Barriers to adoption of pesticide resistance management programs

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Bottom line: Although it is widely acknowledged that pest resistance is an important problem that can lead to serious turf damage, programs to avoid resistance are rarely implemented on golf courses. The article below attempts to summarize our thoughts on the scientific, social and economic factors that contribute to this problem. The text has been adapted from a speech given by Dr. Larry Stowell on April 10, 2003, at a policy symposium that was sponsored by CAST – The Council for Agricultural Science and Technology. For background information on pest resistance in turf, see the August, 2002 *PACE Insights.*

Golf course turf represents an ever-increasing influence, in terms of both acreage and economics, in the U.S. today. In the year 2000, golf course turf was responsible for direct revenues of 20.5 billion dollars (SRI International, 2002). As a rough comparison, the 1994 retail value of cotton, corn, soybeans and wheat were 120.6, 99.0, 72.0 and 24.0 billion dollars respectively (National Cotton Council, 1994). There are currently approximately 16,000 golf courses in the United States serving 35 million golfers (SRI International, 2002). With roughly 100 acres of managed turf and landscape plantings per course, golf courses represent about 1.6 million acres of managed landscape.

Competition among courses for golfers, the popularity of televised tournaments, and demands by golfers for high quality turf are chronically rising, placing added pressures on turf managers to provide perfect, blemish free turf. It is with this backdrop that we begin the discussion of issues and barriers in the implementation of resistance management programs for golf course turf.

Why is there resistance to resistance?

Pesticide resistance management for golf course turf is characterized by a complex interplay between factors that create high risk for development of resistance, and those that act to significantly reduce that risk. High risk factors include:

Perennial crop: Crop rotation, which by introducing new crops into the system also reduces the build-up of resistant pests, is one of the key tenets of resistance management. However,in the turfgrass system, there is no option to rotate to a non-susceptible crop, no ability to lay fallow, and no opportunity for deep plowing practices that may reduce inoculum or bury weed seeds.

Pest complexes: Frequently, no one pest dominates control practices on golf course turf. Instead, pesticide applications are usually targeted at a complex of diseases, insects or weeds, thus increasing the exposure of several pests simultaneously to a given product.

Role of stress in increased pest infestations: Most golf course turf, and particularly the 2 - 3 acres per golf course used for putting greens, is grown under severe stress conditions that increase the likelihood and the damage associated with pest infestations, as well as the frequency of pesticide treatments. Stress factors include heavily trafficked, highly compacted soils; reduced photosynthetic capacity due to low mowing heights; lack of appropriate cultivation and irrigation practices due to their interference with golf play.

Demand for blemish-free turf leads to preventive programs: Unlike many crops, where successful management is judged primarily on yield, golf course turf is judged exclusively on appearance (color, uniformity, density) and playability. As a result, there is significant pressure on turf managers to prevent any and all pest infestations before they ever develop. This reliance on preventive programs, while necessary for preservation of current expectations for turf quality as well as for the superintendent's job, results in more pesticide applications per year than for crops with higher damage thresholds.

Lack of independent information sources: Because retail mark-ups for turf products are high and competition among product sales forces is heavy, turf managers are one of the most heavily serviced end user groups in agriculture. It is therefore not surprising that sales people are the most popular source of agronomic information for turf managers. In contrast, the influence of university research and extension efforts has diminished over the past few decades, as funding for applied research has decreased. This lack of funding has the additional (and perhaps unintentional) effect of strengthening the link between university research programs and the agrochemical industry, which funds an increasing proportion of university applied research. The result is a further decrease in the number of completely independent sources of agronomic and pest management information.

This issue of influence and independence extends beyond university and extension programs to private consultants and contract researchers (including PACE Turfgrass Research Institute), whose research programs are typically funded, at least in part, by the agrochemical industry. While the credibility of university, extension and independent private consultants is still quite high among end users (based on continued production of high quality research and also a determined and successful effort to remain independent of product sales), there are few, if any, research or education organizations whose operations remain completely unassociated with the agrochemical industry.

Lack of proven benefits and guidelines for resistance management: Turfgrass researchers who deal with the question of pest resistance are anything but unified in their approaches to resistance management. Recommendations range from a focus on rotations among pesticide classes to a “use it or lose it” strategy of sequential applications of the same or similar products; and from an emphasis on mixtures of low labeled pesticide rates to a reliance on high labeled rates of single products. These disagreements are highly publicized and well known to end users, who are regularly exposed to the arguments in continuing education courses and through a tight-knit, nationwide communication network of turf managers. The confusion that this lack of unity creates is buttressed by a lack of concrete data that demonstrates the benefits of one approach vs. another -- or even the benefits of any resistance management program at all – for avoidance of resistance. Without a clear set of guidelines available, and without evidence that investment in resistance management efforts will yield results, turf managers are likely to relegate resistance management to a low priority level as they design their management programs.

It isn’t all bad

There are also some factors that are unique to turf that actually decrease the likelihood that resistance will develop.

Emphasis on cultural management practices: Turf managers are well educated on the relationship between pest infestations and plant stress. As a result, there is a strong emphasis on cultural practices including regular soil and water testing, optimized soil nutrition programs, irrigation management, aerification to promote gas exchange and improve soil properties, regular monitoring for soil salinity, weather patterns and pest infestations and selection of pest resistant and climate-appropriate turf varieties during new construction or renovations. As a result, many potential pesticide applications are avoided.

Diverse spectrum of pesticide products: A large number of products, representing several different pesticide classes, are typically available in the turf market. This allows the end user to rotate among pesticide classes if they are so inclined. More importantly, this has allowed turf managers to easily find effective substitute products when other products are rendered ineffective by resistance.

Availability of broad spectrum products: Fungicides such as chlorothalonil and mancozeb have been used with success for many years, with no reports of pest resistance. Although there are new regulatory restrictions on the use of these products, they continue to play an important role in disease control and in avoiding reliance on single-site products that are more likely to cause resistance.

The state of pest resistance on turf

The result of the interaction among these high and low risk factors is that several documented cases of resistance have occurred on golf course turf (Tables 1 – 3), but usually in relatively localized populations.

Table 1. Turfgrass diseases that have been reported to have resistance to fungicides (Fungicide Resistance Action Committee, 2003; Vargas, 1994)

DISEASE	FUNGICIDE
Dollar spot	Rubigan, Bayleton, Banner, Chipco 26019, Vorlan
Pythium	Subdue and related products
Pink snow mold	Dicarboximides (Chipco 26019, Vorlan)
Anthracnose	Heritage, Compass, thiophanate-methyl (Cleary’s 3336, Fungo)
Gray snow mold	Heritage, Compass

Table 2. Turfgrass insects that have been reported to have resistance to insecticides (Potter, 1998; Vittum et. al., 1999)

INSECT	INSECTICIDE
White grubs	Chlordane, dieldrin
Chinch bugs	Diazinon, chlorpyrifos
Black turfgrass ataenius	Aldrin, chlordane, dieldrin, heptachlor
Sod webworms	Aldrin, dieldrin

Table 3. Turfgrass weeds that have been reported to have resistance to herbicides.

WEED	HERBICIDE
Goosegrass	Team and related DNA products (Balan, Surflan, Pendulum)
Annual bluegrass	Simazine (Princep) & related triazine products; Prograss
Smooth crabgrass	Acclaim and related aryloxyphenoxy products (Fusilade)

Product failures due to resistance have typically been limited in scope, due to the availability of substitute products with alternate modes of action. Because of lack of clear guidelines for avoidance of resistance, turf managers generally place a low priority on incorporating resistance management practices into their programs. The relatively low frequency of resistance problems is therefore more a fortuitous outcome of good IPM practices and availability of a wide spectrum of products, rather than a result of a concerted effort to avoid resistance.

Barriers to adoption

Obstacles in the path of more pro-active resistance management programs exist as a result of information deficits, agrochemical company economic pressures and lack of end user incentives: Specific barriers include:

Lack of data on benefits of resistance management: The lack of hard data demonstrating the operational, economic or environmental benefits of implementation of turfgrass resistance management programs has resulted in a parallel lack of incentive among agrochemical companies and end users to invest in what is basically an unproven academic theory. The mixed messages delivered from the turfgrass research community on optimal resistance management strategies further exacerbates this situation.

Economic realities within the agrochemical industry: Competition among companies who market products with the same mode of action is a strong dis-incentive to resistance management stewardship. For example, in the case of a new class of site-specific pesticides with a high level of risk for causing resistance, companies have choices on how to market their products. A company that acts "responsibly" by voluntarily restricting product use based on resistance management principles will be willing to limit their initial sales (via restrictive label language, sales programs, etc) because they believe that their actions will extend the life (and the sales) of the product. But if there is a more aggressive company who markets a product within the same pesticide resistance management group without regard to avoiding resistance, the benefits of resistance management are destroyed. When resistance and cross resistance finally develop as the result of indiscriminate use of one or more of these products, the "responsible" company will be penalized by failing to capture sales in the early, non-resistant window of time. The less responsible companies will be conversely (and contrarily) rewarded for implementing more aggressive marketing strategies that ignore resistance concerns.

In an age where product development costs are increasing, and where the effective life of a patent is shortened by the length of time involved in getting a product to market, the emphasis is on achieving maximum profitability as soon as possible. The benefits of "saving" a product from resistance, thus insuring it's long term use, is intellectually appealing but may not make practical sense to company planners and stockholders.

Fear of "global warning": Researchers, in their attempts to responsibly transmit information, are sometimes excessively cautious in relaying their suspicions that resistance may be involved in product failures. Unfortunately, by waiting until resistance can be conclusively documented before warning end users of a problem, we sometimes inadvertently support additional applications of products to which resistance has developed, resulting in additional product failures and crop damage.

Unwarranted optimism: Company claims that development of resistance to new pesticide chemistries is nearly impossible are sometimes accepted with a minimum of skepticism. Yet it seems prudent, especially in light of recent "surprise" cases of resistance (e.g. QoI fungicide and *Bacillus thuringiensis*) to assume that resistance development is likely to occur, at least until proven otherwise. Under this assumption, all products would be handled as if resistance were an imminent threat, rather than waiting for resistance to appear before management guidelines are put in place.

Solutions

The short term solutions described here are those used by PACE Turfgrass Research Institute, and are based on the assumptions that the issues and barriers described in this manuscript remain unaddressed, but that knowledge of biology and resistance management experiences in other crops (along with a sprinkling of common sense), can form the basis for reasonable turfgrass guidelines:

- Based on current understanding of resistance, the products and pests most at risk for resistance should be identified, as in Tables 4 and 5. These should be the focus of research, education and prevention efforts.
- In the absence of more specific information, products at risk of resistance should be used in block rotations, with no more than two sequential applications of each pesticide class of chemistry.
- For products with longer residual activity that are applied only once or twice per year, (imidacloprid and halofenozide), alternating annual single applications of one product per year should be considered.
- The use of pesticide rotations based on the resistance management groups proposed by the Fungicide (2003), Herbicide (2002) and Insecticide (2002) Resistance Action Committees should be followed.
- When product failures do occur and resistance is suspected to have a role:

1. The company involved should be notified
2. Qualified university researchers should be involved to determine the existence and nature of resistance.

3. End users should be advised of the situation and informed that the existence of resistance is suspected, but not yet proven. They should also be provided with alternate pest management programs that have decreased reliance on the suspect pesticide class for control of the supposed resistant pest.

Longer term solutions address the deficits and barriers described in this paper and include:

- Conduct field research programs to demonstrate the benefits of specific resistance management programs
- Accept that it is in neither the pesticide company's nor the end-user's interest to promote resistance management programs, especially if the benefits of resistance prevention programs have not been effectively demonstrated
- Where a class of pesticide chemistry is deemed an important enough resource, consider more aggressive regulatory involvement in enforcement, more restrictive labeling, mandatory monitoring and public reporting programs. However, this approach is feasible only if there is data available to support the use recommendations that would receive regulatory oversight. Without strong science as its basis, additional regulation will do nothing to delay or avoid resistance, and will squander time, money and credibility.

References

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Table 4. Risk factors for pest resistance in turfgrass: High risk pesticides. Pesticide classes and products characterized by frequent usage, single-site and/or specific modes of action, systemic activity/long residual activity and/or with a history of causing resistance are considered high risk. For some of the products listed below, resistance has not yet been detected among turfgrass pests, but we believe the likelihood of detection in the future is high if frequency of application is not limited in some fashion.

Pesticide Class	Examples
QoI fungicides	Azoxystrobin, pyraclostrobin, trifloxystrobin
Benzimidazoles	Thiophanate-methyl
Dicarboximides	Iprodione, vinclozolin
Phenylamides	Mefonoxam, metalaxyl
Chlorinated hydrocarbons*	Aldrin, dieldrin, chlordane, DDT, heptachlor
Organophosphates	Chlorpyrifos, diazinon
Pyrethroids	Bifenthrin, cyfluthrin, deltamethrin, cyhalothrin
Acetyl chlorine receptor agonists	Imidacloprid
Ecdysone agonist/ disruptor	Halofenozide
Triazine herbicides	Atrazine, simazine
DNA herbicides	Benefin, oryzalin, pendimethalin
Sulfonylureas	Chlorsulfuron, metsulfuron, foramsulfuron, trifloxysulfuron, rimsulfuron
Aryloxyphenoxy	Fenoxaprop, fluazifop

*no longer labeled for use in turf in the U.S.

Table 5. High risk pests. High risk pests have one or more of the following characteristics: dominate control practices on a consistent basis, multiple generations per year, sexual reproduction, high reproductive rates, or a history of resistance to pesticides.

Diseases	Insects	Weeds
Anthracnose Dollar spot Gray leaf spot Gray snow mold Pink snow mold Pythium	White grubs (Japanese beetle, black turfgrass ataenius, chafers) Chinch bugs Sod webworms	Poa annua Crabgrass Goosegrass