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TURFGRASS TRENDS

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TURFGRASS WEED CONTROL

Predict Smooth Crabgrass Emergence Using Degree-Days

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THE CRABGRASSES (*Digitaria* spp.) were originally cultivated as a grain crop, and were grown for food thousands of years before gaining a reputation as a troublesome weed in turfgrasses and agricultural crops (Mitich, 1988). For example, crabgrass was an important food crop in China in 2,700 B.C. In 1849, the United States Patent Office introduced large crabgrass as a forage crop. Today, both large and smooth crabgrass are considered the most competitive, destructive, and invasive weeds in turfgrass sites maintained on golf courses, lawns, and landscapes (Figure 1).

Crabgrass can be effectively controlled through the intervention of cultural practices, and herbicides. However, the ability to predict crabgrass seedling emergence might allow turfgrass managers to precisely time and target weed control strategies. A successful crabgrass control program with a pre- or postemergence herbicide depends on accurate application timing, which is related to the stage of crabgrass growth and development. For example, a preemergence herbicide that is applied too late in the spring will not provide control for the crabgrass that has already germinated and emerged.

In one of the earliest published investigations on crabgrass population biology in turfgrass culture, Gianfagna and Pridham (1951) reported that large crabgrass germinated from May 25 to September 15 in New York. One of the first published reports on crabgrass

Figure 1. Smooth crabgrass in perennial ryegrass test plots. University of Maryland, Silver Spring, MD.

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emergence timing was by Peters and Dunn (1971) who observed over a three year period that large and smooth crabgrass first emerged in mid-to-late May, which coincided with the flower withering of *Forsythia* spp. and the onset of the flowering dogwood (*Cornus* spp.). However, this method can be unreliable at times. For example, in the Mid-Atlantic region in 1998, the warm weather attributed to "El Nino" caused the dogwoods to bloom in mid-February. At this time, soil temperatures remained too low for crabgrass seed germination.

Using other occurrences in nature to predict stages in a pest's lifecycle is related to the science of phenology. Phenology is the study of the relationship between biological events, such as seedling emergence, plant growth, plant development, or an insect's lifecyle, and the environment (specifically temperature). Typically, temperature is used in the development of plant and pest predictive methods since the growth and development of plants and other organisms is dependent on temperature (Danneberger, 1993). A precise way to relate the effects of temperature on plant growth and development is with degree-days.

Degree-days are calculated from temperature data and are used to establish a relationship between temperature and biological processes or events (Baskerville and Emin, 1969). Some synonymous terms used to describe the process of accumulating temperature information over time to predict plant and pest growth processes include: degree-days, growing degree-days, heat units, heat sums, or thermal units (Ritchie and Nesmith, 1991). This measure of accumulated degrees or heat is known as physiological time or thermal time, and this time is measured in degree-days (Ritchie and Nesmith, 1991; Zalom et al., 1983). Many degree-day based methods and models have been developed for use in turfgrass management (Table 1). For a more detailed description on calculating degree-days, please refer to "A Note On Calculating Degree-Day Accumulation" included with this article.

Developing a crabgrass degree-day model

Materials and Methods

Recently, research was conducted at the University of Maryland (at Silver Spring, MD, near Washington, D.C.) with the purpose of developing a reliable degree-day based method for determining the onset of smooth crabgrass emergence in turfgrass and the extent of smooth crabgrass emergence throughout the season (Fidanza et al., 1996; Fidanza, 1997).

This three-year field study was initiated in 1992, however, data from 1993 and 1994 were used to develop a degree-day model for smooth crabgrass emergence (1992 data was incomplete). In 1992, the study was conducted on a mature stand of 'Fylking' Kentucky bluegrass. In 1993, the study was conducted on a mature stand of 'Sydsport' plus 'Merion' Kentucky bluegrass blend. In 1994, the site was a mature blend of unknown perennial ryegrass cultivars. All sites had a history of crabgrass infestation, and were located in close proximity to each other. At each site, the turfgrass plots were maintained at two mowing heights, 1.5 inch versus 2.5 inch, and mowed twice weekly, with clippings removed.

Smooth crabrass emergence was monitored at both mowing heights on a weekly basis from April 1 through August 31. At the University of Maryland test site, records kept since 1982 indicated that smooth crabgrass typically first germinates in bare ground areas during late April to mid-May. Since soil temperatures typically are not favorable for crabgrass germination prior to April 1 in the mid-Atlantic and northern regions of the US, this appeared to be a reasonable starting date for initiating degree-day accumulation. Obviously, the starting date would vary in other regions, especially in the southern areas.

In each experimental plot, smooth crabgrass seedlings were counted and removed from three permanent or fixed grids per plot measuring 10 by 10 inches. Air and soil temperatures were measured with thermocouples, and were monitored and recorded with a datalogger, which is essentially a microcomputer that measured and recorded the environmental information (Figure 2). Two air temperature sensors were used, and three soil temperature sensors were placed in each plot. Air and soil temperatures were recorded at five-minute intervals, averaged each hour, and averaged for each 24-hour period. Air temperatures were measured 12 inches above the turfgrass canopy, and soil temperatures were measured at the 0, 1-, and 2-inch depth.

Although both air and soil temperatures were monitored and recorded, degree-days were calculated from soil temperature data at the 1-inch soil depth because temperatures recorded at this depth were highly correlated statistically with smooth crab-

TABLE 1. MODELS DEVELOPED FOR USE IN TURF MANAGEMENT USING DEGREE DAYS, ENVIRONMENT-BASED DATA, OR PEST BIOLOGY.*

Proposed models for the growth and development of turfgrasses and turfgrass weeds.

Target:	Description:	Reference:
Annual Bluegrass	Predicts seedhead emergence	Danneberger and Vargas, 1984. Agronomy Journal 76:756-758.
Annual Bluegrass	Timing of seedhead control method	Danneberger, Branham, and Vargas, 1987. Agron. J. 79:69-71. Branham and Danneberger, 1989. Agron. J. 81:741-752.
Annual Bluegrass	Predicts temperature stress periods	Danneberger and Street, 1985 Ohio J. Sci. 85:108-111.
Cool-Season Turf	Predicts temperature stress periods	Danneberger and Street, 1985. Inter. Turf. Conf. 5:802-806.
Kentucky Bluegrass	Predicts root growth	Koski, Street, and Danneberger, 1988. Crop Science 28:848-850.
Smooth Crabgrass	Predicts seedling emergence	Fidanza, Dernoeden, and Zhang, 1996. Crop Science 36:990-996.
Tall Fescue	Predicts seedhead emergence	DiPaola, Lewis, and Gilbert, 1987. Agronomy Abstr. 13.

Proposed models for environment-based turfgrass disease warning or risk systems.

Anthracnose	Disease forecast model	Danneberger, Vargas, and Jones, 1984. Phytopathology 74:448-451.
Brown Patch	Disease warning model	Fidanza, Dernoeden, and Grybauskas, 1996. Phytopathology 86:385-390.
Brown Patch	Disease occurrence periods	Schumann, Clarke, Rowley, and Burpee, 1994. Crop. Prot. 13:211-218.
Dollar Spot	Disease occurrence periods	Hall, 1984. Canadian J. Soil Science 64:167-174.
Pythium Blight	Disease forecast system	Nutter, Cole, and Schein, 1983. Plant Disease 67:1126-1128.

Proposed models for predicting the life cycle of turfgrass insect pests.

Chinchbug	Predicts life cycle	Lin and McEwen, 1979. Environ. Ent. 8:512-515.
Sod Webworm	Predicts life cycle	Tolley, 1986. Journal of Econ. Ent. 79:400-404.
Fruit Fly	Predicts life cycle	Tolley and Niemczyk, 1988. J. of Econ. Ent. 81:1346-1351.

*adapted from: Danneberger, T.K. 1993. Turfgrass ecology and mangement.

grass emergence. However, air temperature data also could have been used to calculated degree days. With degree-day based predictive methods, many organisms rely on a base temperature of 50 degrees F, however, it was determined that a base temperature of 54 degrees F was the proper temperature to use for this smooth crabgrass study at this test site in Silver Spring, MD. At the Maryland test site, crabgrass seedlings typically emerged when the minimum soil temperature reached 54 degrees F.

Expressing crabgrass in terms of a population enables us to develop a weed population model to estimate plant population behavior and weed emergence patterns over time.

Results

Actual smooth crabgrass seedling emergence trends were similar in 1993 and 1994 (Figures 3 and 4). During both years, seedlings first emerged sporadically prior to a short, rapid emergence period, immediately followed by a decline in emergence. A second rapid emergence period occurred (more pronounced in 1994), which was followed by a steady decrease through to the end of the season. For the purposes of this field study, these rapid emergence periods were referred to as major emergence periods. Despite the differences in the onset of seed germination and the major emergence period in 1993 and 1994, seedling count data from both mowing heights were similar (data not shown). Since turf cover was uniform within the fixed grids, the lack of crabgrass competition was probably the primary factor responsible for the similar seedling counts between mowing heights in 1993 and 1994. Therefore, seedling counts averaged across both mowing heights are shown in figures 3 and 4.

Soil temperatures and degree-day accumulation associated with smooth crabgrass emergence periods are listed in Table 2. In 1992, smooth crabgrass seedlings were first observed on April 26 on bare ground areas near the test site. Seedling emergence in the study area was first observed on May 4. Between April 27 and May 3, seven days prior to first emergence, the minimum and average soil temperatures were 55 and 61 degrees F, respectively. Degree-day accumulation since April 1 across the site averaged 52.

In 1993, seedlings were first observed in the plot area on April 26, which corresponded to minimum and average soil temperatures of 51 and 57 degrees F, respectively. Average degree-day accumulation since April 1 was 42. During the major emergence period of May 17 to July 6, minimum and average soil temperatures were 67 and 73 degrees F, respectively, and began when the degree-days total reached 140.

In 1994, crabgrass seedlings first

TABLE 2. SOIL TEMPERATURES AT 1 INCH DEPTH AND CUMULATIVE DEGREE-DAYS RELATING TO EMERGENCE OF SMOOTH CRABGRASS.

Year	Soil temperature (°F) at the 1" depth averaged over a 7-day period prior to the first emergence period			Soil temperature (°F) at 1 inch depth during the major emergence period		
	Minimum	Average	Degree Days[1]	Minimum	Average	Degree Days[1]
1992	55	61	52	—[2]	—[2]	—[2]
1993	51	57	42	67	73	140
1994	55	64	78	69	77	230
3-Year Average	54	61	57	68	75	185

[1]Degree-days calculated beginning April 1 using a base temperature of 54°F. [2]Data not available.
University of Maryland Turfgrass Research Facility, Silver Spring, MD.

emerged on April 29, coinciding with minimum and average soil temperatures of 55 and 64 degrees F, respectively, and began when the degree-days total reached 78. The major emergence period occurred between June 1 and June 29, with minimum and average soil temperatures equal to 69 and 77 degrees F, respectively, and began when the degree-days accumulated to 230.

Over the three-year period, in this study the smooth crabgrass first emerged when minimum soil temperatures averaged 54 degrees F, and the degree-day accumulation averaged 57. Utilizing only 1993 and 1994 data, the major emergence period began with minimum soil temperatures reached an average of 68 degrees F and when an average of 185 degree-days were accumulated.

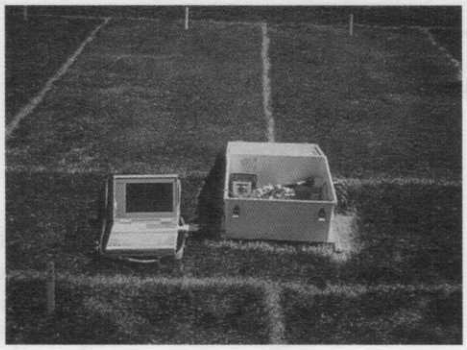

Figure 2. Datalogger and laptop computer used to download air and soil temperature data from the University of Maryland test site.

Since smooth crabgrass seedling counts per square foot and degree-day information differed from year to year, the 1993 and 1994 data was converted to represent cumulative percent emergence over time, essentially expressing the crabgrass population as a percentage that has emerged over time. Expressing the crabgrass in terms of a population, instead of individual seedlings emerged per square foot, enables us to develop a weed population model that can be used to estimate plant population behavior and weed emergence patterns over time.

Over time, the cumulative seed germination curve is typically sigmoidal or "s" shaped and begins with a lag phase (little or no emergence), followed by an exponential phase (period of rapid emergence), then levels off as emergence subsides (Bahler et al., 1989).

In this study, when the actual seedling emergence counts were expressed as cumulative percent emergence, no statistical differences were detected between mowing heights or between years. Cumulative smooth crabgrass emergence expressed as a percentage, was accurately described by a "model" (Figure 5). The "observed" values in figure 5 are the results from actual 1993 and 1994 data, and the "predicted" values were calculated from the mathematical equation or model.

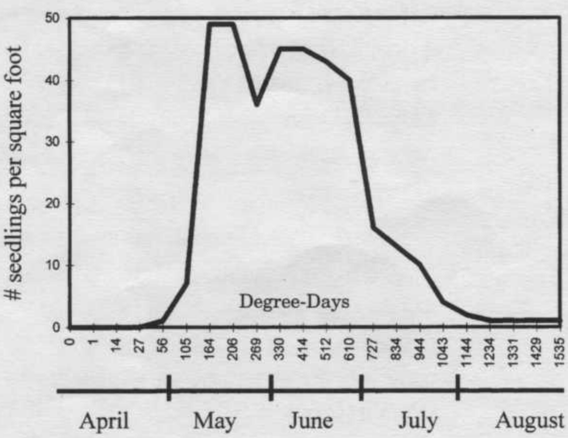

Figure 3. Smooth crabgrass seedlings averaged across turfgrass mowing height treatments of 1.5 and 2.5 inches. 1993

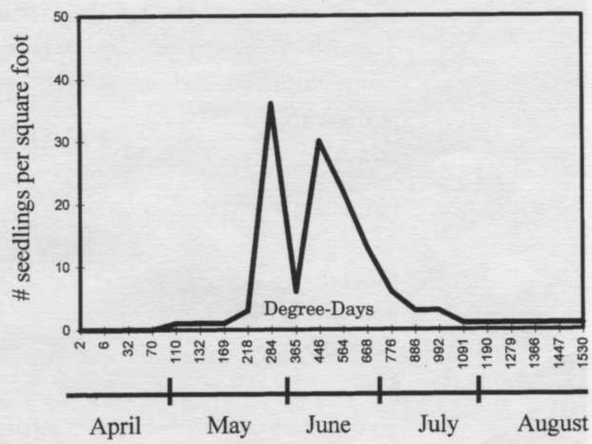

Figure 4. Smooth crabgrass seedlings averaged across turfgrass mowing height treatments of 1.5 and 2.5 inches. 1994

Practical applications for degree-days to predict crabgrass emergence.

The use of degree-days observations on crabgrass germination and emergence, and emergence patterns expressed as cumulative emergence data over time, could be used as a guide for targeting pre- and post-emergence herbicide applications. Herbicide strategies for crabgrass management fit into four programs: (1) preemergence, (2) pre- followed by post-emergence, (3) pre- plus post-emergence tank-mix, and (4) total post-emergence.

For example, referring to figure 5, a pre-emergence herbicide applied at 300 degree-days would have missed 25 percent of the crabgrass that has already germinated and emerged. In this case, a pre- and post-emergence herbicide tank-mix would probably work best, with the post-emergence herbicide targeting the 25 percent of the crabgrass population that has already emerged, and the pre-emergence herbicide targeting the 75 percent of the crabgrass population that has yet to germinate and emerged.

Also, degree-days can provide information about the crabgrass population, and assist the turfgrass manager with deciding on the proper and most effective herbicide strategy. Refer to table 3 for a list of commonly used pre- and post-emergence herbicides for crabgrass control in turfgrasses.

Turfgrass managers can utilize their own local weather and temperature data, and their own observations about the crabgrass emergence occurrences at their particular site, to develop their own degree-day based predicton method. The University of Maryland study was conducted over a three-year period, however, the more sea-

TABLE 3. LIST OF PRE- AND POSTEMERGENCE HERBICIDES COMMONLY USED FOR CRABRASS CONTROL IN TURFGRASSES*

Preemergence crabgrass control herbicides:

Common Name	Trade Name (Manufacturer)
benefin	-Balan (Dow AgroSciences)
benefin + trifluralin	-Team (Dow AgroSciences and others)
bensulide	-Betasan (many)
DCPA	-Dacthal (ISK Biosciences and others)
dithiopyr	-Dimension (Rohm and Haas)
oryzalin	-Surflan (Dow AgroSciences)
oxadiazon	-Ronstar (Rhone Poulenc)
pendimethalin	-Pre-M (many)
prodiamine	-Barricade (Novartis)
siduron	-Tupersan (many)

Postemergence crabgrass control herbicides:

dithiopyr	-Dimension (Rohm and Haas)
fenoxaprop-p-ethyl	-Acclaim Extra (AgrEvo)
fluazifop-p-butyl	-Fusilade II (Zeneca)
MSMA	-Daconate (ISK Biosciences)
	-MSMA (LESCO)
	-many others

*No endorsement of named products is intended, nor is criticism implied for products that are not mentioned.

sons included in the observations, then the more accurate your degree-day predictions should be. It is important to realize that biological occurrences won't begin on a specific degree-day total, but rather will respond to a range of degree-days (for example, with the University of Maryland study, crabgrass first germinated within a degree-day range of 42 to 78).

Further research is needed to confirm the relationship between degree-day accumulation and smooth crabgrass emergence on a regional basis. Also, both air and soil temperatures should be evaluated for calculationg degree-day accumulation. In addition, information on soil moisture can further improve the degree-day based prediction methods. In conclusion, degree-day methods and models should become more useful to turfgrass managers who will be able to utilize this information to make more knowledgeable decisions regarding herbicide use in their integrated turfgrass management programs.

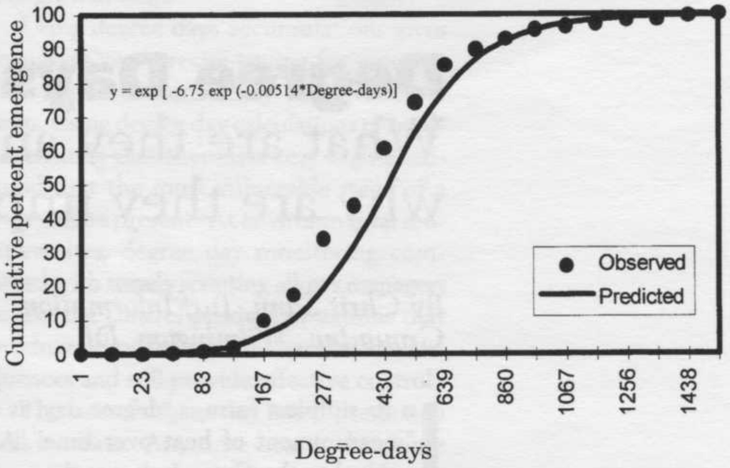

Figure 5. Cumulative percentage smooth crabgrass emergence versus degree-day accumulation combined for 1993 and 1994. Observed = actual crabgrass emergence; predicted = predicted crabgrass emergence generated from degree-day model.

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