White Grub Biology and Management

Principal Investigators: Wendy Gelernter, Ph.D. and Larry J. Stowell, Ph.D., CPAg

Cooperators: Ross O'Fee and Mike Kocour, The Springs Club; Cal Hardin, Morningside Country Club; Douglas Anderson, The Vintage Club; Chris Harvell, Nicklaus Private Course (PGA West)

Sponsors: Hi-Lo Desert Golf Course Superintendents Association; Ross O'Fee and Mike Kocour, The Springs Club; Cal Hardin, Morningside Country Club; Douglas Anderson, The Vintage Club; Chris Harvell, Nicklaus Private Course (PGA West)

Recommendations:

- For control of white grub (black turfgrass ataenius and masked chafer) populations, the first preventive insecticide application should be timed between mid- and late June. Because grubs can cause serious damage to turfgrass from June through October, additional insecticide applications may be necessary (see below).
- Based on high levels of efficacy in field trials, its residual activity of eight or more weeks, and low toxicity to non-target organisms, imidacloprid (Merit) should be the centerpiece of white grub control programs in the Low Desert. Two applications per year will probably be necessary, with the first application (0.1 oz/1000 sq ft) made in the second to third week in June, and the second application (0.1 oz/1000 sq ft) made six to eight weeks later.
- For curative control of white grubs, trichlorfon (Dylox or Proxol) and acephate (Orthene or Pinpoint) also provided excellent control, but because their residual activity is low, they must be applied several times per season. These products will be most useful if unexpected grub populations occur either before the first Merit application in June, or in the Fall, if residual activity from the second application of Merit is not sufficient to protect turf from grub damage.
- Expect grubs of masked chafers to appear in turf in late June and early July. Predicting the appearance of black turfgrass ataenius grubs is more complex, with grub populations sometimes not developing on turf until late August. To gain more insight into the timing of ataenius populations, it is recommended that black light trapping studies be conducted for two additional years (1997 and 1998) and that the proposed degree day model be validated using black light trap data.
- No one method for predicting the appearance of white grubs was infallible. It is recommended that a combination of techniques, including black light trapping, use of the degree day model presented below, a calendar driven approach treatment approach (targeting June 15 for initial preventive treatments) and sampling for grubs be combined to achieve optimum results.

Summary: Larvae (grubs) of the black turfgrass ataenius, *Ataenius spretulus,* and the masked chafer, *Cyclocephala* spp. are serious pests of cool season turfgrass throughout the United States. However, little is known about the biology and the timing of appearance of these insects in the Low Desert, nor is there a good, generally accepted method for monitoring of white grubs. This deficit has made management of these pests difficult. To address this gap in information, the PACE Turfgrass Research Institute conducted three different studies on white grubs during 1996 - 97:

<u>Project I:</u> Predicting the Timing of Adult and Larval Populations of the Black Turfgrass Ataenius and the Masked Chafer Using Black Light Traps

<u>Project II:</u> Predicting the Timing of Adult Populations of the Black Turfgrass Ataenius Using Degree Day Models

<u>Project III:</u> Efficacy of Chemical and Biological Controls for Black Turfgrass Ataenius and Masked Chafers

Key research findings are listed below and are presented in more detail in the three attached reports.

- <u>Black turfgrass ataenius biology</u>: Black turfgrass ataenius adults were present in all study locations. There were three or more discrete generations of black turfgrass ataenius (BTA) adult beetles, beginning in late May, and ending in October or November, although small numbers of adult beetles were observed on greens throughout the year. In contrast, BTA grubs were infrequently observed in the Low Desert, and only beginning in late August, when they did cause damage to cool season turf. This may indicate that BTA grubs do not survive on greens height turf during the hotter months of July and early August, and that they may not be as widespread a problem as previously believed.
- <u>Predicting the appearance of the black turfgrass ataenius</u>: While several methods were developed that accurately predicted when BTA adult beetles would appear, prediction of grub appearance was

more difficult. Based on PTRI data obtained from coastal Southern California golf courses over the past 4 years, it was expected that BTA grub populations would occur two to three weeks after each peak of BTA adult beetle activity. However, although extremely high numbers of BTA adults were detected with black light traps beginning in late May/early June, grubs were not detected until twelve weeks later, in late August. Therefore, while black light traps are a good indicator of when adult BTA beetles will appear, they do not necessarily give an accurate prediction of when BTA grubs will appear on golf course greens. A degree-day model that was developed to predict the appearance of BTA adults was able to use temperature to predict when BTA adults would occur (and was accurate within a range of 2 days before or 14 days after the actual peak), thus making the use of black light traps less necessary. However, like the black light trap, the degree day model only predicts when adult BTAs will occur, and does not predict when BTA grubs will appear.

- Masked chafer biology: Unlike other regions of the country, where masked chafers lay eggs for only a few weeks, Low Desert masked chafer adults were active in June, and then again in August and September, indicating that two different species of chafers may be present in the Desert. Grubs were found on cool season greens beginning in early July, and continuing to the following Spring. The greatest damage from chafer grubs was observed in July and August. Chafer grubs appeared to be a serious pest in more locations than did BTA larvae.

- Predicting the appearance of the masked chafer: Black light trap samples of masked chafer adults accurately predicted the appearance of grubs, with grubs first detected on greens on 7/12/96, or four weeks after the first peak of adults, which occurred between 6/9 and 6/11. A second peak was observed in September/early October. It is likely that the occurrence of two peaks of chafer activity indicates the presence of two different species of masked chafer. Unlike the BTA, masked chafer adults appear to be active during the same time period every year, indicating that changes in temperature from year to year have little effect on chafer activity. For this reason, it is likely that a constant environmental feature, such as day length, has a stronger effect on chafer development than does temperature. Based on these observations, chafer activity can be most accurately and easily predicted using a calendar, with the first peak of adult activity expected during the second week of June, and the first grubs appearing in late June and early July. Black light traps and degree-day models will probably be no more accurate than this calendar approach to predicting masked chafer activity.

- Control of white grubs: The most effective treatments were trichlorfon (Dylox or Proxol), imidacloprid (Merit) and acephate (Orthene and Pinpoint). No phytotoxicity was observed. While Merit provided excellent preventive control of white grubs, its activity declined significantly between 8 and 10 weeks after application. This suggests that two applications of Merit may be necessary to maintain control during the critical months of June, July and August. Applications of Dylox or Orthene provided excellent curative control of grub populations. However, these products have brief residual activity and therefore must be applied several times during the season for optimum control. Dursban, considered by some to be the industry standard for grub management, did not provide acceptable control of white grubs. Other ineffective treatments included two biological insecticides (M-Press and Cruiser), and Tame (a pyrethroid).

Project I: Predicting the Timing of Adult and Larval Populations of the Black Turfgrass Ataenius and the Masked Chafer Using Black Light Traps (Final Report)

Principal Investigators: Wendy Gelernter, Ph.D. and Larry J. Stowell, Ph.D., CPAg

Cooperators: Ross O'Fee and Mike Kocour, The Springs Club; Cal Hardin, Morningside Country Club; Douglas Anderson, The Vintage Club; Chris Harvell, Nicklaus Private Course (PGA West)

Sponsors: Hi-Lo Desert Golf Course Superintendents Association; Ross O'Fee and Mike Kocour, The Springs Club; Cal Hardin, Morningside Country Club; Douglas Anderson, The Vintage Club; Chris Harvell, Nicklaus Private Course (PGA West)

Summary: Accurate timing of insecticide applications targeted against white grubs (black turfgrass ataenius and masked chafers) is critical for optimal control. However, this has been difficult because grubs are difficult to scout for and detect, and because the timing of infestations varies from year to year. To better predict when white grub populations will occur each year, a research trial was implemented to investigate the feasibility of various sampling methods for adults and larvae of the BTA and the masked chafer and the accuracy with which they predict the appearance of white grubs.

Overall, black light trap samples of masked chafer adults accurately predicted the appearance of grubs, but black turfgrass ataenius light trap samples were not always accurate. For this reason, additional predictive tools need to accompany the use of black light traps for accurate prediction of the appearance of grubs and optimal timing of control treatments.

Specific findings include:

- Based on data developed in the Eastern U.S., it was previously believed that white grubs were active in the Low Desert beginning in April or May and ending in August. However, our research indicates that white grubs (larvae of black turfgrass ataenius and masked chafers) were a continuous presence on turf from late June/early July through the winter months, with the most serious damage occurring in July and August. For this reason, timing of preventive insecticide applications with Merit should not be made until approximately mid-June. The manufacturer of Merit, Bayer, has addressed this refinement in application timing by issuing a bulletin (see Appendix 1) with revised recommendations that are based on the research summarized in this report. The exact timing of grub populations will vary from year to year based on changes in climate.
- Black light trap samples of masked chafer adults accurately predicted the appearance of grubs, with grubs first detected on greens on 7/12/96, or four weeks after the first peak of adults, which occurred between 6/9 and 6/11. Low Desert chafers peaked 2 weeks earlier than chafers in coastal Southern California
- It is highly likely that peak chafer beetle activity occurs on the same dates every year (the second week in June), indicating that factors such as day length may have a greater influence than temperature on adult chafer activity.
- For the reasons above, adult and larval populations of the masked chafer can be most accurately predicted on the basis of the calendar, with the first peak of adults expected during the second week in June, and the first grubs appearing in late June/early July.
- Unlike other regions of the country, where masked chafers lay eggs for only a few weeks each June, Low Desert masked chafer adults showed a second peak of activity in late August/early September. As a result, masked chafer grubs are capable of causing damage to golf course greens for a prolonged period (July through October), and multiple insecticide applications may therefore be necessary for their control.
- Black light trap samples of the black turfgrass ataenius (BTA) did <u>not</u> accurately predict the appearance of grubs in the Low Desert, although the light trap has been a fairly successful predictive tool in other regions of the state. In the Low Desert, black light trap counts indicated extremely high numbers of BTA adults present beginning in early June, leading to the assumptions that grubs would appear 2 - 4 weeks later. However, BTA grub populations were not detected on greens in the Low Desert until late August. This delay in the onset of BTA grub populations has several possible explanations which are explored below.
- Direct sampling of turf for the presence or absence of grubs proved to be highly destructive to turf and extremely time consuming. The use of an acoustic microphone that allowed the user to detect the presence of grubs via the sounds they

made chewing and moving was less destructive to turf, but also extremely time consuming.

Materials and Methods:

Black light trapping study: Beginning in 1994, black light traps (Bioquip [Gardena, CA] Model 2851 A) with 22 watt black lights (Bioquip Model 2851 L) were installed at the golf courses listed in Table 1 below. The light traps were equipped with 120 volt AC photoelectric switches (Bioquip Model 2833A) and were installed by each cooperator (Table 1) at a convenient site with electrical power (usually from irrigation control box or weather station) and within clear eye-shot of the turfgrass area under study. A two inch section of Vapona pest strip was placed in each bucket. The strip was changed monthly or sooner if live insects were found in the trap.

Insects were collected from traps by golf course personnel each Monday or Tuesday and were placed in mailing envelopes which were in turn placed in cardboard boxes for shipment to PACE Consulting. Weekly reports identifying the presence and abundance of pest insects, including the black turfgrass ataenius and the masked chafer, were provided to each cooperator via FAX by PACE Consulting. Temporary break-down of the black light trap at the Nicklaus Private Course unfortunately resulted in no samples received after June 25, 1996.

Table 1. Cooperators in the PACE Insect Black Light Trap Study, 1994 - 1996

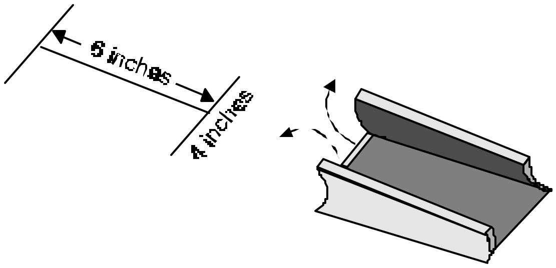
Cooperator name	**Golf course**	**Dates of participation**
Doug Anderson	The Vintage Club	3/96 - 12/96
Brian Darrock	Fairbanks Ranch Country Club	3/94 - 10/94
Raymond Davies	Virginia Country Club	3/94 - 10/94
Bruce Duenow	La Jolla Country Club	3/96 - 12/96
Bill Gallegos	Los Coyotes Country Club	3/94 - 10/94, 4/95 - 10/95, 3/96 - 12/96
Mike Gleason	Callaway Golf	4/95 - 10/95, 3/96 - 12/96
Cal Hardin	Morningside Country Club	3/96 - 12/96
Mike Hathaway	Los Angeles Country Club	3/94 - 10/94, 4/95 - 10/95, 3/96 - 12/96
Jim Husting	Woodbridge Country Club	3/96 - 12/96
Mike Kocour	The Springs Club	3/96 - 12/96
Eric Lover	Dove Canyon Country Club	3/94 - 10/94, 4/95 - 10/95, 3/96 - 12/96
David Major	Del Mar Country Club	3/96 - 12/96
John Martinez	Arrowhead Country Club	3/94 - 10/94
Ben McBrien	Sea Cliff Country Club	3/94 - 10/94, 4/95 - 10/95
Mark Phillips	Monarch Beach Links	3/94 - 10/94, 4/95 - 10/95
Kurt Rahn	Leisure World, Laguna Hills	3/94 - 10/94, 4/95 - 10/95, 3/96 - 12/96
Virgil Robinson	PGA West	3/96 - 12/96
Mark Schaer	San Luis Rey Downs	3/96 - 12/96
Reed Yenny	Mesa Verde Country Club	3/94 - 10/94, 4/95 - 10/95, 3/96 - 12/96

Grub monitoring: Grub monitoring was initiated on June 6, 1996, approximately 2 weeks after the first peak of adult BTA. Grub sampling took place at The Springs Club (bentgrass nursery), The Nicklaus Private Course (Green 1) and The Nicklaus Private Course (practice putting green). Locations were chosen at golf courses that had experienced high populations of grubs in the past, and who were willing to leave approximately 2,000 square feet of cool season turf untreated. Grub sampling was discontinued at the Springs Club in August, when mechanical failure resulted in lack of irrigation to test plots and subsequent turf death.

Detection of grubs was determined using three methods:

1. Visual inspection of turf for evidence of grub damage (thinning, wilting turf; turf that scalps or picks up easily; signs of bird damage). If potential damage was identified, the soil underneath the damaged area was examined for presence or absence of grubs.
2. Plots were sampled in three locations each for grubs by examining soil underneath a 4 inch X 6 inch rectangle of turf (see illustration below). This method proved to be quite destructive to turf, with little or no recovery from the disruption caused by sampling. As a result, an alternate method, described below, was also developed.

Using a knife, a six inch long straight line is cut through the damaged turf, cutting deeply enough to go just beyond the thatch. Perpendicular lines about 4 inches long are cut to form a “T” at either end (diagram on left). Turf is peeled back to examine soil for grubs.



3. Scientists Peng Lee and Robert Hickling of the University of Mississippi collaborated with PTRI to develop a highly sensitive acoustic detection tool (microphone) that could be used to listen to grubs moving and feeding underneath the turf. Because we specified that the microphone must be placed on top of the turf to be effective, this method had the potential to provide grub sampling information without the need to cut into turf.

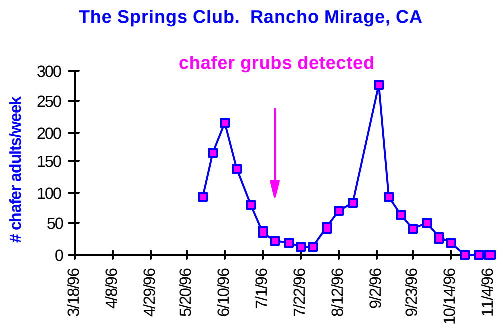
Results and Discussion

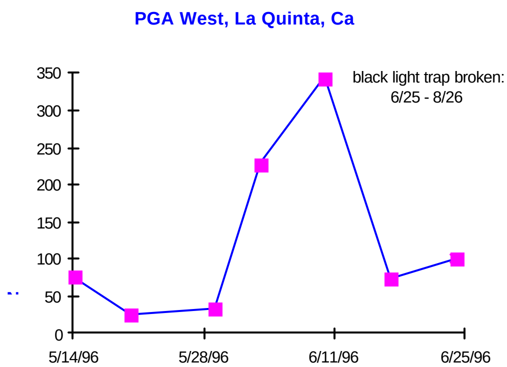
Masked chafers: Masked chafer adult populations first peaked during the second week of June (Figures 1 -2), and were a good predictor for the appearance of masked chafer grubs, which were first detected as second instar larvae on 7/12/96. Feeding of grubs on cool season turf resulted in significant damage to turf, with chafers actively feeding on roots between 1/2" and 1" beneath the thatch layer. Grubs did not appear to migrate down into the soil profile, regardless of soil temperatures which were as high as 95°F at a depth of two inches. Damage caused by chafer grubs resulted in fairly large (1 square foot or more) areas of dead and dying turf. Tunneling by the grubs often caused a characteristic pattern of long, fingerlike areas of damaged turf, arranged in a branching pattern.

Masked chafer adults continued to appear in black light trap samples through the end of October, with two distinct peaks -- one during the second week in June and the other in late August/September. Early data from 1997 confirms the appearance of these two peaks at approximately the same times as observed in 1996. The presence of two peaks of adult masked chafer activity is unprecedented, since published accounts of chafer behavior, and our own observations from coastal Southern California indicate that in those areas, chafers have a relatively brief reproductive period of a few weeks at most, during June and early July. One likely explanation is that there are two distinct species of chafers present in the Low Desert, each with different peak times of activity. Possible species include *Cyclocephala abrupta* or *Cyclocephala pasadenae,* based on host records for this genus (Richter, 1966). This unique situation in the Low Desert means that superintendents must deal with several waves of newly hatched masked chafer adults for several months (June through October), and multiple insecticide applications may be necessary.

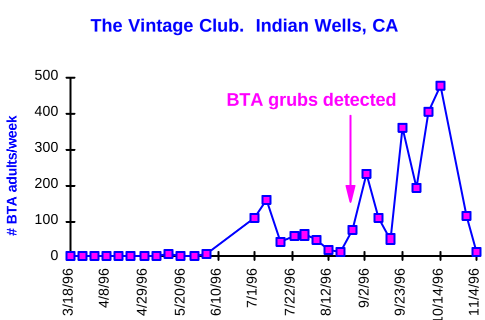
Black turfgrass ataenius: Extremely high populations of BTA adults first developed between June 4 and June 30, 1996 (Figures 3-4). These populations developed approximately two weeks earlier than populations in coastal Southern California, and were approximately ten times higher than Coastal populations. Based on the high adult populations, we expected to see large numbers of BTA grubs developing in late June and early July. However, BTA grubs were not detected at any of the test sites until August 28, 1996.

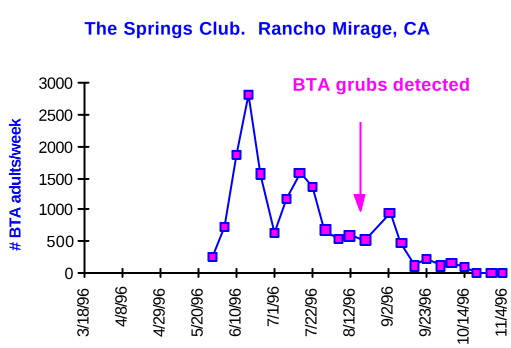
Figures 1-2. Adult masked chafer populations, from weekly black light trap counts, 1996.





Figures 3-4. Adult black turfgrass ataenius populations, from weekly black light trap counts, 1996.





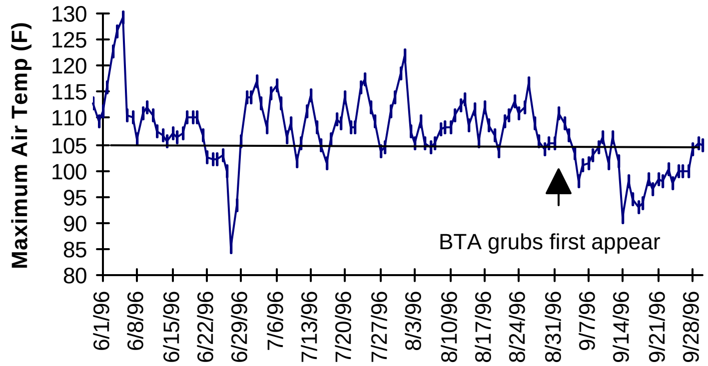
The August 28 date was significantly later in the year than we expected to see BTA grubs based on black light trap counts. It was also later than we expected based on superintendent observations that BTA grubs had been a problem in past years in June and July. Some possible reasons for this discrepancy include:

1. By sheer coincidence, BTA grubs did not occur at the three sites that were sampled, but did occur at other sites in the Low Desert.

2. In previous years, grub infestations had been mis-identified as BTA, when in fact they were chafers. This type of error is not hard to imagine, since small chafer grubs (which occur on greens beginning in late June/early July) are difficult to distinguish from large BTA grubs.

3. BTA grubs could not survive and/or BTA adults did not lay eggs at the high temperatures that occurred during June, July and August. Instead, grubs may have developed in cooler areas with higher mown turf. It was only in late August, when daylengths shortened and temperatures decreased that BTA grubs developed on greens. This hypothesis is supported by several avenues of reasoning. First, maximum air temperatures for 1996 at the Vintage Club in Indian Wells, CA (Figure 5) indicates that maximum temperatures were consistently in excess of 105° F during the period of where BTA grubs were not present (6/1/96 - 8/28/96). However, by the end of August, maximum temperatures rapidly decreased; this is when BTA grub populations began to appear. Secondly, the degree day model that was developed (see attached report "Predicting the Timing of Adult Populations of the Black Turfgrass Ataenius Using Degree Day Models") gave the most accurate predictions when it was assumed that the development of the BTA begins to slow down at temperatures higher than 75° F. It is highly likely that at temperatures over 105° F, BTA grubs either cannot survive, or development of the BTA completely ceases in a type of warm weather hibernation known as **aestivation.**

Figure 5. Maximum air temperatures for the Vintage Club, Indian Wells, CA. Note that BTA grubs did not appear on greens until maximum temperatures were below 105° F for several days.



More data is required to prove or disprove these hypotheses, although at this point, the evidence points to a combination of hypotheses 2 and 3.

The damage caused by BTA grubs was distinct from that caused by chafer grubs, with BTA feeding resulting in irregular sized patches of wilting and browning turf. BTA grubs were found feeding directly below the thatch layer, and like masked chafers, did not appear to move lower in the soil profile to escape higher soil temperatures.

Grub sampling procedures: Three grub sampling procedures were evaluated. The use of visual symptoms (thinning or wilting turf; turf that easily scalps; signs of bird damage) proved to be useful in targeting areas for further sampling, but used by itself, was not a reliable indicator for the presence of grubs. This is because several different conditions (root diseases, lack of moisture) can cause similar symptoms. Intensive soil sampling (4 samples per 100 square feet in at least 3 locations per green, every 2 weeks) provided an excellent indication of the presence or absence of grubs, but was destructive to the turf and was extremely labor intensive. The use of an acoustic microphone to detect the sounds of grubs feeding was useful in detecting the presence of masked chafer grubs, but was not as accurate for detecting the presence of the smaller BTA grub. In addition, it was extremely time consuming to use. While this tool will be useful in research projects on grub behavior, it proved not to be a practical tool for use in monitoring grub populations on a regular basis.

Overall, no one method for predicting the appearance of white grubs was infallible. It is recommended that a combination of techniques, including black light trapping, use of the degree day model presented below, a calendar driven approach treatment approach (targeting June 15 for initial preventive treatments) and sampling for grubs be combined to achieve optimum results.

References:

Richter, P.O. 1966. White grubs and their allies. Oregon State University Press, Corvallis, OR. 219 pp.

Project II: Predicting the Timing of Adult Populations of the Black Turfgrass Ataenius and the Masked Chafer Using Degree Day Models (Final Report)

Principal Investigators: Wendy Gelernter, Ph.D. and Larry J. Stowell, Ph.D., CPAg

Cooperators: Ross O'Fee and Mike Kocour, The Springs Club; Cal Hardin, Morningside Country Club; Douglas Anderson, The Vintage Club; Chris Harvell, Nicklaus Private Course (PGA West)

Sponsors: Hi-Lo Desert Golf Course Superintendents Association; Ross O'Fee and Mike Kocour, The Springs Club; Cal Hardin, Morningside Country Club; Douglas Anderson, The Vintage Club; Chris Harvell, Nicklaus Private Course (PGA West)

Summary:

A study was conducted to determine whether temperature, in the form of a degree-day model, could be utilized to more accurately predict when black turfgrass ataenius (BTA) and masked chafer adults would appear on golf courses, and therefore aid in insect management decisions.

- The model that was developed predicted the appearance of BTA adults with a range from 2 days before to 14 days after the actual peak was observed with black light trap data, which offers a better prediction than the previously developed calendar approach.
- In contrast, for masked chafers, a comparison of the degree-day approach vs. the calendar approach to predicting the occurrence of adults revealed that a calendar approach was much more precise. During 1994, 1995 and 1996, non-Desert courses had masked chafer peaks between 6/24 and 6/29, and Desert courses had peaks between 6/9 and 6/11. Preliminary data from 1997 suggests that these trends have occurred for a fourth year, leading us to expect the appearance of chafer adults every year during these time periods.
- Based on this data, preventive control measures for white grubs should be triggered by the appearance of the first peak of scarab beetle activity. In the Low Desert, this first active peak is for the masked chafer, and it occurs every year in the second week in June. Preventive insecticide applications should therefore be targeted soon after this initial chafer peak, in mid to late June. This application will also control emerging grubs of the BTA, which appear a few weeks after the masked chafer.
- Based on a comparison of the timing of masked chafer populations in the Low Desert vs. elsewhere in California, we believe that the species present outside of the Desert area, *Cyclocephala pasadenae,* is not the dominant species in the Desert. Instead, we propose that one and maybe two additional species of *Cyclocephala* are the dominant species in the Desert. In all key respects other than timing of appearance and anatomy, these chafers appear to cause the same types of damage, and are controlled by the same types of insecticide products as is *C. pasadenae.*

Background: Grubs of the black turfgrass ataenius, *Ataenius spretulus,* and the masked chafer, *Cyclocephala* spp., have been difficult to control on golf courses, primarily because they remain hidden beneath the soil for the majority of their life cycle, and are detected only when irreversible damage has been caused. For this reason, a variety of methods have been explored for their ability to better predict the timing of grub appearance including:

- Soil sampling: this is the most direct method for determining whether grubs are present, but because many samples (more than 5 samples per green, taken every 2 weeks from June - October) must be taken, this method is too destructive and too labor consuming to be practical.
- Black light trapping: using this method, adults of the BTA and masked chafer are captured in black light traps and their numbers quantified on a weekly basis. High numbers of adults in the traps indicates that the turf damaging grubs will be present 2 -4 weeks later. While this method is usually fairly accurate in predicting the appearance of grubs, it has its limitations (see attached report " Predicting the Timing of Adult and Larval Populations of the Black Turfgrass Ataenius and the Masked Chafer Using Black Light Traps") and costs including labor (traps must be maintained and insects collected weekly).
- Temperature based models: as opposed to the direct methods described above, which rely on counts of insects, degree day models use a temperature driven mathematical model to predict the appearance of insects and other living organisms. The advantage of these models is that little labor is required to use them (a calculator or computer and local temperature data is all that's required). However, because the

models are theoretical, they can only estimate when insects are likely to appear.

The value of using temperature to predict plant and animal growth was recognized by the French scientist Renè A. F. de Rèaumur in 1735. By adding together the daily average air temperatures that occurred during the life cycle of several different plant species, he discovered that the sum of temperatures for each species was the same from year to year, even though the number of days required for development varied. In other words, a **thermal constant**, or a specific amount of heat was required for a plant to reach maturity, and this amount of heat was characteristic for each plant species or variety.

de Rèaumur's use of summed temperatures to predict development was supported by the fact that most plant pests, whether they are weeds, insects, fungi or bacteria, are **ectothermic** (meaning "heat from the outside"), or what used to be called "cold-blooded" organisms. The body temperature of ectotherms is based primarily on the temperature of their surroundings, making them sensitive to changes in temperature. Therefore, an increase in air temperature will cause a similar increase in the growth rate of an ectotherm. This relationship between temperature and growth in ectotherms allows us to use temperature to tell us a great deal about the timing and life cycles of ectothermic animals and plants. In contrast, **endothermic** organisms, which include most birds and mammals, regulate their body temperature primarily with heat generated within the organism. There is little relationship between the growth rate of endotherms and the temperature of their environment.

<u>The need for degree-day units:</u> The concept of the thermal constant, which applies to insects, plants and other ectotherms, is the basis for development of the degree-day concept. At the turn of the 20th century, scientists began to propose that the thermal constant be expressed in units called day degrees. Since that time, these units have been called by a variety of names (heat units, degree-days, day degrees, growing degree-days, growth units), but the most commonly used term, and the one I will use throughout this article is **degree-days,** sometimes represented as **°D**. Degree-days can be calculated on both Celsius and Fahrenheit temperature scales, but the values are not interchangeable. There are nine Fahrenheit degree-days for every five Celsius degree-days.

Since the first degree-day models were proposed early this century, over one hundred models now exist that forecast everything from the harvest dates of grains, vegetables and fruits to optimal crop planting dates to the best crop varieties for different geographical areas. Beginning in the 1970s, many degree-day models were developed for agricultural insect pests ranging from the alfalfa weevil to the vegetable leafminer. The majority of degree-day models for turf insect pests have been developed only in the last 15 years.

Degree-day theory and calculations

To calculate the amount of heat an organism is exposed to throughout its life, most of us would at first simply add together the average daily temperatures experienced by the organism, as de Rèaumur did. However, this method will fail at accurately predicting insect life cycles. The reason for this is the effect of very cold and very hot temperatures, or the **developmental thresholds,** on insect growth.

<u>Developmental Thresholds</u>: All organisms live within a relatively narrow range of temperatures above and below which their survival becomes difficult. The **lower developmental threshold** (sometimes also called the base temperature) is the temperature at or below which growth stops. The **upper developmental threshold** is the temperature at or above which growth slows down or stops. The number of degree-days accumulated in one day is the total amount of heat between the lower and upper thresholds (see Example 1 below).

Example 1: Simplified degree-day calculation for one day

1. Potter (1981) has determined the lower developmental threshold for masked chafers to be 51° F
2. The average temperature for one day is 60° F.
3. The number of degree-days accumulated by chafers on that one day is (60° F - 51° F) X 1 day = 9 degree-days.

<u>Degree-day calculations</u>**:** In the simplest terms, degree-days are units of total accumulated heat. Generally, each developmental stage of an organism has a characteristic degree-day requirement. For example, from the time an insect egg is laid until the time larvae hatch from the egg may require 100 degree-days, while the time period between larval hatch and pupation may require 175 degree-days.

The way in which temperature data is utilized determines the complexity of the degree-day model. The simplest degree-day models rely on recording only the daily minimum and maximum temperatures. These temperatures are added together and divided by two to determine the average daily temperature, as illustrated in Example 2 below.

Example 2: Using minimum and maximum temperatures to determine daily average temperatures.

1. The minimum temperature recorded for the day is 55° F and the maximum temperature for the same day is 75° F.
2. The average temperature for the day is then (75° F + 55° F)/2 = 65° F.
3. The hairy chinch bug has a lower development threshold of 45° F. Therefore, the total number of degree-days accumulated by chinch bugs for this day is (65° F - 45° F) X 1 day = 20 degree-days.
4. If the average temperature the next day is a bit higher, at 70° F, then the number of degree-days accumulated that day is (70° F - 45° F) X 1 day = 25 degree-days.
5. The total number of degree-days accumulated by chinch bugs over the two day period is then 20 + 25 = 45 degree-days.

The type of calculation described above has the advantage that degree-days can be determined using only a thermometer that records maximum and minimum temperatures and a simple hand calculator. However, this method has been criticized by many for ignoring the fact that temperatures fluctuate significantly during the day. To remedy this, several models now rely on weather data that is averaged on an hourly, rather than on a daily basis.

Additional precision in temperature data can be achieved by using the maximum and minimum temperatures to generate a **sine curve**, an operation that is easily performed on a personal computer. Because the sine curve does a good job of simulating a 24 hour temperature cycle with cooler temperatures in the early morning and late evening and the highest temperatures during mid-day (Figure 6), it becomes possible to take a more detailed look at daily temperature cycles, and thus to achieve even more precision in degree-day estimates.

Using the **sine curve method**, a computer model estimates degree-days by calculating the area above the lower threshold temperature and below the upper threshold temperature. The shaded areas in Figure 7 represent the number of degree-days accumulated for each of the two days.

Although many additional methods have been proposed in the literature for representing daily temperature cycles, most models rely on some version of the sine curve method described above. It has been shown to be fairly accurate in determining degree-day values, but it does require the use of a computer.

Figure 6. Temperature cycle for two 24 hour periods, as illustrated by a sine curve.

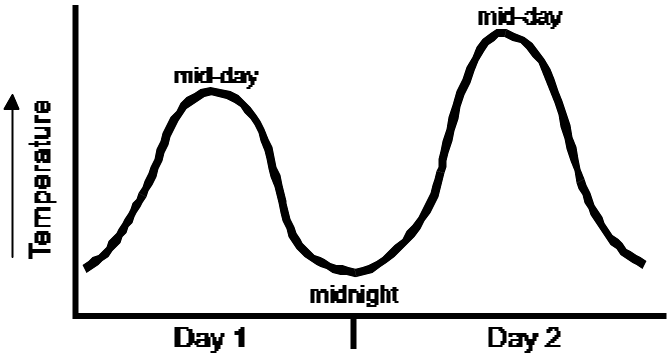
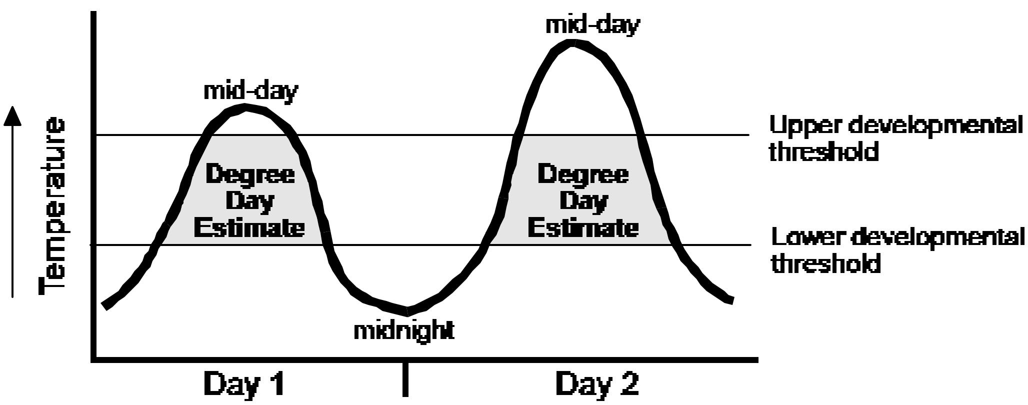


Figure 7: Calculation of degree-days using the sine curve method. The area indicated by shading equals the number of degree-days for each 24 hour period. Through the use of published computer programs, the shaded areas under the sine curve can be easily calculated and converted into degree-day values.



Materials and Methods:

Black light trapping study: Beginning in 1994, black light traps (Bioquip [Gardena, CA] Model 2851 A) with 22 watt black lights (Bioquip Model 2851 L) were installed at the golf courses listed below. The light traps were equipped with 120 volt AC photoelectric switches (Bioquip Model 2833A) and were installed by each cooperator at a convenient site with electrical power (usually from irrigation control box or weather station) and within clear eye-shot of the turfgrass area under study. A 2-inch section of Vapona pest strip was placed in each bucket. The strip was changed monthly or sooner if live insects were found in the trap.

Insects were collected from traps by golf course personnel each Monday or Tuesday and were placed in mailing envelopes which were in turn placed in cardboard boxes for shipment to PACE Consulting. Weekly reports identifying the presence and abundance of pest insects, including the black turfgrass ataenius and masked chafers, were provided to each cooperator via FAX by PACE Consulting.

Cooperators and locations where black light trap data was collected for use in development of a black turfgrass ataenius and masked chafer degree-day models.

Cooperator name	Golf course	CIMIS Station #	Dates of participation
Doug Anderson	The Vintage Club	on-site	3/96 - 12/96
Mike Hathaway	Los Angeles Country Club	99 (Santa Monica)	3/94 - 10/94
Mike Hathaway	Los Angeles Country Club	99 (Santa Monica)	4/95 - 10/95
Mike Hathaway	Los Angeles Country Club	99 (Santa Monica)	3/96 - 12/96
Jim Husting	Woodbridge Country Club	42 (Lodi)	3/96 - 12/96
Mike Kocour	The Springs Club	999 (Thermal)	3/96 - 12/96
David Major	Del Mar Country Club	66 (San Diego)	3/96 - 12/96
Ben McBrien	Seal Cliff Country Club	102 (Long Beach)	3/94 - 10/94
Reed Yenny	Mesa Verde Country Club	102 (Long Beach)	3/94 - 10/94
Reed Yenny	Mesa Verde Country Club	102 (Long Beach)	3/96 - 12/96

Development of degree-day model: A modified single sine wave method was used to calculate degree days based on the method of Allen (Allen, 1976). Black turfgrass ataenius and masked chafer adult population data was obtained from black light trap weekly counts from seven locations, and collected over a period of three years. Average air temperature data was obtained from the CIMIS station closest to the golf course (see above).

To determine the lower and upper developmental thresholds, an empirical process was used. The number of days between peaks of BTA or masked chafer adults at each location was determined via examination of black light trap data. Using the 1994 and 1996 Mesa Verde Country Club BTA data as an example, the data in Figures 8 and 9 and Table 2 were obtained. Note that the number of days between BTA peaks varies widely -- from 19 days at the shortest, to 49 days at the longest. This is not surprising, since the role of the weather during these time periods is at least as important as the actual number of days between peaks.

Figure 8. Black turfgrass ataenius population dynamics via black light trap data. Mesa Verde Country Club, 1994.

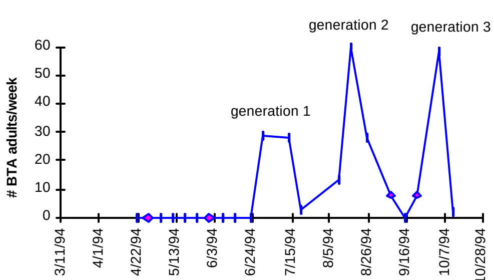


Figure 9. Black turfgrass ataenius population dynamics via black light trap data. Mesa Verde Country Club, 1996.

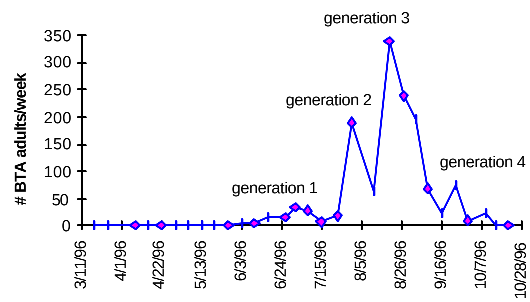


Table 2. Black turfgrass ataenius peaks for Mesa Verde Country Club, 1994 and 1996. Data was obtained via weekly black light trap counts of adult ataenius beetles.

Peak #	Date of peak	# days between peaks
1	6/29/94	----
2	8/16/94	48
3	10/4/94	49
1	7/1/96	----
2	7/31/96	30
3	8/19/96	19
4	9/23/96	35

With this information in hand for each location, the number of degree-days between BTA and masked chafer peaks was calculated using the single sine method (Allen, 1976) and using the 12 different combinations of threshold temperatures listed below in Table 3. An example of the results of these calculations (for BTA at Mesa Verde Country Club, 1994) is shown in Appendix 2.

Table 3. Developmental threshold temperatures (°F) evaluated for development of the black turfgrass ataenius and masked chafer degree day models.

Lower threshold	Upper threshold
50	90
50	85
50	80
50	75
45	90
45	85
45	80
45	75
40	90
40	85
40	80
40	75

When the data from all locations was compared, the combination of a 50°F minimum threshold and 75°F maximum threshold produced the most consistent degree day values among all locations for a generation of both the BTA or masked chafer. When averaged over all locations, this value was 680 degree days (± 108 degree days) per BTA generation (see Appendix 3). For masked chafers, data from Low Desert courses was handled separately from the remaining California data, based on our belief that different species of masked chafers occur in the Desert than in the rest of the state. For the non-Desert courses, the model estimates 1861 degree days (± 210 degree days) from January 1 of each year to the appearance of the first masked chafer peak (see Appendix 3). For the Desert courses, we had insufficient data to develop a model, due to breakdown of traps at all but one golf course, and the break down of CIMIS station 50 (Thermal) between February and March of 1997. The source code for the Microscoft Access degree day function used to generate degree days appears in Appendix 4.

Results and Discussion:

Black turfgrass ataenius: The BTA model, using a value of 680 degree days between BTA generations, a minimum threshold of 50° F and a maximum threshold of 75° F, predicted the appearance of BTA adult peaks with rough accuracy. The predictions had a spread of 35 days around the actual peak, and ranged from as much as 15 days before the actual peak to as much as 20 days after the actual peak (Table 4). However, for courses in the Low Desert, accuracy was much better, with a spread of only 16 days, and ranged from 2 days before the actual peak to as much as 14 days after the actual peak.

As an alternative to the degree day model, black light trapping data can be utilized to develop a calendarized approach to predicting BTA populations. While we know that BTA populations do not actually occur on the same date every year, they do occur on approximately the same date, and it is possible that the level of accuracy of this calendarized approach may be equal to or even better than we obtained with the degree day model. To test this theory, we looked at black light trap data from 1996 which indicates that the first peak of BTA adults occurred between 6/4/96 and 7/1/96 at Low Desert golf courses. In 1997, black light trap data shows BTA peaks occurring between 6/23/97 and 7/7/97, or about 19 days later. In other words, for 1997, the accuracy of a calendar approach was not as good as that of the degree day approach (with deviations from the actual peak of 19 days [calendar approach] vs. 14 days or less [degree day model]).

Masked chafers: For non-Desert golf courses, where the dominant species of masked chafer is *Cyclocephala pasadenae,* a value of 1861 degree days between January 1 and the first masked chafer peak, and a minimum threshold of 50° F and a maximum threshold of 75° F was used to predict masked chafer populations. Once again, accuracy levels were rough (Table 5), with a spread of 34 days, ranging from as much as 20 days before the actual peak to as much as 14 days after the actual peak. For Desert courses, where the dominant species of masked chafer is an unidentified species of *Cyclocephala,* we were unable to create a model, due to lack of data (black light traps were broken at other courses and the Thermal CIMIS (50) station was not operating from 2/2/97-3/12/97). This lack of a model for the Low Desert is not as much of a problem as it initially appears, due to an even more precise approach that is revealed when the black light trap data for masked chafers is carefully reviewed.

The black light trap data for masked chafers (Tables 5 and 6) is remarkable in the similarity of dates from year to year and location to location that masked chafer adults peaks occurred. For example, at the non-Desert courses (Table 5), masked chafers peaked between 6/24 and 6/29 in 1994, 1995 and 1996, with only one exception. At Desert courses (Table 6), the first masked chafer peak was two weeks earlier, on dates between 6/9 and 6/11 (this two week gap is one possible piece of evidence that different species of masked chafers in the Desert than elsewhere in California). This data indicates that the most precise way to predict the appearance of masked chafers is on the basis of a calendar approach (with a maximum spread of 5 days around the actual peak), rather than a degree-day or other mathematical based approach (with a maximum spread of 20 days around the actual peak). This is probably due to the fact that environmental factors tightly linked with the calendar, such as daylength, have a more important effect on masked chafer development than temperature.

Table 4. Accuracy of black turfgrass ataenius degree-day model, using 680 degree days between generations and minimum and maximum threshold temperatures of 50° F and 75° F, respectively. Data from Desert courses is printed in **bold** letters.

Location	Predicted BTA peak	Actual BTA peak	Accuracy (days)
Del Mar CC	7/2/96	7/8/96	-6
Del Mar CC	8/8/96	7/29/96	+ 10
Del Mar CC	9/9/96	8/20/96	+20
Los Angeles CC	7/17/94	6/29/94	+18
Los Angeles CC	8/20/94	8/17/94	+3
Los Angeles CC	7/21/95	8/1/95	-11
Los Angeles CC	8/25/95	9/5/95	-11
Los Angeles CC	7/16/96	7/29/96	-13
Los Angeles CC	8/24/96	8/26/96	-2
Mesa Verde CC	7/12/94	6/29/94	+13
Mesa Verde CC	8/17/94	8/16/94	+1
Mesa Verde CC	9/22/94	10/4/94	-12
Mesa Verde CC	6/16/96	7/1/96	-15
Mesa Verde CC	7/22/96	7/31/96	-9
Mesa Verde CC	8/22/96	8/19/96	+3
Mesa Verde CC	9/24/96	9/23/96	+1
Sea Cliff CC	7/22/94	7/27/94	-5
Sea Cliff CC	8/22/94	8/17/94	+5
The Springs Club	**6/15/96**	**6/17/96**	**-2**
The Springs Club	**7/14/96**	**7/15/96**	**-1**
The Springs Club	**9/3/96**	**9/3/96**	**0**
The Springs Club	**10/17/96**	**9/23/96**	**+14**
The Vintage Club	**7/11/96**	**7/8/96**	**+3**
The Vintage Club	**9/4/96**	**9/3/96**	**+1**
The Vintage Club	**10/3/96**	**10/14/96**	**+11**
Woodbridge CC	4/25/96	4/8/96	+17
Woodbridge CC	6/8/96	5/6/96	+33
Woodbridge CC	7/18/96	7/1/96	+17
Woodbridge CC	8/23/96	8/12/96	+11

Table 5. Accuracy of masked chafer degree-day model developed using all courses except Desert courses, using 1861 degree days from 1/1 to the first adult peak, and minimum and maximum threshold temperatures of 50° F and 75° F, respectively.

Location	Predicted chafer peak	Actual chafer peak	Accuracy (days)
Del Mar CC	6/21/96	6/26/96	-5
Los Angeles CC	7/6/94	6/29/94	+7
Los Angeles CC	7/10/95	6/27/95	+13
Los Angeles CC	7/3/96	6/24/96	+9
Mesa Verde CC	7/2/94	7/13/94	-11
Mesa Verde CC	7/3/95	6/27/95	+6
Mesa Verde CC	6/6/96	6/26/96	-20
Woodbridge CC	7/8/96	6/24/96	+14

Table 6. Dates of the first masked chafer peak each year at Low Desert golf courses

Location	Actual chafer peak
The Springs Club	6/10/96
The Springs Club	6/9/97
PGA West	6/11/96
The Vintage Club	broken trap; no data
The Vintage Club	6/9/97

Accuracy of the models: By and large, degree-day models have not provided highly accurate estimates of insect development cycles, and the same can be said for the models we have developed for the BTA and the masked chafer. This moderate level of accuracy is probably due to a variety of factors including:

- Heterogeneity of habitats: Insects develop in a number of different habitats (golf course greens, higher mown turf, livestock pastures, leaf litter on the forest floor [Wegner and Niemczyk, 1981]) where temperatures on any given day can vary widely. This means that the model might be accurate for some, but not all of the BTA or chafers we see on the golf course.
- Role of other environmental factors: Temperature is the only consideration taken into account in development of this model, but insects may also respond to factors such as relative humidity and precipitation.
- Role of daylength: As we have seen with masked chafers, factors such as daylength may play a more important role than temperature in the development of some insects.

Conclusions:

For masked chafers, a comparison of the degree-day approach vs. the calendar approach to predicting the occurrence of adults revealed that a calendar approach was much more precise. Non-Desert courses had masked chafer peaks between 6/24 and 6/29, and Desert courses had peaks between 6/9 and 6/11 of each year.

Predicting the occurrence of BTA adults was more complex, partly due to the occurrence of multiple generations. However, the degree model gave fairly high levels of accuracy for Desert courses, with a maximum error of 14 days in predicting adult peaks. In this case, the degree day model proved to be more accurate than a calendar approach in predicting the appearance of BTA adults.

We know from the attached studies that it is important to manage both masked chafers and BTA grubs on Low Desert golf courses. For this reason, control tactics for white grubs should be triggered by the first large peak of whichever insect occurs first -- the BTA or the masked chafer. We now know, via the black light trap data, that throughout California, the first significant peak of adult beetle activity comes in June (early June for the Desert, late June for the rest of California) from the masked chafer, to be followed a few weeks later by the first significant BTA peak. A logical management approach is therefore to time the first preventive grub applications soon after key the first key adult masked chafer peak. Using this logic, mid-June to late June should be targeted in the Low Desert for the first preventive white grub applications. These applications will also control BTA grubs, which will occur a few weeks later than masked chafer grubs.

References:

Allen, J.C. 1976. A modified sine wave method for calculating degree days. Environ. Entomol. 5:388-396.

Potter, D.A. 1981. Seasonal emergence and flight of northern and southern masked chafers in relation to air and soil temperature and rainfall patterns. Environ. Entomol. 10:793-797.

Wegner, G.S. and H. D. Niemczyk, 1981. Bionomics and phenology of *Ataenius spretulus.* Ann. Entomol. Soc. Am. 74:374-384.

Project III: Efficacy of Chemical and Biological Controls for Black Turfgrass Ataenius and Masked Chafers (Final Report)

Principal Investigators: Wendy Gelernter, Ph.D. and Larry J. Stowell, Ph.D., CPAg

Cooperators: Ross O'Fee and Mike Kocour, The Springs Club and Chris Harvell, PGA West

Sponsors: Hi-Lo Desert Golf Course Superintendents Association, Bayer Corporation, Valent Corporation

Summary: Research trials were implemented to determine efficacy, optimal timing, phytotoxicity and residual activity of conventional insecticides and biological agents for control of the black turfgrass ataenius (BTA) and masked chafers. Key findings include:

- The most effective treatments were Dylox (trichlorfon), Merit (imidacloprid), Orthene (acephate) and Pinpoint (acephate granule). No phytotoxicity was observed.
- Merit provided excellent preventive control of white grubs, although its activity declined significantly between 8 and 10 weeks after application. This suggests that two applications of Merit may be necessary to maintain control during the critical months of June, July and August.
- Split applications of Merit, with 0.1 oz/1000 applied once in mid-June and again 6 - 8 weeks later, appear to have promise for prolonging the period of grub control.
- Applications of Dylox or Orthene provided excellent curative control of grub populations. However, these products have brief residual activity and therefore must be applied several times per season for optimum control.
- Dursban, considered by some to be the industry standard for grub management, did not provide acceptable control of white grubs. Other ineffective treatments included two biological insecticides (M-Press and Cruiser), and Tame (a pyrethroid).

Materials and Methods:

Locations: Locations were chosen at golf courses that had experienced high populations of grubs in the past, and who were willing to leave approximately 2,000 square feet of cool season turf untreated.

1. The Springs Club (bentgrass nursery), Mike Kocour, superintendent, Rancho Mirage, CA
2. Nicklaus Private Course (bentgrass putting green), Chris Harvell, superintendent, La Quinta, CA
3. Nicklaus Private Course (green 1 [bentgrass]), Chris Harvell, superintendent, La Quinta, CA

Treatments: Two different protocols were implemented as described below. The seven treatments originally funded by the Hi-Lo Desert GCSA and Bayer Corporation were increased, via funding from Valent Corporation, to include several Orthene treatments.

A. Treatments tested at The Springs Club and Green 1, Nicklaus Private Course

	PRODUCT	RATE/1000 SQ FT	FREQUENCY	DATE OF APPLICATION
1.	**Dylox 80****	3.75 oz:	2 applications	6/28, 8/27
2.	**Merit 75 WSP**	0.15 oz	1 application	6/13
3.	**Merit 75 WSP**	0.2 oz	1 application	6/13
4.	**Merit 75 WSP**	0.1 oz	2 applications	6/13, 8/27
5.	**Cruiser Bioinsecticide**	35 million	2 -3 applications	6/28*
6.	**M-Press Bioinsecticide**	6 lb	2 -3 applications	6/28*
7.	**No treatment**			
8.	Orthene TTO	1.5 oz	2 applications	6/28, 8/27
9.	Orthene TTO	1.9 oz	2 applications	6/28, 8/27
10.	Orthene TTO + Tame	1.5 oz + 0.37 oz	2 applications	6/28, 8/27

* Applications discontinued due to lack of efficacy

** Treatments in bold type are those originally funded by the Hi-Lo Desert GCSA and Bayer Corporation. Treatments in plain type were funded by Valent Corporation.

B. Treatments tested at the Nicklaus Private Course, practice putting green

	PRODUCT	RATE/1000 SQ FT	FREQUENCY	DATE OF APPLICATION
1.	**Dylox 80**	3.75 oz:	2 applications	6/28, 8/27
2.	**Merit 75 WSP**	0.15 oz	1 application	6/13
3.	**Merit 75 WSP**	0.2 oz	1 application	6/13
4.	**Merit 75 WSP**	0.1 oz	2 applications	6/13, 8/27
5.	**Cruiser Bioinsecticide**	35 million	2 -3 applications	6/28*
6.	**M-Press Bioinsecticide**	6 lb	2 -3 applications	6/28*
7.	**No treatment**			
8.	Orthene TTO	1.9 oz	2 applications	6/28, 7/14
9.	Orthene TTO + Tame	1.9 oz + 0.37 oz	2 applications	6/28, 7/14
10.	Dursban Pro	6 oz	2 applications	6/28, 7/14
11.	Orthene TTO + M-Pede	1.9 oz + 1%	2 applications	6/28, 7/14
12.	Tame	0.37 oz	2 applications	6/28, 7/14
13.	Pinpoint (granular Orthene)	0.75 lb	2 applications	6/28, 7/14

* Applications discontinued due to lack of efficacy

** Treatments in bold type are those originally funded by the Hi-Lo Desert GCSA and Bayer Corporation. Treatments in plain type were funded by Valent Corporation.

Applications: All insecticide applications were made with a CO_2 powered bicycle sprayer using tandem booms and 8008vs flat fan nozzles which delivered 30 psi at the boom and 3.76 gallons per 1,000 square feet. Calibration of each nozzle was confirmed prior to each application to be within 5% of the desired nozzle flow rate. the boom height was adjusted to 17 inches. The spray swath was 7.2 feet. Speed was monitored using a wheel driven speedometer at 2.0 mph (periodically calibrated to be within 5% of the actual speed). Five gallon stainless steel beverage spray tanks were filled with water to the desired dilution volume using a Great Plains Industries (Wichita, KS) digital flow meter, calibrated to deliver volumes within 1% of the digital value displayed on the meter. Tanks were agitated by shaking twenty times prior to charging with compressed CO_2. The spray lines were purged with CO_2 and then water prior to changing treatments. Irrigation was applied after treatment with 1/10 inch of water delivered to plots. Products were applied on the dates indicated on the treatment lists above.

Application Timing: Applications were timed to target newly hatched grubs. To do this, black light traps were installed at three golf courses in the Low Desert, and adult populations were monitored weekly (see report: " Predicting the Timing of Adult and Larval Populations of the Black Turfgrass Ataenius and the Masked Chafer Using Black Light Traps"). The first masked chafer peak occurred between 5/20/96 and 6/10/96 and the first BTA adult peaks occurred on 6/3/96. As a result, the first applications were made soon thereafter, between 6/13 and 6/28, to target small chafer and BTA larvae. Applications of Cruiser and M-Press were discontinued after the first application, due to lack of efficacy.

Sampling: Beginning 6/13/96, plots were sampled every two weeks for the presence of grubs and/or evidence of damage from grub feeding. Sampling was accomplished using three different methods (see attached report: "Predicting the Timing of Adult and Larval Populations of the Black Turfgrass Ataenius and the Masked Chafer Using Black Light Traps ")

Plot layout: Plots measured 7 X 10 feet at The Springs Club and at Green 1, Nicklaus Private Course, and measured 7 X 20 feet at the putting green, Nicklaus Private Course. Plot diagrams are attached (Figures 10 -12).

Results and Discussion: Masked chafer grubs were first detected at the two PGA West sites on 7/12/96, and newly hatched chafer grubs continued to be observed through the end of August . At the Springs Club, mechanical failure of water pumps on two occasions led to the death of turfgrass and the destruction of our plots.

Black turfgrass ataenius grubs were present only in low numbers, and therefore efficacy responses could not be measured for this pest. Although BTA grub efficacy was not obtained in these trials, masked chafer populations were sufficiently high at one location for valid efficacy tests. The results are summarized in Table 7 below.

Overall, treatment with Dylox, Merit or Orthene provided good control of masked chafer grubs on the 7/12/96 rating date. Chafer grubs treated with these products continued to stay in check at successive rating dates of 7/24 and 8/8/96. However, by the 8/27/96 rating date, none of the products (with the exception of the 0.10 rate of Merit), was effective at controlling chafer populations. Therefore, given the 6/13 application date for Merit, the residual control offered by Merit was 10 weeks or less. The observation that Merit activity was less than the expected 4 months had also been noted by many superintendents following the summer of 1995. The control offered by Orthene, Pinpoint (a granular form of Orthene) and Dylox (with 6/28 and 7/14 application dates) was 6 weeks or less. For these two products, whose half life is just a matter of days, the 6 weeks of good control is probably not due to residual activity, but instead to optimal timing of the application (when the majority of grubs were small), which knocked down grub populations until the next flight of adults occurred, about 4 -6 weeks later.

The results indicate that split applications of Merit, at 0.1 oz/1000 in June, and again 6 - 8 weeks later, can prolong the effective period of grub control with this product. However, the value of this strategy could not be completely confirmed in this trial due to the lack of significant insect populations following the second application on 8/27/96. However, based upon the excellent performance of the 0.1 oz rate of Merit, the strategy of split applications should provide superior grub control, for a minimum of 12 weeks. This strategy also maintains compliance with the label restriction that no more than 0.2 oz/1000 be applied per year.

The lack of control observed with Orthene plus M-Pede was somewhat unexpected. However, the fact that M-Pede has a high pH (10 or more) may have resulted in inactivation of Orthene. Lack of control with Tame (a pyrethroid) and Dursban was somewhat expected, based on published literature and superintendent's experiences. There is little or no evidence that pyrethroids or Dursban are able to penetrate lower than the thatch layer, which is a requirement for targeting grubs, which feed primarily below the thatch layer. Lack of control with the two biological insecticides, Cruiser and M-Press, was disappointing. These products deserve further investigation, since they are more sensitive than most products to subtleties in timing, application method and environmental conditions. Unfortunately, the high standards demanded on golf course greens did not allow us to continue our investigation of these products without the risk of incurring significant turf damage due to grubs. For this reason, Cruiser and M-Press were dropped from the trial in early July. In the future, we should consider placing further investigations with these products in a less demanding environment, perhaps on rented space at a sod farm.

With the potential addition of Orthene to the arsenal of registered products for grub control (registration on turf in California is expected soon), superintendents will have three effective products available for use in managing grub pests -- Dylox/Proxol, Merit and Orthene. Given the long period of time that grubs can cause damage to turf (June through October) and the lack of any product with sufficient residual activity to cover this time period, these products should all be components of future programs for grub management. With the longest residual activity, Merit should remain the centerpiece of these programs, and should be utilized when grub populations are highest and turf is most stressed (June - August), with split applications given serious consideration as a means of extending the period of residual control. Where grub populations have been high in the past, biweekly Orthene or Dylox applications should be considered before Merit is applied (early June) and again after Merit activity has subsided (late August, September and October, if necessary).

References:

Richter, P.O. 1966. White grubs and their allies. Oregon State University Press, Corvallis, OR. 219 pp.

Table 7. Efficacy of Insecticides Against Masked Chafer Grubs. Nicklaus Private Golf Course, PGA West. La Quinta, CA. Efficacy was assessed by rating the frequency of chafer grub damage in each plot, where 0 = no damage observed, 0.3 = damage in 1 replicate (yellow shading in boxes), 0.7 = damage in 2 replicates (pink shading in boxes) and 1.0 = damage in all three replicates (blue shading in boxes). Any value other than 0 is considered unacceptable chafer damage. Values followed by the same letter are not significantly different (Fisher's LSD, P<0.05).

Product	**Rate/1000 sq ft**	**7/13/96**	**7/24/96**	**8/8/96**	**8/27/96***
Dylox 80	3.75 oz	**0.0a**	**0.0a**	**0.0a**	**0.3b**
Merit 75 WSP	0.10 oz (split applications)	**0.0a**	**0.0a**	**0.0a**	**0.0a**
Merit 75 WSP	0.15 oz (single application)	**0.0a**	**0.0a**	**0.0a**	**0.3b**
Merit 75 WSP	0.20 oz (single application)	**0.0a**	**0.0a**	**0.0a**	**0.3b**
Orthene TTO	1.9 oz	**0a**	**0a**	**0a**	**0.3b**
Pinpoint	0.75 lb	**0a**	**0a**	**0a**	**0.3b**
Orthene TTO + Tame	1.9 oz + 0.37 oz	**0.3ab**	**0.3ab**	**0.3ab**	**1.0b**
Orthene TTO + M-Pede	1.9 oz + 1%	**0.3ab**	**0.3ab**	**0.7b**	**0.7b**
Dursban Pro	6.0 oz	**0.7b**	**0.7b**	**0.7b**	**0.7b**
Tame	0.37 oz	**0.7b**	**0.7b**	**0.7b**	**1.0b**
Untreated	----------------	**0.7b**	**0.7b**	**0.7b**	**1.0b**

* values for 8/27/96 ratings were significant at the 0.10 level only

Figure 10. Plot plan for The Springs Club, Bentgrass Nursery (plots are 7 feet X 10 feet)

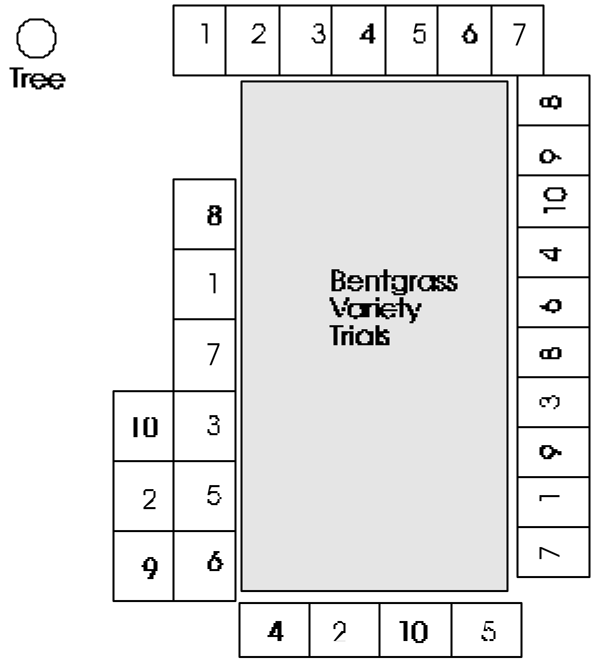


Figure 11 Plot plan for PGA West, Nicklaus Private Course, Green 1 (plots are 7 feet X 10 feet)

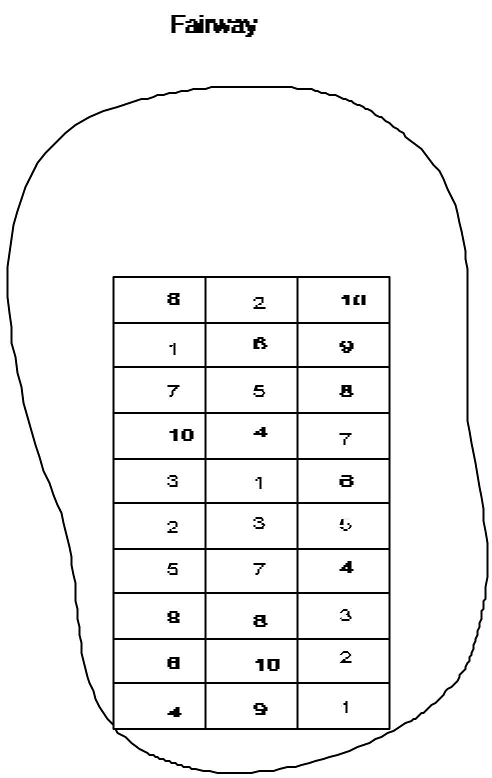


Figure 12. Plot Plan for PGA West, Nicklaus Private Course, Practice Putting Green: (plots are 7 feet X 20 feet)