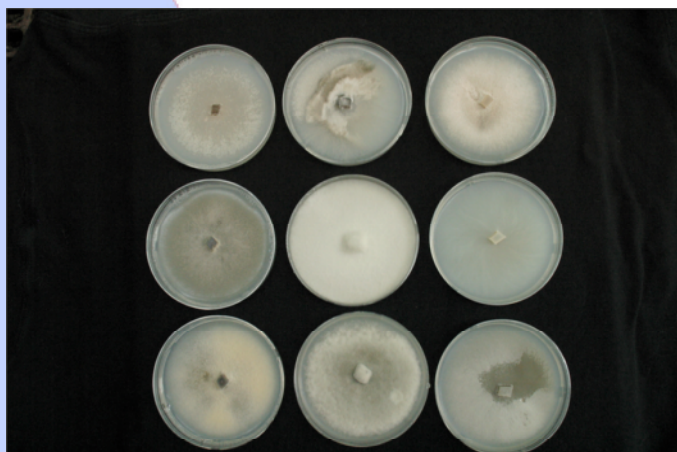




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Over the course of the past two years, the URI Turf Pathology Lab has been examining isolates of anthracnose (*Colletotrichum cereale*) collected from around New England for fungicide resistance. Anthracnose can be a particularly persistent disease and after years of repeated fungicide applications, fungicide efficacy can decline. The project we have been undertaking has been designed to examine changes in fungicide susceptibility of *C. cereale* between isolates collected in 1993 and those collected in 2007. By comparing the results from two different sampling periods, we can show how fungicide resistance is developing over time. This study is being funded with the generous support of the New England Regional Turfgrass Foundation.

formulations containing the same active ingredients may exist, it is generally recognized that most products containing the same amount of the same active ingredient are susceptible to the same level of resistance development. The particular brands chosen for this study were chosen because they were easily on hand and for no other reason, nor is this study any endorsement of one brand versus another.



**Figure 1.** *Colletotrichum cereale* (Anthracnose) isolates collected from across New England during 2007, growing in petri dish cultures.

For this project, we chose to examine eight different fungicides: Signature (fosetyl-AI), Bayleton (triadimefon), Chipco 26019 (iprodione), Daconil (chlorothalonil), Endorse (polyoxin-D), Heritage (azoxystrobin), Medallion (fludioxonil) and Cleary's 3336 (thiophanate-methyl). Although differences between these formulations and other

Fungicide		Average	
		1993-1995	2007
Signature	EC50	72	73 <sup>ns</sup>
	EC90	184	178 <sup>ns</sup>
Bayleton	EC50	13	26
	EC90	40	73
Chipco	EC50	48	56 <sup>ns</sup>
	EC90	358	1599
Daconil	EC50	11	7
	EC90	791	67
Endorse	EC50	<4	13
	EC90	5	37
Heritage	EC50	8	213
	EC90	167	16514
Medallion	EC50	7	9 <sup>ns</sup>
	EC90	134	7139
Cleary's 3336	EC50	>1024	>1024
	EC90	>1024	>1024

**Figure 2.** Results from fungicide resistance trials demonstrate that the efficacy of a number of fungicides has become reduced between 1993 and 2007. Values are in part-per-million. The term EC50 describes how much fungicide is required to reduce fungal growth by 50%. The term EC90 describes how much fungicide is required to reduce fungal growth by 90%. EC90 values are less reliable than EC50 values and generally considered less important. Unless noted by an "ns", comparisons between years are statistically significant.

Over a time span of approximately 12-14 years, fungicide resistance has been developing in populations of *C. cereale* throughout New England. Figure 2 depicts how the average level of various fungicides required to control the pathogen have increased. Those products that did not show an increase in the average level of chemical required to stop fungal growth (based on EC50 values) included: Signature, Chipco 26019, Daconil and

Medallion. The results from trials using Cleary's 3336 indicated that > 1024ppm (our highest tested rate) were required to halt growth in both 1993 and 2007.

Although these numbers can help to establish which active ingredients are going to be more or less useful in controlling anthracnose, they do not tell how actual resistance levels have changed.

## Differences From 1993-2007

- Signature: 92% (1993) to 95% (2007) **less sensitive**
- Bayleton: 14% (1993) to 34% (2007) **less sensitive**
- Chipco: 40% (1993) to 47% (2007) **less sensitive**
- Daconil: 18% (1993) to 13% (2007) **less sensitive**
- Endorse: 0% (1993) to 13% (2007) **less sensitive**
- Heritage: 4% (1993) to 74% (2007) **resistant**
- Medallion: 0% (1993) to 4% (2007) **resistant**
- Cleary's 3336: 33% (1993) to 73% (2007) **resistant**

**Figure 3.** An estimation of how populations of isolates collected from 1993 to 2007 have changed in their levels of resistance. In cases in which resistance occurs in degrees (or a little bit at a time), the term "less sensitive" has been used. In cases where resistance occurs quickly and completely, the term "resistant" has been used. Populations that have become "less sensitive" will still respond to a chemical, just not as well as in the past.

Resistance is a tricky phenomenon. Sometimes resistance is very clear-cut. Sometimes resistance occurs in degrees. Because it is not always easy to determine the cut-off point for where resistance begins, there is some level of subjectivity to determining resistance. Whether resistance is clear-cut or not, historical perspective is necessary to identify resistance.

Luckily, this study incorporates data from 1993 and 2007 populations so that a historical perspective (or baseline) is known. Figure 3 shows how comparing the data from these two sampling periods allows us to see how resistance and sensitivity has changed over time.

Using this data, it becomes apparent that while resistance has increased and sensitivity has decreased in

most cases, extremely large jumps have occurred from 1993 to 2007 with both Heritage and Cleary's 3336. A substantial but smaller jump is also observed with Bayleton. The take-home message from this study is that if you are trying to control anthracnose, azoxystrobin or thiophanate-methyl will not always be your best choice. In some cases (~25%, based on Figure 3) they will still provide control of the disease but in other cases (~75%) they will not. Both Heritage and Cleary's 3336 will still provide excellent control of many other diseases, just not always anthracnose.

Cross resistance is a common occurrence with fungicide resistance and there is also a possibility, based on this data, that chemicals like Insignia and Disarm may have succumbed to some level of anthracnose resistance. The only way for a superintendent to know for sure is to test these chemicals on his golf course and pay careful attention to their effectiveness against anthracnose. The chemicals that have induced the least amount of resistance in *C. cereale* and often provide the best control of the pathogen are Endorse and Medallion.

An important caveat is that every golf course is different. The data presented here are averages across many locations. Your particular location is NOT the average and will not necessarily respond like the average. It is up to the superintendent to determine what actually works for him or her.

Finally, the current study was undertaken in the laboratory under highly controlled conditions. Conditions present on a golf course are highly variable and may prevent these results from translating directly to the field.



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**PESTICIDES ARE POISONOUS!** Read and follow all safety precautions and all labeled directions. The label is the law. Handle carefully and store in original containers out of reach of children, pets or livestock. Dispose of empty containers immediately, in a safe manner and place. Pesticides should never be stored with foods or in areas where people eat.

When trade names are used for identification, no product endorsement is implied, nor is discrimination intended against similar materials. Be sure that the pesticide you wish to use is registered for the state of use.

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