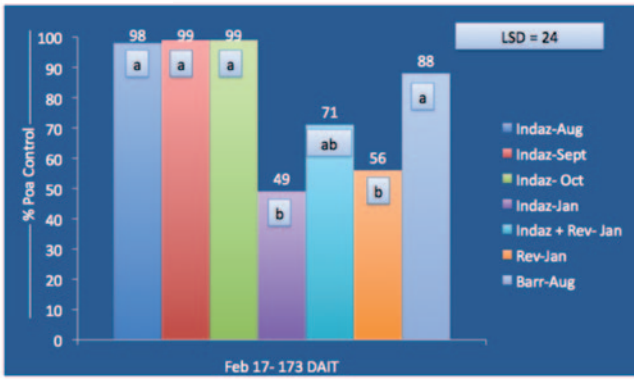
Figure 1



tillers when applied in January. Larger plants could simply be harder to control. Similarly, ethofumesate is known to decrease in control as plants become larger due to a decrease in herbicide absorption. A similar phenomenon could be occurring with indaziflam.

By April 10 rating, Revolver containing treatments control of *Poa annua* was >90% and equivalent to indaziflam alone treatments. Revolver is known for its "slowness" when applied during colder temperatures, especially in removing overseeded perennial ryegrass; however, Revolver is much more active on *Poa annua* than perennial ryegrass. As demonstrated in this study, Revolver control of *Poa annua* is just a matter of time.

Conclusion: Initial results with indaziflam are promising. There are currently no herbicides on the market that control *Poa annua* both pre and postemergence. Such a product would be well received and highly beneficial to the turfgrass industry.

Literature Cited

Myers, D.F., et al. 2009. Indaziflam/BCS-AA10717- A new herbicide for pre-emergent control of grasses and broadleaf weeds for turf and ornamentals. Proc., Weed Sci. Soc. Am. No. 386.

PURDUE UNIVERSITY

The Turf Science research program continues to reap the benefits of the extremely generous support of the Mid-West Regional Turf Foundation and many industry partners.

Pest management studies: Weed management studies have continued to evaluate the use of various novel herbicides like Tenacity for creeping bentgrass removal in Kentucky bluegrass athletic fields. This herbicide is being increasingly adopted by several regional cool-season athletic field managers and is being applied using an autumn application regimen. In addition, several continuing projects have identified various herbicide and management techniques to minimize roughstalk bluegrass encroachment in golf turf.

Insect studies have been evaluating the use of novel endophytes and entomopathogenic nematodes, as well as the role of fertilizer nutrient ratios on turfgrass health and the ability for turfgrasses to resist surface and sub-surface dwelling insects without the use of synthetic pesticides. Additionally, our entomology team has been closely monitoring a newly documented pest problem throughout the Ohio River valley, the occurrence of significant billbug damage in zoysiagrass.

Disease management: Our disease management team has been continuing to investigate various alternatives to traditional fungicides, including biorational products and the potential for disease forecasting models to better time fungicide applications. Furthermore, a multi-year study has been investigating the role of spray carrier volume on fungicide efficacy.

Species and cultivar evaluations: Bermudagrass cultivars—Being located at the northern edge of the upper transition zone, we continue to be an excellent location for the evaluation of bermudagrass cultivars for cold hardiness. In the third week of January, 2009, the air temperatures in West Lafayette plummeted to -22F without snow cover. These environmental conditions negatively affected the winter survival of several standard cultivars like Tifway and TifSport. By contrast, several cultivars with superior performance like the old "stand-bys" Midlawn, VaMont and Quickstand, and the more recent generation, Patriot, Riviera, Yukon, and GN-1, continue to perform well in successive years. In addition, there are some promising new experimental cultivars under development which show promise for the future. These have been developed by the Oklahoma State breeding program and include: OKC-7018, OKC-1119, OKC-1134 and OKS-2004.

Ryegrass—For the cool-season species several studies have focused on the perennial ryegrass. Field and laboratory studies have been conducted to determine the ploidy level of the collection of USDA ryegrass accessions and are evaluating the drought tolerance of these at three contrasting locations throughout Indiana. Using molecular techniques it was determined that in general the plants in the USDA collection as well as many of our commercially available cultivars are very much genetically similar. This information may be of use to our plant breeders as they expand their selection for plant material with improved traits for superior turf performance.

Bermudagrass overseeding: A field study was conducted over two years to determine optimum perennial ryegrass seeding rates for overseeding Patriot bermudagrass football fields and determine if multiple seeding events were superior to a single event for PRG establishment and persistence. This study was arranged in a 3 x 5 factorial with five seeding rates (12.5, 25, 50, 75, and 100 lbs/A/yr) and three application strategies (applying 100% of the seed in one application (100), 70% of total seed in the initial application plus 10% of total seed in each of three successive applications ten days apart (70/10/10/10), or four equal applications of 25% of the total seed applied ten days apart (25/25/25/25). Seed was initially planted the third week of August. The results of this study showed that ryegrass coverage rarely increased at seeding rates > 50 lbs/A/yr regardless of seeding strategy. The 25/25/25/25 seeding strategy consistently resulted in the most coverage, 55-77%, when rated in mid-Nov., regardless of seeding rate, followed by the 70/10/10/10 and 100 strategies with 46-62% and 20-52%, respectively. The relatively low ryegrass coverage values could be due to seedling competition with actively growing Patriot bermudagrass. These data indicate that when overseeding Patriot bermudagrass in the upper transition zone multiple seeding events appear to be superior to a single event and there is little benefit for exceeding seeding rates > 50 lbs/A/yr.

Cale Bigelow, Tim Gibb, Yiwei Jiang, Rick Latin, Zac Reicher and Doug Richmond: Departments of Agronomy, Botany and Plant Pathology and Entomology, respectively.

UNIVERSITY OF MASSACHUSETTS

Traffic, wear & compaction studies by J. Scott Ebdon, PhD:
Effects of Nitrogen and Potassium on Wear Stress Mechanisms in Perennial Ryegrass. Fertility trials were established to investigate the effects of five N rates in combination with three K rates on wear tolerance and associated mechanisms. Wear was applied using wear simulators fitted with metal soccer cleats. Optimum fertility for maximum wear tolerance and recovery was found to be 3 to 5 lbs N/1000ft2/yr. N rates exceeding 5 lbs caused excessive shoot growth rates, higher shoot water content and loss in cell wall components. Shoot density played a secondary role to shoot water content and leaf growth rates in accounting

for wear tolerance in perennial ryegrass. N rates in excess of 5 lbs N/1000ft2/yr promoted rapid recovery but greater wear injury while N rates less than 3 lbs were too slow to recover. Potassium rates in excess of 5 lbs caused a significant loss in wear tolerance and leaf cell wall content. Sponsor: Massachusetts Turf and Lawngrass Association.

Wear Tolerance and Associated Morphological Characteristics in Kentucky Bluegrass.

One hundred and ten cultivars of Kentucky bluegrass are being compared for wear tolerance and various morphological characteristics in field trials. Visual ratings for wear injury, growth habit (horizontal versus upright), shoot density, leaf texture (width) and disease were evaluated in the spring of 2009. Wear tolerance in the field increased with higher shoot density, greater resistance to leaf spot and a more upright leaf and shoot orientation. Leaf texture (fine or coarse leaf appearance) was not important in Kentucky bluegrass wear tolerance. Greater leaf spot resistance was associated with better spring wear tolerance by providing less thinning from disease and greater shoot density. Sponsor: National Turfgrass Evaluation Program.

Differentiating Between the Influence of Wear and Soil Compaction and Their Interaction on Turfgrass (with William Dest, PhD, University of Connecticut). This recently completed study differentiated between the effects of wear and compaction on turfgrass performance and soil physical and surface properties. Kentucky bluegrass and perennial ryegrass were planted in mixture on both sand and silt loam soils. Both soils were compacted to a uniform hardness before planting. Treatments

included a compaction and non-compaction treatment with a wear and non-wear treatment. Wear was applied with a steel brush set into a frame so no compaction was imposed. Compaction significantly inhibited establishment compared to non-compaction. Compaction treatments increased perennial ryegrass content in the stand over non-compaction. The sand promoted greater Kentucky bluegrass and thatch tendency. Rooting in response to compaction increased in the 0 to 3 inch zone and decreased in the 3-6 inch soil depth when compared to non-compaction. Wear accounted for 90% of the total variation in traffic injury with soil compaction effects accounting for the balance. Soil and wear effects were the principal factors affecting turfgrass quality. Wear treatment did not affect soil physical properties while compaction altered aeration porosity, percent of maximum dry density, and internal drainage (saturated hydraulic conductivity).

Wear Stress Mechanisms in Cultivars of Creeping and Velvet Bentgrass. Seven cultivars of velvet bentgrass were compared with seven cultivars of creeping bentgrass in wear tolerance and anatomical, morphological and physiological characteristics. Bentgrass species and cultivars were maintained at greens height of cut and wear injury was imposed using walk behind mowers fitted with grooming brush. Cultivars of velvet bentgrass were found to exhibit significantly better wear tolerance than creeping bentgrass. The greater wear tolerance with velvet bentgrass entries was due to their greater leaf cell wall content, upright tiller and leaf orientation, and greater shoot density. Sponsors: New England Regional Turfgrass Foundation and National Turfgrass Evaluation Program.

Wear Trials in Bentgrass Maintained as Fairway and Putting Green Turf. Nineteen cultivars of creeping and velvet bentgrass maintained as putting green turf are being compared for overall performance under wear stress. This 5-year evaluation was established in the fall of 2008. In 2009 Villa velvet bentgrass and Alpha creeping bentgrass exhibited the best wear tolerance. In fairway trials, creeping bentgrass entries exhibited significantly better wear tolerance than colonial bentgrass. Authority, Benchmark DSR, Declaration, L-93, T-1 and 007 creeping bentgrass provided the best wear tolerance under fairway height of cut. Sponsor: National Turfgrass Evaluation Program.

Increasing Water Use Efficiency by J. Scott Ebdon, PhD:

Efficient Irrigation for Recreational Turf in New England: Evapotranspiration and Crop Coefficients. This new study planted in the fall of 2009 will measure evapotranspiration (ET) losses from pure stands of Kentucky bluegrass (Touchdown), perennial ryegrass (Exacta) and creeping bentgrass (Memorial). Different mowing heights and N fertility will be compared. Monthly crop coefficients along with reference ET val-

ues from weather stations will be determined for low- and high-maintenance turf. These values can be used to assist turf managers in applying irrigation water more efficiently to sports and golf turf in the cool-humid New England region. Sponsor: New England Regional Turfgrass Foundation.

Increasing Water Use Efficiency by Michelle DaCosta, PhD:

Evaluation of Wetting Agents on Drought Resistance and Irrigation Requirements of Bentgrass Species. The objective of this field study slated to begin in the summer of 2010 is to quantify the influence of wetting agents on improving turf performance of three bentgrass species that vary in drought sensitivity and irrigation requirements under golf course fairway conditions.

Environmental Protection and Applicator Safety by J. Marshall Clark, PhD:

Optimization of Vegetative Filter Strips for Mitigation of Runoff from Golf Course Turf. The loss of pesticides and nutrients into surrounding bodies of water and the resulting decreases in water quality have led to the use of best management practices such as the use of vegetative filter strips (VFS) to intercept runoff water and thus prevent its loss and the loss of any associated pesticides and nutrients to surrounding water bodies. This three year project, begun in 2008, will evaluate selected plants for their effectiveness in removing pesticides and nutrients from turfgrass runoff waters. Preliminary data indicates that the vegetative filter strips have the potential to intercept pesticides.

Utilizing Reduced Risk Pesticides and IPM Strategies to Mitigate Golfer Exposure and Hazard

This 3-year project, initiated in 2007, seeks to determine actual levels of exposure to "reduced risk" pesticides following application to turfgrass. The fate of pesticides after application largely determines how much of it is available for potential human exposure.

Pesticide residues in the air and on turfgrass (dislodgeable foliar residues, DFR) using either chlorpyrifos, carbaryl, cyfluthrin, chlorothalonil, 2, 4-D, MCPP-p, dicamba, imidacloprid, carfentrazone or azoxystrobin have been analyzed. In 2009 two applications of the "reduced risk" insecticide halofenozide were made. Analyses of these samples are in progress.

This study is also evaluating best management practices for reducing exposure to "reduced risk" turfgrass pesticides.

To determine precisely how much of the environmental residues are actually transferred to people, we measure exposure to volunteer golfers using dosimetry (measuring pesticide residues on full body cotton suits and personal air samplers) and biomonitoring (measuring urinary metabolites). Dosimetry and biomonitoring, together with concurrently collected dislodgeable foliar and airborne residue data, provide a unique database on exposure and have allowed us to develop an exposure model. We will compare the biomonitoring and dosimetry results for these "reduced risk" compounds, such as halofenozide, with those previously determined for chlorpyrifos, carbaryl, cyfluthrin, 2,4-D, MCPP, dicamba, chlorothalonil and imidacloprid .

To date, Hazard Quotients (HQs), using the EPA Hazard Quotient criteria, determined for chlorpyrifos, carbaryl, cyfluthrin, 2, 4-D, dicamba, MCPP, chlorothalonil, imidacloprid and carfentrazone have been 20- to 1.25 million- fold below 1.0, indicating safe exposure levels. HQs less than or equal to 1.0 indicate that the exposure resulted in a pesticide dose at which adverse effects are unlikely. Sponsor: New England Regional Turfgrass Foundation.

Integrated Pest Management by J. Scott Ebdon, PhD:

Resistance of Perennial Ryegrass Cultivars to the Ingress of Annual Bluegrass. This recently completed study assessed perennial ryegrass resistance to the ingress of annual bluegrass over a 4-year period. Visual percent Poa in 120 cultivars of perennial ryegrass was assessed annually beginning in the 2nd year after establishment. Percent Poa increased with age of the stand from 12.6% in 2006 to 17.6% in the last year of the test in 2009. Significant genetic variability was observed between cultivars with % Poa ranging from 6.7% to 70% in the last year of the test. Cultivars with the lowest Poa (6.7%) in 2009 included Accent II, Exacta II GLSR, Manhattan 5, Pianist, Secretariat II, and SR-4600. Only one entry, an experimental (SRX 4682), was found to have no Poa by the last year of the test. Sponsor: National Turfgrass Evaluation Program.

Tolerance of Kentucky Bluegrass Cultivars to the Herbicide Certainty (with Prasanta

Bhowmik, PhD): This study assessed Kentucky bluegrass tolerance to the herbicide sulfosulfuron in 173 cultivars of Kentucky bluegrass. Sulfosulfuron was applied at 1.5 ounces per acre in July 2009. Visual injury was assessed and rated (1 to 9, 6=minimum acceptable, 9=no injury) weekly following treatment, with the greatest injury occurring 3 weeks after treatment (WAT). The following cultivars exhibited good tolerance to sulfosulfuron (ratings 7 and higher) at 3WAT: Baronie, Bluemax, Eagleton, Langara and Serene. Some cultivars showed significant and unacceptable injury (ratings approaching 4) including: Avalanche, Champagne, Champlain, Chelsea, Chicago II, Misty, North Star, Princeton 105, Rampart, and Washington. Sponsor: National Turfgrass Evaluation Program.

Integrated Pest Management by Geunhwa Jung, PhD:

Assessing the In Vitro Sensitivities of Dollar Spot to Fungicides and Plant Growth Regulators.

This study investigated the effect of fungistatic PGRs on development of DMI resistance in populations of *Sclerotinia homoeocarpa*. The effective concentration (EC 50) and single discriminatory concentration (EC 50(D)) for six demethylation inhibitor (DMI), two dicarboximide, one anilene, one benzimidazole fungicide, and three plant growth regulators (PGRs) were conducted for 64 selected *Sclerotinia homoeocarpa* isolates in vitro. A significant correlation of in vitro sensitivities was confirmed among the 6 DMI and 2 PGRs (paclobutrazol and flurprimidol) which indicated that the PGR applications might increase development of DMI resistance and facilitate a shift toward resistance. Multiple resistance was confirmed between benzimidazole and DMI as well as between benzimidazole and dicarboximide fungicides.

The Effect of Demethylation Inhibitor Fungicides on Dollar Spot, *Sclerotinia homoeocarpa*, Population Structures. This project investigated the effect of propiconazole (DMI) rates on changes in dollar spot population structure using in-vitro fungicide assays and field efficacy tests. *S. homeocarpa* samples were collected from existing dollar spot populations at sites in MA and CT in 2009 and assayed for DMI resistance. The preliminary results indicate that each site has a unique dollar spot population structure with differing levels of DMI resistance depending on cultural management and history of fungicide uses at that site. Reduced field efficacy using propiconazole was observed at sites with preexisting DMI resistance, whereas complete control was observed at sites with total DMI sensitivity. A repetition of this study will take place in 2010 and 2011 to confirm the existence of the site-specific population structures and to study how the structures have changed after two years of DMI application at different rates and intervals.

This research has directly contributed to the formation of a Fungicide Sensitivity Assay diagnostic service for turf managers who have difficulty controlling dollar spot. The assay is conducted at the UMASS Turf Pathology lab using all commonly used fungicide classes to test levels of fungicide resistance to each. Results of the assay give clients a holistic understanding of their dollar spot populations along with effective cultural and chemical control options saving some thousands of dollars in misapplications of chemicals to dollar spot populations with fungicide resistance.

Reverting DMI-Resistant Dollar Spot Populations with the Use of Non-DMI Fungicides (boscalid, Emerald®; chlorothalonil, Daconil Ultrex®; iprodione, Chipco 26GT® and Ipro SE®; vinclozolin, Curalan®; and more) at a Golf Course on Cape Cod.

This experiment began in 2007 and is intended to identify non-DMI fungicides capable of reverting DMI-resistant populations back to sensitive populations so that the DMI fungicides can be used again. This experiment is also examining the length of reversion time while maintaining acceptable turf quality. Based on 3 years' careful monitoring of the populations using laboratory assays and evaluating field control, we did not observe any significant shift of the resistant populations

QTL Mapping of Resistance to Gray Leaf Spot (GLS) in Perennial Ryegrass. This project aims to research the interactions between the GLS pathogen variability and host resistance. The ultimate goal is to produce perennial ryegrass plants having a broad spectrum of gray leaf spot resistance by pyramiding various resistant genes originated from different Lolium species and cultivars. The gray leaf spot resistant cultivars being studied showed only moderate resistance to the 13 geographically diverse isolates of the disease causing organism. This result may indicate non-race specific resistance in perennial ryegrass. Sponsor: United States Golf Association.

Disease Management Trials: Trials investigating the effectiveness of specific fungicides are being conducted at the UMass Joseph Troll Turf Research Center as well as at field sites. These include evaluation of: 1. twenty-nine different fungicide treatments for preventative control of dollar spot (caused by Sclerotinia homoeocarpa) on a mixed stand of creeping bentgrass and annual bluegrass; 2. 34 different fungicide treatments with variable timing for preventative control of Typhula blight (caused by Typhula ishikariensis and T. incarnata) and pink snow mold (caused by Microdochium nivale); and 3. fungicides for preventative control of foliar Pythium blight (caused by Pythium aphanidermatum) on a seedling stand of perennial ryegrass (Lolium perenne).

Disease Management Trials by Robert Wick, PhD:

Alternatives to Fenamiphos for Controlling Plant Parasitic Nematodes in Golf Greens Biological controls, botanicals, conventional and unconventional chemistry are being tested as alternatives to fenamiphos for controlling plant parasitic nematodes in golf greens. Sponsors: New England Regional Turfgrass Foundation and the United States Department of Agriculture.

Disease Management Trials by Patricia Vittum, PhD:

Management of Turfgrass Damaging Insects

Various studies concentrating on the management of turfgrass damaging insects are underway at field sites in the northeast. These include: seasonal control of white grubs with neonicotinoids; efficacy of biological control agents (Bacillus thuringiensis buibui, another strain of BT, and entomopathogenic nematodes) against white grubs; identification of distribution and behavioral differences of white grubs in New England (Japanese beetle, oriental beetle, European chafer, Asiatic garden beetle); and mating disruption as a means to reduce oriental beetle grub populations.

Disease Management Trials by Michelle DaCosta, PhD:

Winter Injury of Cool-Season Turfgrasses. Several studies are underway to determine the physiological basis for differences in freezing tolerance among cool-season grasses, with an emphasis on understanding mechanisms of cold acclimation and deacclimation. Sponsors: New England Regional Turfgrass Foundation, United States Golf Association, and Adirondack Golf Course Superintendents Association.

Compiled by Mary Owen, Extension Turf Specialist ■