed Germination

Understanding the process of seed germination is basic to the development of a successful establishment program. A seed contains the genetic material, inherited from parents within a miniature plant (embryo), and an adjacent food supply (endosperm). The process of germination is triggered by the imbibition of water that sets in motion a chain of events that enables the plant to transition from heterotrophic (requiring complex organic compounds for energy) to autotrophic (produces its own energy) as it emerges from the soil to begin photosynthesis. If a seed is planted too deep in the soil, it may deplete its endosperm (food supply) and die before it can become autotrophic.

Interestingly, the transition from heterotrophic to autotrophic is the stage at which some preemergence herbicides limit competition from weed seedlings. As a weed seedling germinates and the radicle emerges, it encounters the soluble herbicide in the soil. The herbicide will inhibit cell division, but allow for cell enlargement. As the radicle continues to swell in a club shape it depletes the energy in the seed before the radicle can emerge from the soil similar to planting the seed too deep.

Seed Priming

Germination time varies depending on turfgrass species. Cool season grasses such as perennial ryegrass, tall fescue and creeping bentgrass can germinate and establish within a few weeks, while Kentucky bluegrass and some fine leaf fescues may require up to six to eight weeks to establish. To reduce the establishment time in the field, techniques



Water triggers germination, which is a chain of events that enables the plant to convert from an energy-dependent organism to one that produces its own energy.

that enhance emergence under less than ideal conditions have been developed. One of the more popular is seed priming. Seed priming is the process by which the hydration status of the seed is manipulated so that the seed imbibes water at a regulated rate, initiates germination, but does not allow for radicle emergence. Seed priming can be accomplished using an osmoticum such as salt or polyethylene glycol (PEG) or through solid matrix priming (SMP) with compounds that have a high water holding capacity such as soft coal, leonardite, or sphagnum moss. Experiments were conducted at Penn State University to investigate the viability of SMP as a means of enhancing cool season turfgrass (bluegrass, ryegrass and tall fescue) establishment.

Field experiments indicated that success of SMP treatment was dependent on species and cultivars with some cultivars of Kentucky bluegrass such as Glade, Gnome, and Marquis showing substantial benefits. Perennial ryegrass cultivars were not substantially different, while tall fescue cultivars Guardian and TF300 were only slightly enhanced. Still, the researchers concluded that SMP seed could be desirable under cool periods when seedling emergence would be reduced or for quick establishment. In a separate experiment conducted on Kentucky bluegrass, SMP seed did not directly increase seedling growth rate, however, seedlings were larger. Again, this could be desirable for enhanced establishment under sub-optimal conditions.

Pregerminated Seed

Golf turf and sports turf managers who manage intensively disrupted sites or experience a catastrophic loss of turf have been using a system that applies germinated seedlings to the turf area. Pregermination is generally accomplished over several days through a meticulous series of hydration regimes with various temperatures. Once the radicle has emerged, the seedling is applied to the turf area. This is a very sensitive time in the life of the seedling where it is most susceptible to desiccation as a result of the leaf surface area and the lack of adequate rooting.

The use of pregerminated seed has been shown to be successful under early spring conditions in northern climates when used with turf covers to increase soil warming. Still, while many species can be pregerminated, slow to establish species such as Kentucky bluegrass will still require several weeks for adequate tillering and subsequent increase in surface density. Field observations using pregerminated creeping bentgrass seed on a heavily damaged putting green in the early spring in Wisconsin indicated that annual bluegrass was able to recolonize the damaged area. This is primarily a result of the vigorous seedling growth of annual bluegrass under cooler temperatures, outcompeting the bentgrass. Systems of re-establishment that utilize a turf cover to enhance soil warming often result in higher populations of creeping bentgrass.

Seed Rates and Carrying Capacity

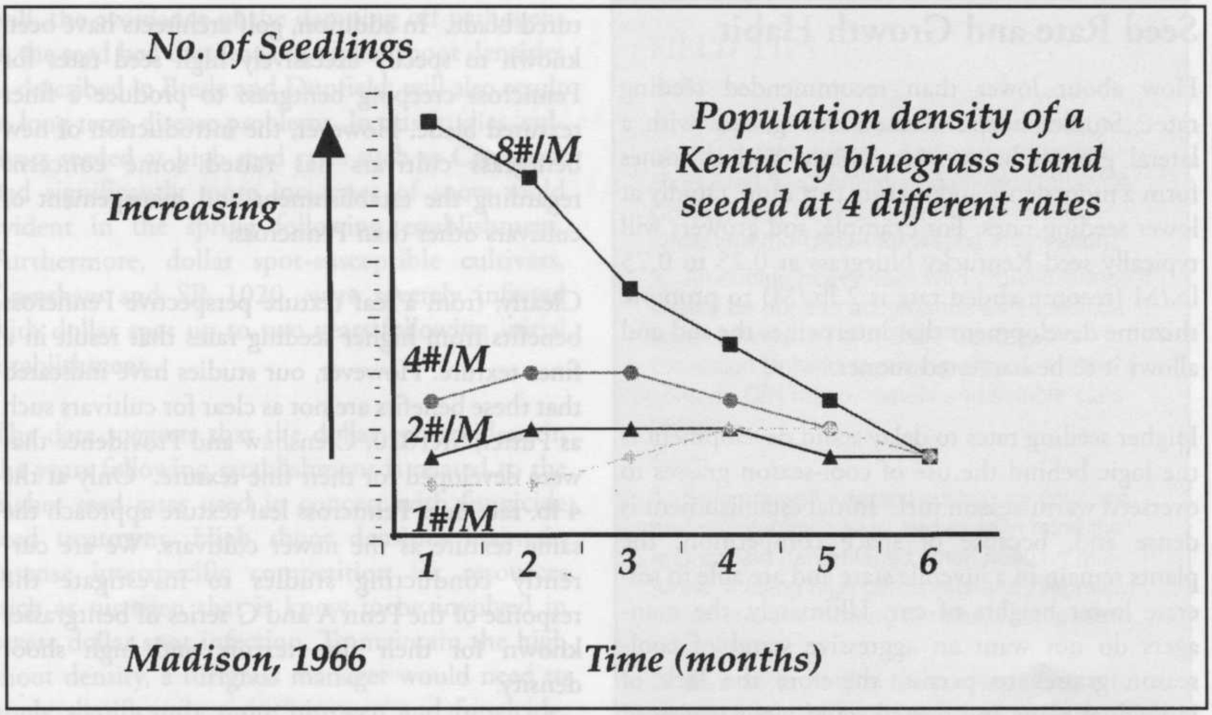
Seed rate is a primarily a function of seed size. However, it also depends on the turfgrass species, pure live seed (purity & germination) in a seed lot, environmental conditions at establishment, seed cost, growth habit (upright vs. prostrate) and establishment rate desired. Most cool-season turfgrasses are seeded at a rate that results in approximately 10 to 25 seeds per square inch, except for the bentgrasses. There are between 6 and 8 million seeds in one pound of creeping bentgrass, while a pound of Kentucky bluegrass has between 1 and 2 million seeds and a pound of perennial ryegrass only 200,000 to 300,000 seeds. Subsequently, bentgrass seed rates were designed to deliver 30 to 60 seeds per square inch, typically achieved by sowing 0.5 to 1.0 lb. per 1000 square feet (M).

Madison conducted a study to determine the optimum seed rate of turfgrasses. This work, like many other studies conducted by Madison, provided the baseline information that to this day is still relied upon. There were several interesting results including the observation that Penncross creeping bentgrass seeded at 0.5 lb. rate had the same visual cover rating at 1 month after establishment as the 5 lb. rate.

Madison monitored Kentucky bluegrass seedling density over a six month period. At establishment, high seed rate plots had up to 10 times more seedlings than the lower seeding rates. However, during the succeeding months seedling populations in the plots converged so that at the end of six months, all plots had similar shoot densities. Finally, Madison reported increased disease incidence associated with higher seeding rates. It was concluded that a fine textured dense turf can be achieved more rapidly at higher seeding rates, however, there will be increased seedling mortality and disease incidence as the intraspecific competition for resources limits intensifies.

The convergence of the number of seedlings following different seeding rates is an example of an ecological principle known as, carrying capacity. The carrying capacity is defined as the amount of life that can be supported (or carried) by a habitat. Theoretically, a lower seeding rate would result in fewer "strong" plants and high seeding rate more "weaker" plants. Eventually both systems reach the carrying capacity of the habitat and further population growth is subject to severe competition resulting in plant death. Ecologically, the loss of an individual plant is more than compensated for by the extended growth of the surviving plants. As stands mature, a balance is achieved between number of individuals and the size (tillering) of the individuals. This balance is explained by the self-thinning principle described in Danneberger.

Studies conducted using high seed rates for creeping bentgrass indicated that seedling survival is increased when the seed is pretreated with a fungicide. In fact, the number of shoots per unit area continues to be significantly greater in these plots one year after establishment. The period of self thinning appears to be extended through the reduction of seed bed diseases. It has been noted that certain organisms can, for periods of time, overshoot the carrying capacity, however, plants are not known to be one of these organisms. Plants have the ability to "sense" each other by picking up radiation reflected by nearby leaves and changing their growth characteristics well before their resources are reduced. Still, the data reveal as the stand matures and intraspecific competition for resources continues, the long term consequences of thinning and plant death can be severe.



Madison concluded that a fine textured, dense turf can be achieved more rapidly at higher seeding rates, however, there will be increased seedling mortality and disease incidence as the stand nears carrying capacity.

Interspecific Competition

Rapid establishment of a dense cover is one of the desirable characteristics of turfgrass. As mentioned earlier, the grasses differ in the time required to germinate and establish a dense cover. The lack of parity among the grasses in this area can have a substantial effect on the resultant stand population, especially when planting a mixture of several species. The interspecific competition for resources will result in a stand population that does not reflect the actual number of individual seeds sown.

It is recommended that perennial ryegrass not exceed 20 percent by weight of a mixture with Kentucky bluegrass because of the rapid seedling growth of ryegrass. The ryegrass becomes established and utilizes resources such as light, water and nutrients before a bluegrass is germinated. This results in a stand made up of mostly perennial ryegrass.

A useful technique that could limit the competitive edge of the ryegrass is immediate close mowing. This has been shown to substantially reduce ryegrass populations in the resultant stand, while utilizing the benefits of a rapid cover.

Turfgrass species competition with annual bluegrass is of critical importance to turfgrass managers. Brede and Dunfield conducted studies on variable seed rates of Kentucky bluegrass a means of limiting annual bluegrass invasion where a seed bank was present.

They found that increasing seed rates of certain aggressive cultivars can reduce annual bluegrass invasion in the seed bed. However, these high seed rates tended to have greater seedling disease incidence. Using treated seed enhanced seedling survival and maintained a high shoot density that was more reliant on pesticides to remain healthy.

The competitive ability of creeping bentgrasses with annual bluegrass would be an important selection standard, however, very little information exists on the new bentgrass cultivars. Harivandi and Hagen conducted a study with new cultivars seeded at the 0.5 lb. rate and collected data in the second year on annual bluegrass populations. The results indicated that there were differences from 10 to 50 percent depending on cultivar. Additional research is currently underway at Rutgers University.

Seed Rate and Growth Habit.

How about lower than recommended seeding rates? Studies have indicated that grasses with a lateral growth habit from stolons and rhizomes form a more dense and mature turf more rapidly at lower seeding rates. For example, sod growers will typically seed Kentucky bluegrass at 0.25 to 0.75 lb./M (recommended rate is 2 lb./M) to promote rhizome development that intertwines the sod and allows it to be harvested sooner.

Higher seeding rates to delay stand development is the logic behind the use of cool-season grasses to overseed warm-season turf. Initial establishment is dense and, because of space competition, the plants remain in a juvenile state and are able to tolerate lower heights of cut. Ultimately, the managers do not want an aggressive stand of cool-season grasses to persist, therefore the lack of individual plant and overall stand vigor is viewed as an advantage. Why else would a sane person seed perennial ryegrass at 30 lb./M (5 times the recommended rate)?

Morphologically, many of the new bentgrass cultivars were developed for more upright growth that would provide a more superior putting surface. In fact, higher seeding rates for the cultivars tested in our trials that were developed for upright growth (Putter, Crenshaw and SR1020) provided a dense turf sooner at slightly above the recommended rates. Penncross ratings from our study were consistent with those reported by Madison (1966): Seeded at the 0.5 lb. rate the cultivar had the same visual cover rating as the 5lb. rate. The moderately upright Providence provides 95% cover at six weeks when seeded between 0.85 and 1.15 lb. rates, while the upright Crenshaw seemed to require about 2 lb. Any recommendations based on these results should be made with consideration for the cultivar regarding disease susceptibility as well as time to full cover.

Seed Rate and Leaf Texture

As seed rate increases the number of individuals per unit area increases and the tend to be more upright, and narrow blade (fine texture). This is a common technique for enhancing the fine texture of tall fescue stands that typically have a coarse textured blade. In addition, golf architects have been known to specify excessively high seed rates for Penncross creeping bentgrass to produce a finer textured blade. However, the introduction of new bentgrass cultivars has raised some concerns regarding the establishment and management of cultivars other than Penncross.

Clearly, from a leaf texture perspective Penncross benefits from higher seeding rates that result in a finer texture. However, our studies have indicated that these benefits are not as clear for cultivars such as Putter, SR1020, Crenshaw and Providence that were developed for their fine texture. Only at the 4 lb. rate does Penncross leaf texture approach the same texture as the newer cultivars. We are currently conducting studies to investigate the response of the Penn A and G series of bentgrasses known for their fine texture and high shoot density.

Pathology

This discussion has primarily addressed plant to soil and plant to plant interactions. A critical aspect of the seed bed that exerts a strong influence on seedling establishment is the interaction between plants and microbes. To many turfgrass managers, this is most evident when the seedling becomes infected, symptoms are visible, and stand population is reduced as part of the self thinning rule. Researchers have determined that the interaction between plants and microbes begins as the seed imbibes water and commences germination.

Ruttledge and Nelson have identified how the process of seed germination actually can stimulate the germination of *Pythium* spp. in the soil known to cause damping off diseases. During germination, fatty acid compounds released from the seed stimulate germination of spores in the soil. These spores eventually lead to infection.The more seed present, the more fatty acid released and the greater the potential for damping off problems. This has been increasingly evident as more turfgrass managers use higher seed rates to accelerate establishment. The result is increased disease problems. We are currently collaborating with Dr. Nelson's lab to investigate the fatty acid release patterns of creeping bentgrass cultivars and their influence on subsequent *Pythium* infection.

Still, the avoidance of the damping off pathogens in the seed bed that leads to higher shoot densities as described in Brede and Dunfield, will also result in long term disease problems. In our studies, cultivars seeded at high seed rates such as Crenshaw had significantly more incidence of snow mold evident in the spring following establishment. Furthermore, dollar spot-susceptible cultivars, Crenshaw and SR 1020, were severely infested with dollar spot up to two years following initial establishment.

The data suggests that the dollar spot evident in the years following establishment is related to the higher seed rates used in concert with fungicide seed treatment. High shoot densities maintain intense interspecific competition for resources such as nitrogen that is know to be involved in severe dollar spot infection. To maintain the high shoot density, a turfgrass manager would need to apply significantly more nitrogen and fungicide, an approach not recognized as sustainable.

Summary

The pressure to reduce energy intensive inputs for turfgrass management and become more resource efficient is most easily addressed at establishment. For example, it is much easier to amend a soil when it is not vegetated than to attempt long term amending using core cultivation.

Ecological and pathological principles at work in the seed bed and throughout seedling growth must be observed to limit the amount of plant loss during establishment. Finally, the logistical aspects of seedling establishment are well documented and many have been researched for their effectiveness. It makes good sense to employ knowledge based decisions founded on sound scientific principles than to rely on magazine advertisements and sales pitches. Simply put, a well adapted species sown on a healthy adequately drained soil will be a more resource efficient stand over time.

Dr. Frank Rossi is assistant professor of Turfgrass Science and Extension Turfgrass Specialist at Cornell University in New York. His research interests include turfgrass ecology and stress physiology.

FIELD TIPS

Soil

1. Proper soil preparation is essential for successful establishment. Soil testing should be conducted for chemical and physical analysis. Contact your local Cooperative Extension office and the USGA for testing information.

2. Amending heavy soils with organic compost should be done in accordance with specifications outlined in Penn State Cooperative Extension Bulletin regarding organic matter content, C/N ration, metals and soluble slats present.

Seed

1. Select a well adapted cultivar for your use and maintenance level and keep in mind the appropriate percentages when seeding mixtures. If using high percentages of ryegrass, consider close mowing to reduce competitive advantage.

2. Be sure to seed at recommended rates to ensure minimum intraspecific competition. If high seed rates are used, be sure to compensate for additional plants by increasing inputs to maintain high density.

3. Primed and pregerminated seed are viable options for seeding under less than ideal conditions but are species and cultivar dependent.

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Turfgrass Seedling Treatments For the Control of Pythium Diseases And the Improvement of Stand Establishment

Eric B. Nelson, Ph.D.
Cornell University

Seedling establishment is the most critical stage in new turfgrass installations of renovations. Establishment efficiency can be affected by many different factors, including speed of germination, inherent competitiveness with other turfgrass varieties and weed species, and susceptibility to seed rotting and damping-off pathogens. The latter is perhaps the most troublesome, yet one of the most infrequently recognized causes of establishment failures. To understand ways of improving stand establishment, it is important to understand the nature and control of seed rotting and seedling pathogens of turfgrasses.

Seed and Seedling Pathogens

Seed rotting and damping-off fungi are often the major limiting factors to stand establishment. The more common seed and seedling rotting fungal pathogens include species of *Pythium, Fusarium,* and *Rhizoctonia*. More than 15 fungal genera are represented in this category. Few studies have focused on the ecology, epidemiology, and control of *Fusarium-* and *Rhizoctonia-* incited damping-off diseases of turfgrasses. Diseases caused by *Pythium* species have been studied most widely because they appear to be the most important in limiting stand establishment.

Not only are *Pythium* species major pathogens of seed and seedling rotting, but they also become major root rooting pathogens once established in a turfgrass planting. In a survey of pathogenic *Pythium* species recovered from mature bentgrass turf, the more aggressive creeping bentgrass damping-off pathogens included *P. myriotylum, P. tardicrescens,* and *P. volutum*. All of the highly aggressive isolates were more virulent to creeping bentgrass seedlings at warm temperatures (28-32 degrees C) than cooler ones (16 degrees C).

In a survey of *Pythium* species on creeping bentgrass and perennial ryegrass, Nelson and Craft found that Pythium graminicola was isolated most frequently from mature stands of turfgrasses and nearly all isolates tested were highly virulent as seed rotting pathogens of creeping bentgrass and perennial ryegrass. Among other pathogenic species recovered were isolates of *P. aphanidermatum, P. aristosporum, P. torulosum,* and *P. vanterpoolii*. At least one isolate within each species was highly virulent to creeping bentgrass seeds and seedlings. *Pythium torulosum* was the species most frequently recovered from turfgrass roots and crowns. However, nearly all isolates were nonpathogenic. Five pathogenic isolates of *P. torulosum* were recovered. With the exception of one isolate, all were only weakly virulent to creeping bentgrass seedlings at cool (13 degree C) or warm (28 degrees C) temperatures.

Conditions Favoring Pythium Damping Off That Affect Stand Establishment

Pythium damping off of turfgrasses is known to be affected by a number of factors that directly impact establishment efficiency. These include a number of important environmental and cultural factors. They are:

1.) **Germination Time.** The longer seeds spend in moist soil, the greater the potential for seed and seedling rots. Kentucky bluegrass can take two to three weeks after planting before emergence, whereas fescues and bentgrasses take only a week to ten days for emergence. Perennial ryegrass generally requires less than one week.

2.) **Soil Moisture and Oxygen Levels.** All *Pythium* species require abundant moisture for germination and dispersal. Prolonged wet soils favor seed and seedling rots. Unfortunately, these prolonged wet periods are necessary for adequate seed germination and seedling establishment. Oxygen levels are generally lower in soils with high soil moisture. Increased soil compaction also decreases soil oxygen levels by decreasing the amount of air-filled pore space.

3.) **Soil Temperatures.** *Pythium* species are capable of inciting severe seed and seedling rots at both cool and warm temperatures. We have found in laboratory tests that the majority of *P. graminicola* isolates and all *P. aristosporum* isolates recovered from mature stands of turf are highly virulent as seed and seedling rot pathogens at both 13 and 28 degrees C.

In these studies, damping-off severity of specific isolates of *P. graminicola* and *P. vanterpoolii* on creeping bentgrass was favored by either cool or warm temperatures, depending upon the isolate. Although isolates of *P. aphanidermatum* were virulent at both temperatures, in general, they were more virulent at 28 degrees C than at 13 degrees C. At 28 degrees, some isolates of *P. graminicola, P. aphanidermatum* and *P. aristosporum* were pathogenic to perennial ryegrass in growth chamber experiments, whereas none of the isolates of *P. torulosum* and *P. vanterpoolii* were pathogenic. On perennial ryegrass, isolates of *P. graminicola* ranged from nonpathogenic to highly virulent. Because of the wide temperature optima of individual strains, as well as the presence of both "cool temperature" and "warm temperature" strains in many turfgrass soils, it is difficult to find temperature conditions that are not favorable for seed and seedling diseases caused by *Pythium* species.

5.) **Planting Depth**. Planting depth affects susceptibility of seedlings to damping off by increasing the amount of time susceptible tissue spend in soil exposed to pathogens. The more quickly the seedling emerges, generally the more quickly the plant can escape infection from seed rotting pathogens.

6.) **Sowing Density**. Seeds of turfgrasses are sown into a variety of habitats. Typically, seeds are sown into a well-prepared, plant-free seed bed or they are overseeded into an established turfgrass stand. It is common practice to continually overseed thinning areas of turf or to overseed a warm-season turfgrass with a cool-season one during the fall. In both cases, seeding rates are generally excessive.

The notion among most turfgrass managers is the more seed you sow, the better the stand. However, it has been shown in studies with other plant species that increased seedling densities can enhance Pythium damping-off severity. The increased seedling densities are comparable to increasing the soil inoculum of *Pythium*. Increasing the seedling density increase the germi-

Table 1. Fungicide Seed Treatments for the Control of Seedling Pathogens

Fungicide	Target Pathogen	Grass Species	Rates
Benomyl	*Fusarium culmorum*	Perennial Ryegrass	1.5g a.i./kg.
Captan	*Fusarium culmorum*	Perennial Ryegrass	1.5g a.i./kg.
	F. oxysporum	Perennial Ryegrass	3.0g a.i./kg
Chloroneb	*Pythium aphanidermatum*	Annual Ryegrass	4 oz./100 lb.
Etridiazole	*Pythium aphanidermatum*	Annual Ryegrass	4 oz./100 lb.
Iprodione	*Fusarium culmorum*	Perennial Ryegrass	1.5g a.i./kg
Metalaxyl	*Pythium spp.*	Perennial Ryegrass	1.5g a.i./kg
	P. graminicola	Creeping Bentgrass	3.2g a.i./kg
	Cladochytrium caespitis	Kentucky bluegrass	7.0g/kg
Thiram	*F. oxysporum*	Perennial Ryegrass	3.0g a.i./kg

nation frequency of *Pythium* propagules and also enhances the plant-to-seed spread of the pathogen.

7.) **Cultivar Selection.** In a dated and limited survey of turfgrass species, bermudagrasses and all of the cool-season were susceptible to *Pythium aphanidermatum*. Warm-season grasses, with the exception of bermudagrass, were resistant. No complete and contemporary studies on susceptibility of bentgrass varieties to Pythium damping off have been carried out and no known resistance to Pythium blight or Pythium root rot exists among cultivars currently in commercial use.

Why Are Seeds and Seedlings So Susceptible To Damping-Off Pathogens?

Of all stages of plant development, the germinating seed and seedling stages are perhaps the most vulnerable to a variety of stress-related factors that can be fatal. Not only are plants at these stages more vulnerable than mature plants to water deficits, temperature extremes, and pesticide toxicity, they are also much more susceptible to infection by soil-borne pathogens.

One of the principal reasons for the increased susceptibility of germinating seeds and seedlings to infection, particularly by *Pythium* species, is the exudation of cellular compounds into the soil surrounding the seed (or spermosphere) during the germination process. During initial stages of seed germination, the uptake of water into the seed results in the physical damage to cell membranes. Even though the plant eventually repairs this damage, many cell constituents leak out of the seed into the surrounding soil during the first few hours of germination before these repair processes are complete. Under high moisture conditions or suboptimal conditions for seed germination, seeds release more exudates.

Nearly all seed- and seedling-rotting pathogens utilize these exudates as a food source and to sense the presence of a susceptible host plant. Many pathogens, such as *Pythium* species, are ecologically adapted to respond very rapidly to the presence of these exudates since they do not persist for long periods of time in the soil.

The presence of seed and seedling exudates are critically important in regulating responses of pathogens to plants and in supporting microbial interactions and processes in the spermosphere. If there are insufficient concentrations of exudates in the spermosphere, *Pythium* species do not respond to the presence of the plant and do not infect the seed or seedling.

Seed Treatments To Improve Stand Establishment

Pregerminated Seed. Presoaking seed treatments that result in the emergence of the radicle are referred to as pregermination treatments. These treatments generally involve the soaking of seed in water until radicle emergence. The germinated seed is then planted as a slurry. This is done to enhance the germination rate of seed once planted in the soil. Even though this method greatly decreases the establishment time, seeds planted in this manner are difficult to handle and must be planted immediately. Specialized equipment is also required. Germinated seeds are much more susceptible to physical damage than are ungerminated seeds.

Studies with pregerminated seeds of other plant species have shown that the soaking process causes the releases of pathogen stimulating exudates within the first 24 hours. When these seeds are then planted after soaking, in soil infested with pathogenic *Pythium* species, seed and seedlings are much less susceptible to disease.

Seed Priming. Seed priming has also been referred to as osmoconditioning. This process differs from presoaking treatments because the radicle never emerges from the seed coat. During the priming process, seeds are soaked in a solution of various salts or polyethylene glycol to limit water availability to the seed. Concentrations of these solutes are adjusted to allow the seed to imbibe just enough water to initiate the biochemical processes required for seed germination without radicle emergence. Unlike pregermination treatments, primed seed can be rinsed and dried after the priming process. Therefore, it can be planted just like untreated seed.

Table 2. Effective microbial seed treatments for the control of Pythium damping off incited by *Pythium graminicola*

Species	*Strain #*	*Original target pathogen*
Azospirillum brasiliense	Cd-1	None
Enterobacter cloacae	MN9	*Pythium ultimum*
	EcCT-501	*Pythium aphanidermatum* *Sclerotinia homoecarpa*
Enterbacter spp.	Bf-14	*Magnaporthe poae*
Paenibacillus macerans	144/88.4	Various
	91/15.3B	Various
Pseudomonas aureofaciens	Tx-1	*Sclerotinia homoecarpa*
Pseudomonas fluorescens	AN4	*Pythium ultimum*
	Pf-5	*Pythium ultimum*
	FN3	*Pythium ultimum*
Pseudomonas putida	11/91.72B	Various
Seratia marcescens	9M5	*Magnaporthe poae*

Both types of presowing treatments are most effective on slow-to-germinate species, such as Kentucky bluegrass or bermudagrass. They can reduce the emergence time by up to ten days over nontreated seed. These effects are particularly pronounced in cool soils where Pythium seed rots and damping off can be more serious problems.

The time these processes take to complete varies according to species, varieties, and even seed lots. Without knowing the exact priming times required, it is possible to end up with seed that has been insufficiently primed or deteriorating because it has been soaked too long.

In both pregermination and seed priming techniques, solutions must be aerated to supply sufficient concentrations of oxygen to the seed during water imbibition. This allows the seed to imbibe water normally. If done properly, pathogen stimulatory exudates are removed in both techniques, making seeds much less susceptible to *Pythium* seed and seedling diseases when planted in the soil.

Fungicide Seed Treatments. In nearly all of the studies with fungicide seed treatments on turfgrasses, positive improvements in seedling stands have been obtained. Nearly all of the published studies have been conducted with annual or perennial ryegrasses. To my knowledge, only one study has been conducted on creeping bentgrass and this has not been published in widely accessible sources. Table 1 summarizes what is known about effective rates for selected seedling pathogens. In some cases, improvements in seedling stands of more than 70 percent have been observed. In other cases, protection can last up to ten weeks after sowing.

Seed treatment fungicides are formulated either as a slurry or as a dust treatment and are applied at relatively low rates. Fungicide seed treatments provide control equivalent to spray applications at a fraction of the fungicide use.

Biological Seed Treatments For Control of Seed and Seedling Pathogens

Biological seed treatments and seedbed amendments have proven to be quite effective in suppressing damping-off diseases of turfgrasses incited by the *Pythium* species. In a study, nearly 45 percent of all bacteria recovered from mature stands of creeping bentgrass and perennial ryegrass were suppressive to damping off incited by *P. aphanidermatum*. A higher frequency of antagonistic strains was found among the general heterotrophic bacteria than within the selected groups of enteric bacteria and *Pseudomonas* spp., groups known to be antagonistic to many turfgrass pathogens.

Although isolations of general heterotrophic bacteria yielded higher frequencies of effective antagonists, strains of enteric bacteria, particularly strains of *Enterobacter cloacae*, were more highly suppressive to *P. aphanidermatum* on perennial ryegrass than general heterotrophic bacteria or *Pseudomonas* spp. The level of control was as good as that provided by the fungicide metalaxyl.

Other studies have shown that a wide variety of bacterial strains, in addition to *E. cloacae*, are suppressive to damping off of creeping bentgrass incited by *P. graminicola* when applied as seed treatments. These strains are effective at both cool (20 degrees C) and warm (28 degrees C) temperatures and suppression lasted for at least 11 days.

There are a number of products on the market now that consist of microbial preparations. These are marketed in a variety of ways, but are generally targeted at improving soil properties. Some of these products might provide some benefit in reducing problems with Pythium damping off, particularly when seed is sown in a high sand content environment where microbial activity is somewhat low. Unfortunately, there is no microbial-based product that is currently registered with the US Environmental Protection Agency for control of Pythium damping-off diseases of turf.

Some composted organic amendments are also suppressive to Pythium damping off and the subsequent symptoms from root rot damage. Amending sand with composts, prepared from a variety of feedstocks, suppressed seedling and root diseases of creeping bentgrass caused by *P. graminicola.*

Among the more suppressive materials in laboratory experiments are industrial sludge and composted municipal biosolids. Among those generally not suppressive are leaf, yard waste, food, spent mushroom composts, cow manure, chicken manure, and combinations of these two manures with leaf compost. Pythium-suppressive composts typically have higher microbial populations. Furthermore, a strong negative relationship between compost microbial activity and Pythium damping-off severity was observed, indicating that much of the suppressive activity was due to microbial activities present in the compost amendment. A number of microbes recovered from these suppressive composts are equally suppressive to damping off incited by *P. graminicola* when applied as seed treatments.

Conclusions

Pythium seed rot and damping off take a countless toll on newly developing turfgrass seedlings. In the past, seedling stand losses due to Pythium damping off have never been of particular concern because of the relatively low cost of turfgrass seed. To my knowledge, the magnitude of losses during seeding and overseeding programs has never been documented. However, there is much more interest currently in stand losses because of the ever-increasing cost of seed and the increasing amount of overseeding during transitioning of golf course turf. Seed treatments can provide a significant improvement in stand establishment as well as a significant savings in seed cost.

A variety of options are available for the treatment of turfgrass seed. Presowing germination and priming techniques appear to be of limited value to most turfgrass species, particularly those that germinate quickly, such as ryegrass. The greatest benefit of these techniques has been seen with slowly germinating varieties sown in cold soils in situations where rapid weed-free turf cover is essential.

Although presowing treatment methods have been described in publications, it is advisable to leave them to seed producers because light, temperature, oxygen levels, and solution concentrations are critical and must be monitored carefully. Any mistakes can result in the loss of the seed.

Fungicide seed treatments are currently the most effective approach for controlling Pythium damping off in newly sown areas. Several products are currently available as seed treatment formulations. Although microbial products are not presently labelled for seed and seed bed treatments, many of these types of products can be used successfully to improve stand establishment by reducing damage from seed rotting pathogens.

Dr. Eric B. Nelson is a professor of Plant Pathology at Cornell University. He has degrees in botany from Indiana State University and plant pathology from Ohio State University. Dr. Nelson is active in research on the ecology and control of soilborne plant pathogens, concentrating on biological control of plant diseases. He also conducts extension programs in turfgrass pathology.

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New Tools for Overseeding Success

Bill Baker, CGCS
University of California, Riverside

September is the month when golf course superintendents begin putting the final touches on their plans for fall overseeding. By the first week of the month, truck and trailer loads of seed start to arrive. Extra equipment is being rented and crews are put on notice regarding overtime in the coming weeks. In the South, everyone knows that the outcome of overseeding will set the tone of either success or failure for the winter golfing season and possibly beyond.

Changes in the golf business during the past several years have required superintendents to adjust their methods to meet new demands. Television has caused standards to rise so rapidly that what was considered "*in good shape*" ten years ago would hardly pass muster today. Because October, the prime month for overseeding, is also one of the most beautiful and popular for golfers, superintendents are under pressure to complete overseeding earlier every fall.

New levels of expectations for higher quality, consistency, and course availability have forced superintendents to instigate changes in overseeding practices. They began to search for ways to get better fall establishment of ryegrass and rough bluegrass without heavy competition in the fall from the bermuda.

First came Diquat herbicide, a desiccant that dries out the bermuda and temporarily stops its growth without permanent harm. What took weeks of cutting back on irrigation before, now takes one day with the herbicide. It can be sprayed as soon as two to three days prior to seed bed preparation without serious side effects.

Flushing out Diquat residue before seeding is a wise move. However, the herbicide might not last long enough to hold off the bermuda in the event of an autumn warm spell.

A newer approach is to use growth regulators that offer longer lasting suppression of the bermuda. Primo is replacing or augmenting Diquat on many courses as an aide to overseeding. It retards bermuda's foliar growth without drying it out and without retarding root growth.

In fact, the material's mode of action forces carbohydrates into the root system. The plant takes on dwarf characteristics, such as slower growth, finer blades and darker color. The result is finer, lower, greener and less competitive bermuda. Consequently, the overseeded turf has a better chance to germinate and become established. Primo, like Diquat, can be applied very close to renovation time.

The two chemicals make an effective pair when used together. Superintendents apply Primo first, because the bermuda must be growing actively for the growth retardant to work. A day or two later, the bermuda is sprayed with Diquat. It reduces the volume and weight of clippings, and makes it easier to break into the dense bermuda thatch. Less competition from the bermuda increases the survival rate of the overseeded turfgrass during establishment. Next spring when it's time for the bermuda to take over again, and the winter golf season extends further and further into the year, the bermuda rebounds vigorously to reclaim its position as the summer turf of choice..

Bill Baker is a certified golf course superintendent and golf course manager at Sun City West in Arizona. He teaches classes in turfgrass culture at the University of California, Riverside. He is past president of the California Golf Course Superintendents Association and widely recognized as an expert in golf course management in the desert Southwest. The above article was reprinted from the September 1997 issue of Southwest Trees & Turf magazine, phone (702) 454-3057 or e-mail: stonepeak@earthlink.net.

From the Editor

I spent the majority of my academic career as an extension specialist. My primary job was to provide educational opportunities for professional turfgrass managers. I did not conduct any research studies. It could be suggested that research did not play a role in my career. That could be further than the truth.

As an extension specialist, I not only planned and conducted educational programs, but I spent a considerable part of my time working in the field with professionals, like you, helping to solve every day turfgrass problems. I've made hundreds of recommendations. I would like to say that there isn't any turf problem that I haven't seen, but I know better.


Dr. Knoop

I owe any ability that I had as an educator and extension specialist to turfgrass research. The basis for our turfgrass education is founded in research. Turfgrass research, over the years, established the facts that became the basis for our education. If it weren't for turfgrass research, our profession certainly wouldn't be where it is today.

There is no question that we learn through experience. But, experience can be a very slow learning process. The time-proven, best way to improve one's turfgrass management skills is to combine the facts gained through good turfgrass research with experience to solve problems and to establish better management techniques and systems.

The future of our profession is directly wrapped around turfgrass research. If research is in trouble because of reduced funding, then we are all in trouble. We all must support research.

PO Box 1637
Mt. Vernon, TX 75457
(903) 860-2239
Fax: (903) 860-3877
e-mail: knoop@mt-vernon.com

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