A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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DISEASES

Genetic resistance to snow mold fungi in bentgrass

By Michael Casler, Jeff Gregos, Zhichun Wang and John Stier

Winter diseases of turfgrass, collectively referred to as snow molds, are a major problem on golf courses and other turf areas in Wisconsin and similar regions. Golf course greens, fairways and tees are of primary concern because of their high dollar value. Nearly all golf course superintendents spray putting greens with fungicides to inhibit snow mold fungi. Most superintendents also spray tee boxes, while many also spray their fairways.

This control method is highly expensive, it has limited effectiveness and it may adversely affect the environment. In addition, some fungal pathogens have developed resistance to fungicides after years of repeated applications.

Our objective was to determine if existing cultivars of creeping bentgrass (Agrostis palustris L.); colonial bentgrass (Agrostis tenuis Sibth.); creeping red fescue (Festuca rubra L.); and Chewings fescue (Festuca rubra L. commutata Gaud.) differ in snow mold reaction. In addition, our goal was to determine if snow mold resistance is genetically inherited in creeping bentgrass.

Nearly all golf course superintendents spray putting greens with fungicides to inhibit snow mold fungi. This is expensive, has limited effectiveness and may adversely affect the environment.

Creeping bentgrass is a highly desirable species for golf courses, but most cultivars are generally considered to be highly susceptible to various snow mold pathogens.

Snow mold fungi

Snow mold fungi are facultative parasites, capable of surviving and growing on necrotic tissue, becoming particularly serious when susceptible hosts are compromised either through injury or stress. These pathogens are most active at temperatures ranging from 32 to 55°F and are favored by extended snow cover. Disease symptoms begin as small, round patches (2 to 4 in. in diameter) with a water-soaked appearance. As the pathogen grows, the turf foliage dies, leaving brown patches that coalesce into extensive areas of severely damaged turf. In Wisconsin, areas of golf courses that routinely receive severe snow mold damage will have a low population of perennial turf grasses and a high population of annual-type Poa annua that regenerates in late spring from the soil seed banks.

There are four common snow mold fungi in Wisconsin. Pink snow mold is caused by Microdochium nivale and occurs throughout the state. Gray snow mold is caused by Typhula

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incarnata and occurs throughout Wisconsin. Speckled snow mold is caused by Typhula ishikariensis and occurs largely in the northern half of Wisconsin. Another fungus of unknown pathogenicity, Typhula phacorrhiza, occurs largely in the far northern part of Wisconsin.

In the spring of 1998, we initiated a series of experiments to compare several cultivars of creeping bentgrass (Cato, Penncross, Penneagle, Seaside II, and SR 1119); colonial bentgrass (Astoria, Highland, SR7100, Tendez, and Tiger); creeping red fescue (Dawson, Jasper, and Pennlawn); and Chewings fescue (SR5100, Tiffany, and Victory). Plots were seeded at three locations in Wisconsin: O.J. Noer Turfgrass Research and Education Facility near Verona (southern WI), Sentryworld Golf Course near Stevens Point (central WI), and Gateway Golf Course near Land O' Lakes (northern WI). All plots were managed as golf course fairways with a mowing height of 1/2 in. at Verona and Stevens Point and 3/4 in. at Land O' Lakes.

Each experiment was planted in spring 1998 and late summer 1999. The experimental design was a split-split-split-plot with host genus as whole plots, host cultivar as subplots, pathogen as sub-sub-plots, and inoculated (cultured inoculum) vs. non-inoculated (natural inoculum) as sub-sub-sub-plots.

Isolates of each pathogen were collected from each experimental site and used to inoculate plots only at their respective site. Isolates were cultured and multiplied in the laboratory on millet seed. Because T. phacorrhiza was not found at the two southern sites and T. ishikariensis was not found at O.J. Noer, these treatments were not included at these two sites. Plots were inoculated in October of the establishment year and visually rated for snow mold damage the following spring.

Cultivar variation

The fine fescue cultivars were consistently more resistant to all snow mold fungi than the bentgrass cultivars (Table 1). The differences were greatest at the central and northern locations where there was greater average snow mold damage. T. ishikariensis was the most pathogenic to bentgrass at the central and northern locations and to fescue at the northern location. T. incarnata was most pathogenic to fescue at the central location and to both species at the southern location.

There was a considerable amount of natural inoculum at each site, as indicated by the damage to non-inoculated plots. Inoculation with T. ishikariensis or T. incarnata significantly increased damage to bentgrass at all locations. Inoculation with T. ishikariensis at the northern site or T. incarnata at the central site significantly increased damage to fescue. M. nivale and T. phacorrhiza did not cause increased damage to either bentgrass or fine fescues.

Compared to creeping bentgrass, colonial bentgrass was damaged less by all snow mold fungi at all locations (Table 2). This difference was significant ($P<0.05$) in nearly all cases, the only three exceptions being the most pathogenic isolate (T. ishikariensis at the northern site) and the two treatments with the least damage (non-inoculated and M. nivale at the southern site).

In some cases, creeping bentgrass cultivars had more than double the damage to colonial bentgrass cultivars. Increases in damage to creeping and colonial bentgrass cultivars, due

RELEVANT LITERATURE

Hsiang, T., N. Matsumoto, and S.M. Millet. 1999. Biology and management of Typhula snow molds of turfgrass. Plant Dis. 83:788-798.

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Posselt, U.K. and F. Altpeter. 1994. Improvement of snow mould resistance by conventional and in vitro techniques. Euphytica 77:251-255.

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to inoculation, were generally similar, with the exception of T. incarnata at the central and southern sites.

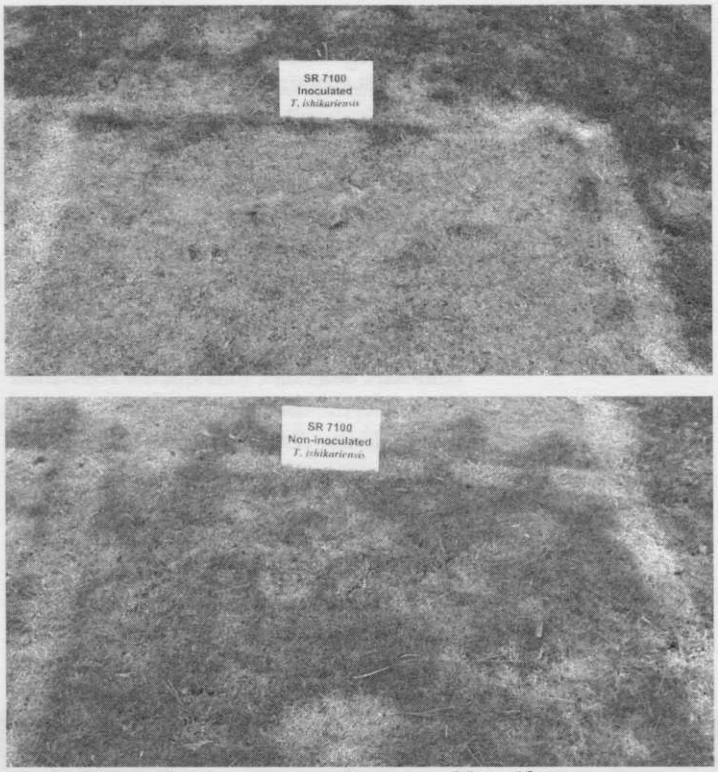
For creeping bentgrass, cultivar x environment interactions were frequent. Creeping bentgrass and fine fescue cultivar rankings were highly inconsistent across locations, years, and fungal species. Colonial bentgrass cultivar rankings were somewhat consistent across these environmental factors. Across all locations, years, and fungal species, SR7100 and Tiger ranked lowest in damage (30 and 34%, respectively) compared to Astoria and Highland (42 and 44%, respectively).

Creeping bentgrass clonal collections

In 1997, we began a creeping bentgrass breeding program with the objective of developing genetic resistance to snow mold. Seeded cultivars of creeping bentgrass consist of heterogeneous seed mixtures. Each seed potentially contains a different combination of genes so that its appearance, or phenotype, will differ from that of its neighbors. On golf courses, this leads to natural selection between neighboring plants for adaptation to various stresses and management factors. One can easily see this phenomenon on golf courses by observing patchiness of a single species on putting greens or fairways.

In our search for genetic resistance to snow mold, we focused on fairways of Wisconsin golf courses with three criteria: north of U.S. Hwy 10; infrequent or no treatment with fungicides to control snow mold fungi; and frequent snow mold damage following a typical winter. We sampled plants that had a large diameter, green color and absence of snow mold patches within two weeks of the final snow melt. We also collected plants from golf course greens in both northern and southern Wisconsin, with selection based on large diameter, bright green color, fine leaf texture and absence of Poa annua within the bentgrass patch.

We screened 326 of these clones for reaction to an isolate of T. ishikariensis during the summer of 1999. The clones were split into six pieces, grown in 1.25 x 1.25 x 2-inch containers, and managed to simulate a fairway with a half-inch mowing height. The clones



SR 7100 creeping bentgrass at Sentryworld Golf Course inoculated with T. ishikariensis (top) not inoculated (bottom).

were arranged in a randomized complete block design with six replicates. Flats were placed in a growth chamber to simulate a fall hardening period, with a gradual temperature reduction to 41°F and a gradual reduction in day length.

Four of the six replicates were inoculated with T. ishikariensis and all plants were kept in the dark for 8 weeks. Plant chlorosis/necrosis was scored weekly using a 0-to-10 scale, where 0 = completely green plant and 10 = completely dead plant. Plants were then placed in a greenhouse where they were scored two more times, using the same rating scale.

We screened a subset of 72 clones twice in a second experiment. The second experiment was similar to the first, but included an isolate of T. incarnata and a second isolate of T. ishikariensis. There were three replicates each of the control and the three fungal isolates and two separate runs of the second experiment.

Five creeping bentgrass clones will be intercrossed to make an experimental synthetic population in summer 2001.

Clonal variation in creeping bentgrass

Plant chlorosis/necrosis scores were highly repeatable and significant differences (P<0.01) were found among clones for the control (non-inoculated) treatment, the inoculated treatment, and the difference. Clonal variation within the control was due to variable tolerance to extended cold/dark conditions. Clonal variation within the inoculated treatment was due to a combination of cold/dark tolerance and disease resistance. Therefore, the difference was used as a measure of disease reaction.

Chlorosis and necrosis symptoms developed gradually during the dark period. Scores for inoculated and non-inoculated treatments were highly correlated during the first three ratings, because disease symptoms were not highly expressed. As disease symptoms became highly expressed during the last three weeks of cold/dark conditions, the correlation between inoculated and non-inoculated approached zero. All data in this paper are taken from means over the last three weeks of cold/dark conditions and the two weeks of recovery in the greenhouse.

Clones selected from fairways had a mean difference between inoculated and non-inoculated of 1.9 compared to clones selected from greens with a mean of 3.0 (P<0.01; Fig. 1). If we define snow mold resistant clones as those with mean differences <1, fairway collections had 22% resistant plants and green collections had 3% resistant plants. As expected, based on snow mold management, there appears to be more natural selection for snow mold resistance in low-maintenance golf course fairways than on putting greens.

There were also large differences among golf courses in the frequency of resistant plants, with a range of 0 to 42% resistant

TABLE 1

BENTGRASS VS. FINE FESCUE: PERCENTAGE OF PLOT SHOWING SNOW MOLD DAMAGE IN SPRING OF THE 2ND YEAR.

Location/	Inoculum [a]				
Host genus	None	Mniv	Tinc	Tish	Tpha
NORTHERN WI					
Bentgrass	47.0	44.0	71.3*	80.0*	52.5
Fine fescue	15.3	16.8	14.0	54.8*	17.1
P-value [b]	<0.01	<0.01	<0.01	<0.01	<0.01
CENTRAL WI					
Bentgrass	39.4	38.6	59.5*	69.7*	—
Fine fescue	34.6	27.3	49.1*	39.2*	—
P-value [b]	0.01	0.03	<0.01	<0.01	
SOUTHERN WI					
Bentgrass	10.8	12.5	18.5*	—	—
Fine fescue	3.6	1.9	5.3	—	—
P-value [b]	<0.01	<0.01	<0.01		

* SIGNIFICANTLY DIFFERENT FROM THE RESPECTIVE NON-INOCULATED VALUE AT P<0.05.

A MNIV = MICRODOCHIUM NIVALE, **TINC** = TYPHULA INCARNATA, **TISH** = TYPHULA ISHIKARIENSIS, AND **TPHA** = TYPHULA PHACORRHIZA.

b = PROBABILITY THAT DECLARING A DIFFERENCE BETWEEN BENTGRASS AND FINE FESCUE MEANS WILL RESULT IN AN INCORRECT STATEMENT.

plants on the northern-WI golf courses. Thus, local conditions and/or the source of the original bentgrass germplasm has a lot to do with the likelihood of finding snow mold resistance.

The proof of the above snow mold challenge would come with repetition, which could only be done on a smaller set of clones. The 72 clones chosen for the second experiment were based on the full range of reactions in the first experiment. The repeatability of these ratings was similarly low to that observed for creeping bentgrass cultivars in the field studies reported above. Correlations between experiments, runs of experiment #2, and between fungal isolates of experiment #2 were all positive, but low, ranging from 0.1 to 0.4.

Despite this low apparent repeatability, each experiment was internally highly repeatable, with significant differences observed among clone means for reaction to all isolates and to the control in each run and averaged over runs of experiment #2.

After sifting through all this data on these 72 clones, were able to find five clones which appeared to have higher-than-average resistance to each snow mold isolate (Table 3). These clones had mean disease reactions consistently lower than the other clones for all four inoculations. They did not differ from the other clones in chlorosis/necrosis as control plants, indicating that they appeared to be unique in having repeatable snow mold resistance but were average for cold/dark tolerance.

Because the comparisons made in Table 3 are data-based (i.e., they were suggested by the results), the P-values are not correct, but they nevertheless suggest the type of consistency that is necessary in order to make successful selections.

TABLE 2

CREEPING VS. COLONIAL BENTGRASS: PERCENTAGE OF PLOT SHOWING SNOW MOLD DAMAGE IN SPRING OF THE 2ND YEAR

Location / Inoculum [a]					
Host genus	**None**	**Mniv**	**Tinc**	**Tish**	**Tpha**
NORTHERN WI					
Creeping bentgrass	54.5	55.5	78.5*	81.8*	63.7
Colonial bentgrass	38.7	31.4	63.8*	77.6*	40.0
P-value [b]	<0.01	<0.01	0.01	0.43	<0.01
CENTRAL WI					
Creeping bentgrass	52.2	48.2	85.7*	83.5*	—
Colonial bentgrass	26.2	29.0	29.9	54.7*	—
P-value [b]	<0.01	0.05	<0.01	<0.01	
SOUTHERN WI					
Creeping bentgrass	11.8	14.3	24.0*	—	—
Colonial bentgrass	9.8	10.7	13.0	—	—
P-value [b]	0.22	0.06	<0.01		

* SIGNIFICANTLY DIFFERENT FROM THE RESPECTIVE NON-INOCULATED VALUE AT P<0.05.

A MNIV = MICRODOCHIUM NIVALE, **TINC** = TYPHULA INCARNATA, **TISH** = TYPHULA ISHIKARIENSIS, AND **TPHA** = TYPHULA PHACORRHIZA.

b = PROBABILITY THAT DECLARING A DIFFERENCE BETWEEN CREEPING AND COLONIAL BENTGRASS MEANS WILL RESULT IN AN INCORRECT STATEMENT.

These five creeping bentgrass clones will be intercrossed to make an experimental synthetic population in summer 2001. This population will be tested on golf course fairways to determine if this selection protocol was successful in increasing resistance to snow mold fungi. Our future plans are to continue selecting for increasing levels of snow mold resistance, in new germplasm and in the experimental synthetic, using field-based screening techniques. We have also made crosses to study the inheritance of resistance and to map resistance genes in collaboration with Dr. Geunhwa Jung of the Department of Plant Pathology.

Michael Casler is Professor of Agronomy and Plant Breeding/Plant Genetics; Jeff Gregos is Director of the Turf Disease Laboratory; Zhichun Wang is a graduate student; and John Stier is Assistant Professor of Horticulture, University of Wisconsin-Madison.

TABLE 3

MEAN CHLOROSIS/NECROSIS SCORES FOR 72 CREEPING BENTGRASS CLONES CHALLENGED WITH THREE ISOLATES OF FUNGAL SNOW MOLD PATHOGENS OR GROWN UNDER COLD/DARK CONDITIONS WITHOUT INOCULATION

Experiment/Inoculum [a]						
Measurement/Group	Expt. 1 Control	Expt. 1 Tish 3	Expt. 2 Control	Expt. 2 Tish 3	Expt. 2 Tish 1	Expt. 2 Tinc 1
COLD/DARK REACTION [b]						
Best five clones	2.93	3.55	3.85	5.63	5.53	5.17
Other 67 clones	3.19	6.00	3.75	4.05	6.23	5.64
P-value [c]	0.36	<0.01	0.46	<0.01	0.01	0.02
RECOVERY REACTION [b]						
Best five clones	1.50	1.30	2.69	6.79	5.21	4.63
Other 67 clones	1.58	3.68	2.75	8.03	6.31	5.60
P-value [c]	0.71	<0.01	0.84	<0.01	0.01	0.01

A TISH = TYPHULA ISHIKARIENSIS AND TINC = TYPHULA INCARNATA.
B COLD/DARK = MEAN OF RATINGS TAKEN AT 6, 7, AND 8 WEEKS AFTER INOCULATION. ALL PLANTS WERE MAINTAINED IN THE DARK AT 41°F. RECOVERY = MEAN OF RATINGS TAKEN AT 1 AND 2 WEEKS AFTER REMOVAL FROM COLD/DARK CONDITIONS TO A GREENHOUSE WITH A 16-HR DAYLENGTH AND 65-72°F.
C PROBABILITY THAT DECLARING A DIFFERENCE BETWEEN CREEPING AND COLONIAL BENTGRASS MEANS WILL RESULT IN AN INCORRECT STATEMENT.

Spoon-feeding with granular materials?

By M.J. Howieson and N.E. Christians

The increase in the popularity of sand-based greens provides a unique and interesting problem for a growing number of turf managers. While sand-based greens provide superior drainage and aeration compared to native, or push-up greens, their nutritional status is often less than satisfactory.

The low cation exchange capacity (CEC) inherent in sand-based systems, coupled with high water permeability rates, makes it difficult to provide adequate nutrition to turf and at the same time minimize fertilizer leaching and runoff.

Soil CEC is a measure of a soil's ability to retain basic cations, such as ammonium ($NH4+$), calcium ($Ca+2$), magnesium ($Mg+2$) and potassium ($K+$), which are essential for normal plant growth and development. The CEC of sand-based greens rarely exceeds 3-meq/100 g of soil, while the CEC of a fertile clay loam soil will generally be in the range of 25-30 meq/100 g of soil. As cations are removed from the soil solution, either by plant uptake or by leaching, they are replaced by elements from CEC sites.

Soils with low CEC are often deficient in several essential elements, as fewer sites are available to hold cations. As a result, sand-based greens have limited nutritional reserves, which could be detrimental to plant growth and development if special considerations are not made in fertilization.

By design, greens with high-sand root zones are very permeable. Sand-based greens are normally constructed using 80 to 85% sand, which reduces compaction and facilitates rapid drainage and water movement through the root zone. These properties are generally desirable as they limit the influence of excessive rainfall on sports play. However, a very permeable root zone may also increase the rate of leaching.

Spoon-feeding programs

Spoon-feeding fertilization is the frequent application of liquid fertilizers at low rates. It has become the standard means to fertilize sand-based greens and overcome their nutrient holding capacity shortcomings. In a typical program, nitrogen (N) is applied in the range of 0.10-0.25 lb. per 1000 sq. ft. every one or two weeks. Spoon-feeding affords versatility in a fertility program, as it allows turfgrass managers to rectify nutrient deficiencies quickly, while providing just enough nutrition to promote healthy growth. Judicious applications will also limit nutrient leaching from the root zone.

Historically, spoon-feeding programs have necessitated the use of liquid fertilizers to produce uniform turf response. Dry materials applied at low application rates of N generally produce a spotted appearance on the green surface because they cannot be applied uniformly. New production methods and formulations have resulted in granular materials that can potentially be used for spoon-feeding.

To be considered for use in spoon-feeding, a granular material must have a relatively low N analysis and a large enough volume to be applied uniformly to the surface. The particle size should also be relatively small for uniform application and to decrease the possibility of removal by mowers.

Liquid vs. granular materials

Public perception, personal preference and the cost of the product fuel the debate between liquid and granular fertilizers. Liquids are thought to provide more flexibility. With liquids, turf managers can easily change the N-P-K analyses and include micronutrients and different pesticides in the same application. With granulars, mul-

In a typical spoon-feeding program, nitrogen (N) is applied in the range of 0.10 to 0.25 lb. per 1000 sq. ft. every one or two weeks.

tiple products and applications would be needed to achieve the same flexibility.

New granular production techniques allow for custom formulation for each application. Custom blended granular fertilizers can be manufactured with micronutrients and pesticides.

The public generally assumes that granular materials are safer for them and the environment. Phrases such as "spray drift" and images of applicators wearing respirators and protective suits reinforce this belief. The public may react more favorably to granulars because they can relate to it as something they may do on their own lawns.

Traditionally limited to liquid fertilizers, spoon-feeding may also be possible with dry materials if the right fertilizer formulation is used.

Cost and storage space may also affect a decision between granular and liquid materials. The initial cost of granular materials is often higher than liquids. But application equipment is more expensive when using liquid materials due to the initial investment in sprayers. Storage space can also be an issue, as granular materials take up a larger volume than liquids for a comparable amount of product, increasing the room required for storage.

The principal objective of recent research performed at the Iowa State Horticultural Research Station was to determine the effect of granular fertilizers on turf color and uniformity when applied in a spoon-feeding regimen as compared to a liquid fertilizer comprised of urea and potassium sulfate.

Materials and methods

The trial was arranged on a 'Penncross' creeping bentgrass (Agrostis palustris Huds) green built to USGA specifications. The green was mowed daily at 0.150-in. and irrigated as necessary to prevent desiccation. A randomized complete block design with three replications was used.

Each individual block consisted of nine fertilizer treatments and an untreated control. The nine fertilizers used in the study included eight granular, controlled-release urea fertilizers and a liquid fertilizer composed of urea and potassium sulfate (Table 1).

All of the fertilizers were applied at a rate of 0.25 lbs. of N/1000 sq. ft. at 10-day intervals. Granular fertilizers were applied to 5X5 ft plots by hand, and in two different directions, to ensure uniform coverage.

The liquid fertilizer applications were made using a CO2-powered backpack sprayer calibrated to deliver 3.0 gallons of material/1000 sq.ft. The first fertilizer treatment applications were made on May 22, 2000 with subsequent applications made at 10-day intervals.

Weekly, visual turf evaluations of color and uniformity were made on a scale from 1 to 9, with 9=best, 6=lowest acceptable and 1=worst. In addition, tissue samples were taken from each treatment plot every thirty days and analyzed for total nitrogen content. The Iowa State University Horticulture Nutrition Laboratory used the Kjeldahl method to determine the total nitrogen content.

Results

Weekly color ratings indicate that all three of the Novex materials and the Sustane/Novex 12-2-12 fertilizer produced high color ratings, with the liquid fertilizer consistently producing the best color ratings (Table 2).

The UHS 14-14-14 fertilizer and the untreated control resulted in the lowest color ratings and the Sustane/Nutralene 10-2-10, Lesco PPSCU 29-0-0 and Scotts Contec 19-3-19 produced intermediate ratings. The liquid fertilizer also consistently produced the highest uniformity ratings (Table 2). At the other end of the spectrum was the UHS 14-14-14 treatment. The UHS 14-14-14 treated plots at times exhibited several small green spots of over-stimulated turf and poor nitrogen distribution characteristics. Only the untreated control received lower uniformity ratings than the

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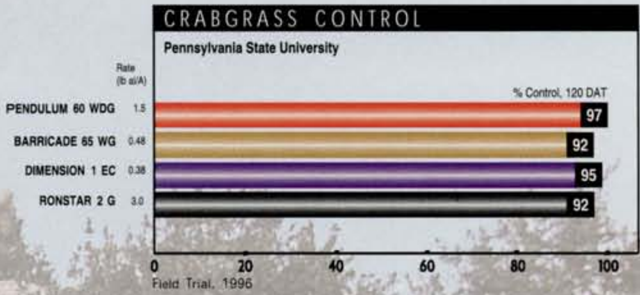

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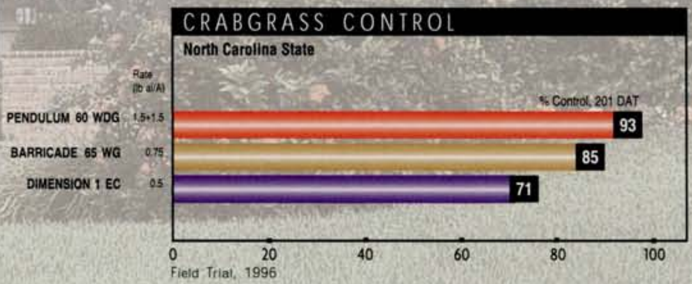

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TABLE 1

FERTILIZERS EXAMINED IN THE STUDY

Fertilizer	Analysis	Designation	Manufacturer
Liquid[1]	NA	Soluble	NA
PPSCU	29-0-0	Sulfur-coated urea	Lesco
Novex	18-2-18	Aminoureaformaldehyde	Lesco
Novex	19-2-19	Aminoureaformaldehyde	Lesco
Novex	32-0-0	Aminoureaformaldehyde	Lesco
Contec	19-3-19	Methylene urea	Scotts [2]
Sustane/Nutralene	10-2-10	Organic-methylene urea	Sustane
Sustane/Novex	12-2-12	Organic-aminoureaformaldehyde	Sustane
Signature	14-14-14	Methylene urea	UHS
Untreated Control	NA	NA	NA

1 COMPRISED OF UREA (46-0-0) AND POTASSIUM SULFATE (0-0-50)
2 NOW HANDLED BY THE ANDERSONS FERTILIZER COMPANY
NA INFORMATION IS NOT APPLICABLE

TABLE 2

AVERAGE VISUAL QUALITY AND TOTAL NITROGEN CONTENT OF 'PENNCROSS' CREEPING BENTGRASS OVER THE 14 WEEKS OF THE STUDY

Treatment	Color	Uniformity	Total Nitrogen
Liquid3	8.8	8.5	2.9
Lesco PPSCU 29-0-0	8.0	7.7	2.8
Novex 18-2-18	8.5	7.9	2.9
Novex 19-2-19	8.6	7.9	2.9
Novex 32-0-0	8.4	8.0	2.8
Scotts Contec 19-3-19	7.9	7.9	2.9
Sustane/Nutralene 10-2-10	8.0	7.8	2.8
Sustane/Novex 12-2-12	8.6	8.0	3.0
UHS 14-14-14	6.9	6.6	3.0
Untreated Control	5.6	5.8	2.3
$LSD_{0.05}$	0.3	0.6	0.4

UN NAMED

1 VISUAL RATINGS WERE ASSIGNED USING A 1 TO 9 SCALE, WITH 9=BEST, 5=LOWEST ACCEPTABLE AND 1=WORST.
2 REPORTED AS PERCENTAGE OF NITROGEN PER GRAM OF DRY WEIGHT TISSUE
3 COMPRISED OF UREA (46-0-0) AND POTASSIUM SULFATE (0-0-50)
NS - MEANS BETWEEN TREATMENTS ARE NOT STATISTICALLY SIGNIFICANT PER FISCHER'S LSD TEST.

UHS 14-14-14 fertilizer. The remaining seven fertilizer materials achieved uniformity ratings that were intermediate between the liquid and UHS 14-14-14 fertilizer treatments.

Plant analysis of the total N content of grass tissue indicates no significant differences between any of the fertilizer treatments (Table 2). This suggests that all of the fertilizers were equally effective supplying the grass with N. As expected, the grass in the untreated control had the lowest total N content.

The liquid fertilizer treatment resulted in the highest color and uniformity ratings of all the treatments. The three Novex and Sustane/Novex 12-2-12 materials also produced high color and uniformity visual ratings. They were similar in color to the liquid treatment, with only a slight reduction in uniformity. Based on these results, we believe that these fertilizer materials can be used in a spoon-feeding program.

The Scotts Contec 19-3-19, Sustane/Nutralene 10-2-10 and Lesco PPSCU 29-0-0 produced plots of intermediate overall quality and may also be considered for use as spoon-feeding materials.

The only fertilizer tested that we would be hesitant to include into a spoon-feeding regime would be the UHS 14-14-14. The authors acknowledge that this product was not designed for spoon-feeding. This fertilizer would simply not be capable of providing acceptable color and uniformity if utilized in this manner.

The UHS 14-14-14 fertilizer particle is large and was designed primarily for use in higher mown turf and at higher application rates. Under these conditions this material performs well, producing turf of more desirable color and uniformity, but when applied at low application rates it was unable to produce an even turfgrass nitrogen response.

Conclusion

Spoon-feeding represents a precise form of nutrient management as it allows for great versatility and flexibility in a fertilizer program. Turf managers can correct nutrient deficiencies quickly, while negating the possibility of nutrient leaching and runoff from the site of fertilizer application. Traditionally limited to liquid fertilizers, spoon-feeding may also be possible with dry materials if the right fertilizer formulation is used.

With the advent of new technological improvements, however, granular fertilizers have been created that can potentially be used in a spoon-feeding program. The Novex and Sustane/Novex fertilizers utilized in this study produced excellent turf color and uniformity when applied at light, frequent applications. This implicates that these materials could be incorporated into a spoon-feeding fertilizer program and offers another management option for turfgrass professionals.

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The Food Quality Protection Act: How it affects turfgrass pest management

By Dr. David Gardner

Increasing amounts of literature demonstrate the ability of turfgrass to retain and degrade pesticides more rapidly than what is observed in production agriculture. While this is important to the industry in the context of defending responsible pesticide usage, it does not automatically ensure that pesticides will continue to be registered for use in turfgrass.

The primary determinant of what pesticide choices will be available in coming years is the Food Quality Protection Act.

The Food Quality Protection Act (FQPA), passed in 1996, was supported by the federal government, as well as many environmental, industrial, agricultural and public health groups. As the guidelines of the act are mandated, they are producing sweeping, and sometimes dramatic, changes in the choice of pesticides available and concomitantly, in pest management strategies.

The FQPA mandates that all pesticide tolerances in the U.S. (currently around 9,700) be reviewed by the year 2006. The following is a brief summary of FQPA, and the reader is referred to state extension literature, such as that produced by Penn State Cooperative Extension, for a more thorough treatment of the subject.

FQPA under the microscope

There are many technical aspects of the Food Quality Protection Act.

Briefly, a pesticide tolerance is a limit set by the EPA on the amount of residue that can remain on a treated food. The act considers the application frequency and amount of the pesticide, the pesticides toxicity, and how much remains in and on the edible crop. A wide margin of safety is then required to ensure that the residue levels are many times lower than what could cause adverse effects.

What separates FQPA from previous regulation is that this new "reasonable certainty of no harm" standard also considers sources of exposure other than food crop residue such as home and garden usage, pet care, and residues in drinking water. A tenfold safety factor to account for increased sensitivity of children to pesticide residues is also mandated in addition to the 100x safety factor that was already in place.

FQPA mandates that all pesticide tolerances in the U.S. (currently around 9,700) be reviewed by the year 2006.

Another feature of the FQPA is that pesticides with similar modes of action are grouped together when assessing risk. In other words, when human exposure to a pesticide is considered, exposure to all other pesticides with similar mechanisms is also considered.

All pesticides like cyproconazole have a primary registrant, which is usually the company that developed the chemical. That company is responsible for maintaining the pesticide's registration with the EPA. If it determined that the risk of exposure to a pesticide must be reduced, the primary registrant has several options. It can either voluntarily remove the pesticide from the market, or it can eliminate some of the pesticides uses.

For example, chlorpyrifos was registered for use in food production, nursery production, lawn and landscape use, and also for many household uses including termite control. Under the guidelines established by the Food Quality Protection Act, it was determined that human exposure to this pesticide was too high, and its primary registrant, Dow

AgroSciences LLC choose to cancel most of its uses. Under the agreement with the EPA, most in-and-around-the-home uses of chlorpyrifos were cancelled, including use as a full-barrier termiticide. The product will however, remain available for use on golf courses, ornamental nurseries, and all crops except tomatoes.

In the case of cyproconazole, it was determined that human exposure was too high. The primary registrant, in turn, chose to voluntarily cancel some of its uses, including its use in turfgrass management, in order to reduce human exposure to this pesticide.

While the act encourages minor use pesticide registration, which is defined as registration on crops planted on less than 300,000 acres nationally, it does not set any guidelines as to what crops or uses the product can or must remain registered for if exposure is deemed too high under the new standards. Changes in product registration are done between the EPA and the primary registrant on a case-by-case basis.

Unfortunately, and ironically given all of the debate over turfgrass pesticide usage, the turfgrass management market is not as lucrative (e.g. high volume) as many other agricultural commodities. Therefore, even if the product is not cancelled outright, the primary registrant may eliminate usage in turfgrass in order to reduce human exposure, while still maintaining registration in the more lucrative crop market.

In the case of cyproconazole, the product was sold to Bayer as a part of the Novartis-AstraZeneca merger and is now marketed by that company for, among other thing, the control of coffee rust in coffee producing nations..

The goal of the Food Quality Protection Act is sound, and one with which no one should argue. Unfortunately, there are some aspects of the language of the Act that have and will continue to result in reductions in the number of pesticides available for use in turfgrass management. New products with different chemistries are being introduced. But sound management practices, including judicious and proper usage of pesticides, will continue to be important aspects of a successful turfgrass maintenance program.

Dave Gardner is an assistant professor of turfgrass management at The Ohio State University. He received a B.S. degree in horticulture from Iowa State University in 1993. After graduation, he was employed as a pesticide applicator at Moore Landscapes in Glenview, Illinois. Dave resumed his education in 1995 and received a M.S. degree from Iowa State in 1996 and a Ph.D. degree in 2000 from the University of Illinois.

Should you let a computer do your disease scouting?

By Frank H. Andorka Jr.

The e-mail chilled Douglass Larson to the bone. His Skybit weather service warned him that conditions in July were ripe for a gray leaf spot (GLS) outbreak — the same disease that wiped out fairways and tees in the mid-Atlantic as recently as 1998.

Based on the information, Larson, superintendent at Manufacturers Golf & CC in Fort Washington, PA mobilized his crew members to scour the course for signs of the disease. They found the telltale spots and immediately sprayed a fungicide to prevent spreading. Larson reports that the blitzkrieg succeeded and the course lost little turf.

"We've never seen the disease earlier than September, so the warning took me by surprise," Larson says. "But it's a good thing we received it. If we hadn't, we could have been in serious trouble."

Overcoming skepticism

Despite others' skepticism, Larson and other East Coast superintendents are singing the praises of Skybitís computerized weather service. Boalsburg, PA-based Skybit (www.skybit.com) started 10 years ago as an information technology company that delivered customized weather and disease forecasts to the agricultural and energy industries. In 1994, the company moved into the turfgrass industry.

Skybit gathers weather information from the National Weather Service (NWS) and other remote sites, such as Penn State University's weather station, to provide detailed weather reports for courses, based on their latitude and longitude.

After observing natural disease behavior in the field, researchers develop models based on the factors that they can reproduce in a laboratory, such as evapotranspiration rates, temperature and precipitation. Scientists then create formulas that mirror the way diseases behave.

To make its predictions, Skybit developed its own models and feeds raw data into a computer, which then produces alerts.

In 1994, the company was looking for courses willing to test its system, and Dennis Watkins, superintendent at Lords Valley CC in Newfoundland, PA agreed to try it. Prior to subscribing to Skybit, Watkins gathered his weather information from the evening news, which was notoriously inaccurate.

A salesman convinced him to try the service, touting its disease modeling as another weapon in the battle to keep Watkins' course in tip-top shape. Watkins was skeptical, but still signed up.

"I was at a loss to explain the accuracy of its reports," Watkins says. "I spent a year trying to pick the process apart —then I gave up."

The system costs $75 per month without disease modeling and $150 per month with it. Watkins says most subscribers use the disease modeling service during the height of the golf season, but remove it during the off-season. For each individual course, Skybit currently tracks five diseases: anthracnose, brown patch, pythium blight, summer patch and GLS. It delivers superintendents the information by fax or e-mail.

"[Skybit] can compare conditions from the last outbreak of a disease at your course with what conditions are today," Watkins says. "It's the historical database that makes the difference."

Watkins worked with Skybit to develop the GLS model, which has been winning the service accolades this year. Watkins says Skybit can break the country down into one-kilometer squares, which are analyzed for weather patterns. Skybit also created a 30-year weather database that allows it to compare weather conditions today with those in the past. That's what makes its disease predictions relevant.

"It can compare conditions from the last outbreak of a disease at your course with what conditions are today," Watkins says. "It's the historical database that makes the difference."

Pythium problem-solver

H. Jim Loke, superintendent at Bent Creek GC in Lititz, PA says the service also helped him deal with an outbreak of pythium blight a few years ago. A heavy rain had flooded his course, and the level of silt that covered his golf course, along with the water, created the perfect conditions for pythium.

"[Skybit] was right on with that prediction," Loke says. "I wouldn't rely on it as the only source of information, but I've found that its temperatures are accurate within a couple of degrees — and that's almost impossible to do where my course is."

While the system may have nailed a GLS outbreak this year, some plant pathologists remain skeptical, and caution superintendents against putting all their faith in Skybit forecasts to fight disease.

One more tool in the kit

"Skybit is a good complementary product to other pest management strategies, but it doesn't replace looking for the disease yourself," says Paul Vincelli, professor of plant pathology at the University of Kentucky in Lexington. "We donít have any data to prove that it will work over an extended period of time."

"It's great that superintendents are getting a heads-up, but there's a lot we don't know about some of these diseases," says Gail Schumann, plant pathologist at the University of Massachusetts in Amherst. "We're going to take a wait-and-see attitude toward the service, but the fact that someone is trying to do it is encouraging."

Schumann says she was getting calls from superintendents throughout New England saying they were warned about GLS by Skybit, but examination of turf samples from the courses showed no evidence of the disease.

"I've heard that for other parts of the country that Skybit's prediction was deadly accurate," Schumann says. "But it never got as far north as [Skybit predicted] it was going to get."

What gives some academic observers pause is the proprietary nature of Skybitís predictive models. Schumann and Vincelli want to see the models undergo scientific scrutiny. Schumann says that no matter how accurate Skybit's models, they will never replace good scouting by maintenance crews.

"Don't think of this as a black box that will give you all the information you need," Schumann says. "You're still going to have to test its predictions yourself and make sure they're accurate.

"You can count weeds, you can count grubs, but there's no way to do that with diseases," she adds. "Predictive models are the closest you can get, and itís exciting that there are people working to take some of the guesswork out of disease prevention."

Watkins understands the skepticism — he was once a skeptic himself. But Watkins says the company will let anyone test its formulas, and Vincelli says he is working with Skybit to develop a study at the University of Kentucky, although details are still being worked out.

"I'm treating [Skybitís] models the same way I would if one of my colleagues had put forth a theory," Vincelli says. "I just want to test them under controlled, laboratory conditions."

The service currently has 100 subscribers mainly in the East, but Watkins says it plans to expand the service around the country. Skybit is working on models for bermudagrass and other Southern grasses and expects to sign deals with cooperating university sites within the next few years.

"Right now, we're perfectly situated for the East, but we're not satisfied with that," Watkins says. "We'd really like to make it a nationwide service."

Frank Andorka Jr. is managing editor of Golfdom magazine in Cleveland, OH.

Understanding fertilizer formulas

Q: *How do they get 23 lbs. N, 7 lbs. P and 7 lbs. K in these liquid fertilizers when the bucket itself only weighs 18 lbs. total? Is there some kind of equivalency working here? Or are the lbs. of NPK per 1000 sq. ft.?*

A: The numbers 23-7-7 refer to the percent by weight of N, P, and K in that particular formulation. If there are 18 lbs. of that fertilizer in the bucket, then the bucket actually contains 4.14 lb. of N, 1.26 lb. of P, and 1.26 lb. of K.

How far the contents of that bucket go depends on the application rate desired. If the desired application rate applies 1 lb. of N per 1000 sq.ft., then the bucket has enough total fertilizer to cover 4,140 sq.ft. But if the desired application rate is 1/8 lb. of N per msf, the bucket will cover 33,120 sq.ft.

To determine how many buckets of fertilizer are needed, determine how much actual N is in the bucket/container by multiplying the first number in the fertilizer formula (in this case 23) times .01 to convert to a decimal and then by the weight of the container in lbs. (or 18 lbs. in this bucket). The formula looks like this: 23 X .01 X 18 = 4.14 lb. of N. If the area to be treated is 20.8 msf and the application rate is 1 lb. of N per 1000 sq.ft., then the total number of buckets needed to treat 20.8 msf is five buckets.

You can do the same calculation for any element in a fertilizer formula, but you are limited in the amount of the lesser concentrated nutrients that you can apply, since in this example N is three times as concentrated as both P and K. If you want to apply one lb. of P per msf, you would be forced to apply almost 3.3 lbs of N to make sure that the total P equaled 1 lb. per msf. Under most circumstances 3.3 lb. of N is too high and will either cause excessive vertical growth or burn the turf because of the excess N.

To apply high P or K this 23-7-7 formula is not a good choice. This has been recognised by manufacturers and there are a number of high P and K fertilizers available. For applying a high P application so called starter fertilizers typically have P as the highest concentrated nutrient usually in 15-25-10 NPK ratios. And high K fertilizers are typically formulated as 15-0-30 or 15-0-15 formulations. Both of these formulas allow for high P or K fertilization without providing an excess amount of N.

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