The Impact of Climate
On Turfgrass Pest Activity

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Over the years, turfgrass experts like Dr. Eric B. Nelson at Cornell University and Dr. Dave Shetlar at The Ohio State University have more than once emphasized to me various aspects of the general relationship between climate and pest activity. However, it wasn't until I became actively involved in the production and running of a series of computer-based models to produce turfgrass pest activity favorability forecasts, using recent, current, and forecast weather conditions, that this direct linkage has become clear.

To the existing breadth of these experts' understanding, born of their strong understanding of pest biology, I would add the following observation based on two years of working with these models. Even in the presence of a relatively large insect population or a dense mass of disease innoculum, significant visual host damage is not likely to occur when conditions of temperature and moisture are substantially outside the minimums required for pest activity to occur.

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Restated, pest activity, whether that activity leads to significant damage or not, is a direct function of the interaction between the pest, the host and the recent and/or current weather conditions that fall within definable ranges. If the conditions fall substantially outside (either below or above) these ranges, then significant pest activity is not likely to occur.

Pest Activity and Climate

All of the common pests of turfgrasses are exothermic — meaning they do not produce the majority of their own internal heat. Insect, disease, and weed pests absorb most of the energy required in their life processes from their surrounding environment. Within some limits, these life processes are greatly dependent on this inflow of outside energy to function properly. Also, the speed of progression to maturity is directly related to the quantity and pace of the energy inflows.

From a pest management point of view, understanding this biological concept can lead to a significant new set of tools. If you can measure the energy inflows (usually as temperature) in some meaningful way and relate that measurement to a pest's observed life processes, then it should be possible to estimate the current life-cycle stage, called phenology, of a pest at any point in time. Once the pest's phenology (in relation to turf damage) and the progress toward maturity is understood, then measuring potential energy absorption should provide a means of estimating the likelihood of pest damage.

In addition to temperature (energy), all three types of the turfgrass pests mentioned above are also dependent on moisture availability in at least one portion of their life cycle. Like temperature, measuring moisture availability can also be used to estimate the likelihood of pest activity, if it is understood what role moisture plays in the life cycle.

Temperature and Moisture

Although it is difficult to generalize about the roles that temperature and moisture play in common turfgrass pest biology, for the most part it can be said that moisture plays an 'enabling role' and temperature plays a 'driving role'.

Moisture *enables* the life processes to occur or continue because it often plays a crucial role in the pest's life cycle stages, such as when a newly laid chinchbug egg absorbs moisture from the soil or thatch prior to hatching, or when prolonged leaf wetness periods induce fungal spore germination or enhance mycelial growth. Furthermore, temperature provides the energy required to *drive* the life cycle toward maturity, such as the progress of a scarab beetle through three instar grub stages, pupation, and adult emergence and activity.

In other words, as long as the minimum moisture requirements of a phenology are met, then progress of that species toward maturity is a function of the amount of energy absorbed.

Moisture

How moisture enables pest activity will vary significantly by species. For instance: Once a chinch bug egg has been laid in the soil or thatch at or near the soil's surface, the egg must absorb several times its own weight in water within first 48 to 72 hours or egg mortality rises significantly. Research has shown that grubs will migrate down into the soil profile as soils begin to dry. Several scarab beetle species may have the apparent ability to delay adult emergence from their pupal stage during dry soil periods. Spore germination for certain foliar diseases like Dreschlera Leaf Spot can only occur during prolonged leaf wetness periods and Brown Patch mycelial growth is enhanced by a dense turf canopy with a moist microenvironment.

The nature of the role that moisture plays for each species will vary. In the case of the chinch bug egg during the period after ovaposition and prior to hatching, the need for enough moisture to be absorbed is critical, but short-lived. In the case of many soilborne diseases like Pythium, Summer Patch, etc., the pathogen's moisture needs can be met by a broader range of values and over longer periods of time.

Temperature

How temperature drives the progress toward maturity is less species specific than moisture, but just as important.

Temperature or energy availability over a geographic area is often more consistent than moisture, since it generally follows large-scale trends such as rising temperatures during the transition between spring and summer or falling temperatures in the fall. Temperature is always there from one day to the next with incoming solar radiation providing the relatively consistent energy source that drives all life. Moisture, on the other hand, is far more a function of seemingly random events.

Energy — The Driving Force

An insect's life is predetermined, meaning that one life cycle stage must follow another and the insect's growth can only progress through this defined number of stages, often within a finite period of time.

Whether a species survives or not at a given location is ultimately a function of how much energy (as heat) the insect can absorb during its various phenologies and how fast it can absorb that energy. If the total available accumulated annual heat (energy) at a location is not enough to complete the species' life cycle, then the chances are very high that the species will not survive in that location. If, however there is more then sufficient available energy to complete the insect's life cycle, than the likelihood that the species will survive at that location is greatly enhanced. If there is sufficient available energy to complete more than one generation per year, then the likelihood that an insect species will thrive is substantially increased.

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If the total available energy of a geographic area is marginal or insufficient for the establishment of a viable population of a scarab beetle species with an annual life cycle (meaning all life cycle stages are completed in 365 days), then that species will not likely survive over the long-term. Even though there is not enough available energy for an annual scarab to survive, there may be enough available energy for a two-or three-year life cycle scarab species to survive and thrive in the same area. This is an example of how the climatic conditions at a location can limit the number and types of pests species found in that area.

In a slightly different way, the long-term survivability of diseases is also determined by temperature. Some population of almost all of the common disease pathogens can be found at virtually any location at any time of the year. This 'survival' or 'background' population can survive various and prolonged adverse climatic conditions in resting bodies for several years. It is only when these survival populations are subject to optimum growth conditions for a long enough period of time that host disease symptoms actually develop.

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Pest Population Dynamics

Because of the seemingly rapid onset of many turfgrass diseases and some insects, turf managers often fail to realize that pathogens or insects have often been active for extended periods prior to the first appearance of damage.

This period of population building is actually very logical from a theoretical point if view. If, for instance, the total population of all of the plant disease pathogens that grew in area during one year were to survive the extended periods of adverse conditions, both summer and winter, that normally occur and germinate and produce an ever increasing population the following year, then the pathogen populations would have built up to the point that most vegetation in that area would most likely have been killed off. With the loss of most of the vegetation, all the animals that directly or indirectly depended on plants as the ultimate food source would also die.

This same principle applies to plant damaging insect pest populations. If all of the insects that were alive prior to the onset of prolonged periods of adverse climatic conditions survived and reproduced the following year, then all vegetation that those insects feed on would most likely cease to exist also.

Insects are subject to the same population buildup as diseases. It is common knowledge in cool season areas that only a small fraction of the previous year's chinch bug population survives over most winters. Once the spring temperatures rise above a minimum level, early overwintering chinch bug adult activity begins with a subsequent rapid buildup of actively feeding juveniles and adults often leading to visual damage at a later date.

The understanding of the mechanisms of this buildup in actively feeding chinch bugs has lead to a management strategy that targets these overwintering adults just as they begin to become active. This early intervention strategy targeted at reducing the population of fertile adults is said to be so effective, that depending on the location (available energy), the species targeted, and the control product used, it can take one to three years for the population of chinch bugs to return to the precontrol application levels.

How Climate & Pest Biology Interact

The rebuilding of pathogen populations, following prolonged adverse climatic periods, from low background levels to those required to cause the onset of symptoms, is most likely to occur during a series of multiple short and long favorable climatic periods.

During any 365-day period, there are likely to be many short periods when suboptimal to optimal pathogen growth conditions are met. During these periods, sometimes as short as 72 hours, pathogens can become active and progress through a complete generation ending in an intermediate or long-term resting or survival stage.

Through a number of these short favorability periods, the pathogen populations can either stay stable or slowly build. If, however, as often happens, these short favorability periods are followed by extended favorability periods, then the disease's ability to cycle through a complete generation in a relatively short period of time can lead to multiple generations and a building population or rise in so called disease innoculum levels. Once a threshold of innoculum (which varies by pathogen species, host species, host susceptibility, and climatic conditions) has been reached, any additional periods of favorable weather, even if only marginally favorable, can rapidly lead to an exponential increase in internal disease damage and the onset of external visual symptoms on the host.

Following this scenario, it becomes evident that there can be prolonged periods of pathogen activity without the onset of significant internal effects or external visual symptoms on the host species. But once the pathogen population reaches a minimum threshold, any additional pathogen activity can lead to significant damage.

A direct example of this apparent delay between the onset of pathogen activity and the appearance of external visual symptoms can be seen in the results of aerial remote sensing of agricultural crops fields or golf course turf. When multispectrum infrared scanners are used to examine fields or areas of crops or turf, the resulting output will often show normally appearing plants with unseen internal damage or stress that only develops into external visual symptoms at a later date.

The same scenario applies to insects. Insects are often active before a so-called threshold population can produce significant visual symptoms. As with diseases, the threshold population that produces identifiable visual symptoms will depend on the pest species, the host species, the host condition and the climatic conditions.

Measuring Activity Ranges

Since temperature and moisture are the principle elements that determine climatic favorability for pest activity, it is necessary to establish a range of values for each.

There are two approaches to determining these ranges. The first method is use the most basic concept in applied climatology and take systematic measurements of these weather elements and correlate the resulting data to field observations of pest activity. The second is to use the same observation and correlation techniques, but done under controlled laboratory conditions.

In the case of insect activity, since moisture plays a secondary role to temperature, comparing the direct observations of insect activity and a quantitative measurement of temperature collected in the field works fairly well.

The most common measured method of relating insect activity to temperature is to use an accumulation measure called 'degree-days'. Degree-days are a means of measuring daily or hourly average temperature, which are then summed over a period of time to create a measure of accumulated heat (energy).

Degree-days are calculated by summing the daily high and low temperature (F or C), dividing that sum by two, and then subtracting a predetermined species-specific threshold number (usually 42 or 50 degrees F). The result, if it is a positive number, is added to the sum of all of the previous positive numbers calculated during the observation period to create 'accumulated degree-days'. If the result of the daily DD calculation is a negative number, then it is ignored.

This accumulated degree-day number is then correlated to observed insect activity or phenology change by beginning the DD accumulation at a repeatable point, such as egg hatch. In the case of the Hairy Chinch bug, early overwintering adult activity (the point each spring when overwintering adult activity starts) is expected to begin when the accumulated degree-day YTD total reaches ~ 145 DD (base 50 degrees) at a turf location. (Note: The phrase base 50 is used to denote the accumulating threshold of 50 degrees F.)

The nice thing about using YTD degree-day accumulations to estimate the current phenological stage and likely early activity period of Hairy Chinch bugs, or most other turfgrass damaging insects for that matter, is that the likelihood of damage from early insect activity is very small. It's small, because the amount of accumulated heat/early activity is low and the initial insect population is also usually low. Additionally, the first estimate of insect activity of the season allows for sufficient time to scout suspected or historic activity locations to monitor whether there is actually any activity.

The negative part about using DD accumulations for estimating insect activity is that the numbers are fairly squishy approximations, usually based on correlations done at only a few locations. And they do not take localized microclimate conditions, like a southern exposure or thin turf cover, that would increase local YTD DD numbers into account and they ignore any accumulated heat below the observation threshold temperature level.

The setting of observational or accumulating thresholds is based on the assumption that the majority of an insect's progress toward maturity occurs simultaneously with observable activity. Unfortunately, work done on an insect's metabolic mechanisms has shown that a substantial amount of internal metabolic activity may be taking place at temperatures between freezing and the threshold value in the absence of observable activity, enough metabolic activity that this below threshold energy may be the cause of the substantial variances seen between estimated activity and actual observed activity.

Because of this assumption of no significant progress toward maturity at temperatures below threshold and that observations were done in the field setting subject to several uncontrollable variables as well as the observation multiple insect phenotypes, estimations of specific insect activity using DD accumulations will always be just approximations.

The timing or implementation of insect control activities should always be subject to change from those created using DD calculations when any local or special conditions related to potential insect populations occur. Conditions, like milder than normal winter conditions that allow a larger than normal percentage of the previous year's insect population to survive, should always prompt earlier than normal scouting, often considerably before the accumulated DD estimate of initial activity.

In the case of diseases, most of the correlations between climate and pathogen activity are based on a combination of laboratory created data for temperature and both laboratory and field level observations for moisture.

A considerable amount of temperature work has been done on pathogen growth on auger plates. In these cases, pathogen growth on a growing media is checked for the temperature at which it is occurring and often the speed at which the colony growth progresses.

For instance, laboratory growth plate tests have shown that the fastest growing common turfgrass pathogen is Pythium at something over 3 cm per day and that Brown Patch probably has one of the shorter intergenerational times of ~ 72 hours, beginning to end.

Moisture studies for diseases are usually done in two ways - either as growth chamber studies on inoculated hosts or through direct observation field studies. These techniques are often used to determine optimum leaf wetness for pathogen germination and/or mycelial growth.

As effective as they are at measuring the ranges of both temperature and moisture in pathogen activity, there are several shortcomings in the use of these techniques.

First, because many of these studies are done in the controlled environment of a growth chamber, the resulting data may overestimate the speed and intensity of field level symptom onset because of the studies uniformity and optimization of conditions — something that is rare in the field. Second, in many cases the studies involve the practice of inoculating hosts with an unnaturally high concentration of pathogens to precipitate symptom onset thereby saving time.

Finally, many of these laboratory growth and plant greenhouse tests are done in the absence of any naturally occurring competitive or antagonistic pathogens that could change the intensity and speed of symptom onset in the field.

Within the obvious limitations of the work done to date, the establishment of workable ranges for minimum and optimum pest activity can provide a foundation for the beginning of a substantial look at how changes in each parameter are liable to effect pest activity.

How Precipitation Changes Affect Pest Activity?

Direct quantitative field measurements of the effects of climate parameter changes on pest activity are rare and may not actually exist for turfgrasses. However, there is a substantial amount of raw observational data that could be translated to describe these cause-and-effect relationships, if enough time and resources were available, but lacking both, what follows are several model predictions that can serve as a means to illustrate these relationships.

An analysis of the effects of the addition of 1.25 inches of supplemental irrigation per week during the summer months on the estimated annual Anthracnose favorability at five U.S. locations is very instructive.

Table 1 shows how the use of weekly supplemental irrigation during summer months added to the average climate over the last 30 years causes a change in the average annual Anthracnose favorability.

In the case of Tucson, the addition of supplemental irrigation raised the average estimated favorability to a numerical value of 18 from 0, in Atlanta the average rose from 38 to 39, in Chicago from 19 to 26, in Dallas from 21 to 51 and in San Francisco from 6 to 28.

(Note: In the above example, the average annual favorability means that in the case of Atlanta, for 38 or 39 percent of the year, climatic conditions are favorable to Anthracnose pathogen activity.)

This information illustrates two concepts. First, the addition of added moisture to turfgrass can dramatically increase pathogen activity favorability in areas that normally have low rainfall (see Tucson and Dallas).

Second, added moisture in areas of moderate to high rainfall may not increase favorability as much.

In fact, added moisture during periods of suboptimum temperatures may have no additive effect on pathogen activity at all. So added moisture requires the proper range of temperatures for long periods to have a substantial effect on the average favorability over the course of a year.

For added moisture to actually increase favorability over what might be expected under normal conditions, it must come at a time of optimal temperatures but suboptimal moisture. Added moisture to a wet environment will usually not increase the level of pathogen activity: Optimum moisture conditions means just that.

What added moisture can do in this circumstance is to prolong a favorability period, and that can lead to increased disease innoculum, which can lead to increased symptom expression at a later time.

Adding moisture over and above normal rainfall during insect activity periods may have the effect of reducing insect activity. First, air temperatures during rainfall/irrigation events are usually lower causing less available heat. Second, added rainfall/moisture at the wrong phenology stage can actually increase insect mortality, such as soil inhabiting insects suffering from lack of

SUPPLEMENTAL IRRIGATION AND ANTHRACNOSE

Table 1. The effects of supplemental irrigation (@ 1 1/4 inches/week) on annual average Anthracnose favorability.

	Growth potential	
Location	**without irrigation**	**with irrigation**
Tucson AZ	0	18
Atlanta GA	38	39
Chicago IL	19	26
Dallas TX	21	51
San Francisco CA	6	28

available oxygen in saturated soil or causing an increased population of naturally occurring insect predacious microbes.

Temperature Fluctuations

Table 2 shows a comparative analysis of the occurrence dates of both the 450 and 1500 DD totals for the eight climate districts of North Carolina for 1997 versus the 1961 - 1990 expected normal average.

Early in 1997 was one of the warmest springtimes in this century, and the occurrence dates of the 450 DD and 1500 DD thresholds showed a substantial change from the expected. The 450 DD threshold is the expected date for hatching of the first new generation of Chinch bugs in North Carolina.

The average date for the eight districts was 14 days sooner than would normally be expected, with two of the districts reaching the threshold more than 30 days early.

The average for the 1500DD threshold or the expected hatch date of the second generation of Chinch bugs, was five days sooner than expected, with two districts more than ten days early as temperatures in the early summer were actually below normal.

Whether this early probable chinchbug activity actually led to visible damage is a function of the size of the overwintering adult population, the strategy used to determine control product application timing and the overall condition of the hosts.

But it is safe to assume that the use of early intervention control strategies, based on the historic average first expected occurrence calendar dates, particularly when using short duration control materials, were not applied at the optimal times.

Summary

Many of the elements of climatic conditions and plant pest activity have been shown in a very indirect way in turfgrass research. However, since little actual research has been done to describe these connections, computer modeling can produce a significant amount of information. Modeling can provide managers and researchers with good, practical information about how climatic conditions can affect both pest species and host plants.

Until the exact nature of connection between climatic conditions and pest activity can be more thoroughly researched, turfgrass managers will have to continue to rely on their observational skills to judge when, how, and with what actions or materials to control the many species of insect, disease, and weed pest that damage or disrupt their managed sites.

EFFECTS OF WARM SPRING ON CHINCHBUG HATCH

Table 2. The effects of 1997 warm spring temperatures on the likely timing of 1st and 2nd generation egg hatch of Chinch bugs in North Carolina.

	1st Hatch		2nd Hatch	
Location	Normal	1997	Normal	1997
Normal DD	450 DD	450 DD	1500 DD	1500 DD
CD # 1	May 20	May 17	Jul 16	Jul 20
CD # 2	Jun 7	Jun 2	Aug 3	Jul 28
CD # 3	May 17	May 2	Jul 5	Jun 30
CD # 4	May 12	Apr 5	Jul 1	Jun 25
CD # 5	May 7	Apr 5	Jun 26	Jun 11
CD # 6	May 2	Apr 12	Jun 21	Jun 10
CD # 7	May 4	Apr 17	Jun 22	Jun 20
CD # 8	May 12	Apr 27	Jun 30	Jun 23