Relating Degree-Day Accumulations to Calendar Dates: Alfalfa Weevil (Coleoptera: Curculionidae) Egg Hatch in the North Central United States

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ABSTRACT We present a technique for determining dates of alfalfa weevil, *Hypera postica* (Gyllenhal), egg eclosion by correlating degree-day accumulations with calendar dates. This technique uses historical climate data from various locations to calculate the median date a degree-day accumulation has been reached. ClimProb 3.1, a computer software program and weather database, was used to assess these correlations. We used 165 locations in 12 midwestern states for the analysis. Sixty years (1931–1990) of continuous daily climate data (maximum temperature, minimum temperature, and liquid precipitation) were used for each location. We began degree-day accumulations on 1 January of each year and used a minimum developmental threshold of 8.9°C (48°F). Degree-day accumulations were determined using a sine-wave method. The relationship between the date when the accumulated degree-days reached a threshold and the location (expressed as degrees north latitude) was quadratic from 36° N to 48° N. The technique gives approximate dates when egg hatch is likely to occur throughout the north central United States, and these dates can be used to augment existing decision criteria for initiating sampling programs for alfalfa weevil. This technique can be used for other pest management programs that depend on estimating pest development.

KEY WORDS Curculionidae, *Hypera postica,* degree-day, sampling

DECIDING WHEN TO initiate sampling programs for arthropod pests involves 2 basic approaches: monitoring and timing. Monitoring refers to broad qualitative sampling of pests or their effects which is then used to initiate more quantitative sampling programs (Higley and Peterson 1994). Timing refers to considerations of seasonality, weather, and temperature that may help determine when to initiate sampling programs.

Degree-days (DD) are used in integrated pest management programs primarily to time sampling activities. Sampling activities need to be timed properly because it is inefficient to sample when the pest is not active or present. Conversely, financial risk may be incurred by waiting too late to sample because economic damage can occur before a management tactic is used.

Using calendar dates to initiate sampling activities has long been used for insect pests. This timing approach has been successful for many pests because of the relationship between insect life histories and seasonal cycles, especially in temperate climates (Higley and Peterson 1994). However, the calendar dates traditionally used have been determined from subjective experience, rather than from intensive research. Consequently, calendar dates are not as precise as degree-day accumulations. In a sense, calendar dates are analogous to nominal economic thresholds (Poston et al. 1983); they may be imprecise, but they are better than using nothing at all. Indeed, in many instances, these nominal calendar dates represent the only practical technique available for determining when to begin sampling. Monitoring techniques, such as trapping or surveying, may be too expensive, or degree-days may not be known for specific pest species (Higley and Peterson 1994).

Although degree-day accumulations are more precise, calendar dates are a valuable technique for determining when to initiate sampling programs. Calendar dates can be used by growers and consultants who do not have access to current, or real-time, degree-day information. However, this approach can be made more precise by using long-term temperature data from various locations to determine the average date when a degree-day accumulation has been reached. Such a technique can make it possible to progress from nominal calendar dates to calculated calendar dates. Herbert et al. (1988) used historic temperature data from 47 locations throughout Alabama to determine degree-day accumulations for 5 soybean insect pests. They then mapped isothermal regions to identify areas where the pests would be most likely to develop at faster rates.

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In this article, we determine dates for alfalfa weevil, *Hypera postica* (Gyllenhal), egg eclosion by correlating degree-day accumulations with calendar dates. ClimProb 3.1, a computer software program and weather database developed in the Department of Agricultural Meteorology at the University of Nebraska-Lincoln, was used in these assessments.

Materials and Methods

ClimProb. ClimProb 3.1 (Meyer et al. 1994) assesses specific climatic events by assigning probabilities to the likelihood of occurrence of those particular events, based on historical climate data. After ClimProb is accessed, a historic daily climate file is selected, a specific time window is opened, and a desired analysis is chosen. ClimProb offers 17 temperature analyses, 6 precipitation analyses, and 8 DD analyses. Depending on the analysis selected, threshold values may need to be specified. The software then generates a chronological history of the climatic event selected for the time window that has been opened. The climatic events are then placed in ranked order and probabilities are assigned from a direct count of their incidence in the long-term history of the climate station (rank per number of years of record).

Most ClimProb data sets are derived from the National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS) Cooperative Observer Network. The remaining data sets come from NWS 1st-order stations (airport stations). The data are maximum temperature, minimum temperature, precipitation, and date (month, day, year). Because ClimProb assigns probabilities based on the length of record of the climate station, it follows that the longer the climate history the more value the generated probabilities hold. Therefore, ClimProb data sets are at least 50 yr in length, with many data sets in the Midwest and Great Plains region approaching 100 yr.

Analysis. Using ClimProb, we determined the date when alfalfa weevil egg hatch is likely to occur for 165 locations in 12 Midwest states. Sixty years (1931–1990) of continuous daily climate data were used for each location.

Input variables for the specific degree-day routine in ClimProb include the minimum developmental threshold (°C or °F), the maximum developmental threshold (°C or °F), the degree-day accumulation, the beginning date for accumulation, and the degree-day calculation method. We began degree-day accumulations on 1 January of each year and used a minimum developmental threshold of 8.9°C (48°F). We did not use an upper developmental threshold because this parameter typically is not used for alfalfa weevil. Most insects typically do not experience temperatures at the developmental maximum during spring development in temperate regions (Higley et al. 1986, Higley and Wintersteen 1987).

We used 93, 121, and 149°C degree-days as accumulations for alfalfa weevil egg hatching. Egg eclosion typically occurs between 93 and 149°C degree-days (200–300°F DD), depending on fall oviposition activity (Wedberg et al. 1980, Whitford and Quisenberry 1990, DeGooyer 1993). The accumulations we chose are commonly used in Cooperative Extension Service recommendations throughout the midwestern United States (for example, Wedberg et al. 1980, Foster 1986, Higley and Wintersteen 1987).

Degree-day accumulations were determined with a sine-wave method (the temperature curve was approximated as a sine wave, and degree-day accumulations were calculated as the area under the sine wave and above a minimum developmental threshold) (Higley et al. 1986).

Results and Discussion

The relationship between the date when degree-days reached a predetermined accumulation and location (expressed as degrees north latitude) was quadratic from 36° N to 48° N. These results can be used to identify approximate dates when egg hatch is likely to occur throughout the north central United States (Fig. 1). Different frequencies of occurrence for the dates at which degree-day accumulations occur are presented so that decision makers can consult a variety of probability levels for deciding when to initiate sampling (Fig. 1).

The results presented here can be used to augment existing decision criteria for initiating sampling programs for alfalfa weevil. For example, in West Point, NE (41° 50′ N, 96° 43′ W), 121 DD typically are accumulated around 26 April (median value); that is, 50% of the occurrences will occur either before or after 26 April. In terms of extremes, 121°C DD have been accumulated as early as 30 March and as late as 17 May for that location. Therefore, a decision maker may choose the 25% frequency date as a relatively conservative guide, and begin sampling on 21 April.

Although latitudes can be used to identify likely dates when an accumulated degree day threshold would occur, differences among locations within latitudes exist. These differences are primarily caused by changes in elevation and regional climatology. The higher elevation and lower humidities of the semiarid High Plains tend to produce a greater range in diurnal temperatures than is observed in the subhumid Midwest. Differences may also result from variations in observation times, topography, and urbanization (Baker et al. 1985). Therefore, we believe that results from individual locations should be consulted first to assure that the most accurate dates are used.

Even though there is a strong correlation between the day of year and latitude for each degree-day accumulation, it is necessary to determine if calculated calendar dates for individual locations are more accurate than potential nominal calendar

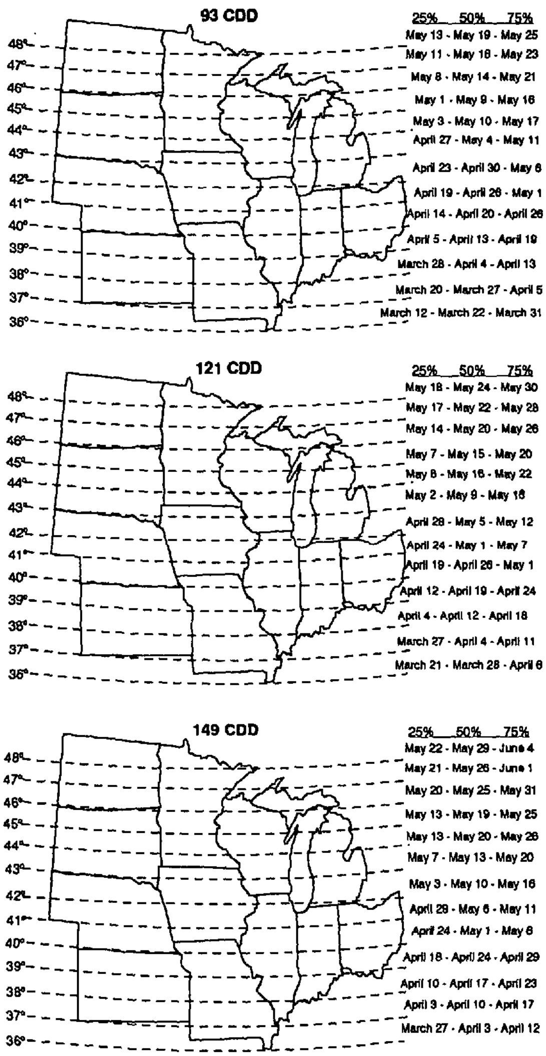

Fig. 1. Relationship between calendar dates and latitude for 3 DD accumulations for alfalfa weevil egg hatch. Calendar dates refer to different probabilities of occurrence.

date recommendations for initiating sampling. This determination is required because our analysis is based on a large data set, which may obscure individual location differences. Therefore, we analyzed results from 7 locations throughout the Midwest by comparing nominal dates with calculated dates (Table 1). For each location, the nominal dates, based on early- to midmonth sampling initiation scenarios, were at much lower frequencies of occurrence (0–11%) than the calculated dates, based on a 25% frequency of occurrence of 121°C DD accumulations. Therefore, the nominal dates were more conservative guides than the calculated dates. Because only 75% of the occurrence dates would occur after the 25% frequency date (as opposed to 89–100% for the nominal dates), the calculated dates would miss alfalfa weevil egg hatch

Table 1. Comparison of nominal calendar dates and calculated calendar dates for 7 locations in the Midwest

Location	Nominal calendar date[a]	Calculated calendar date[b]
Langdon, ND (48° 45′ N, 98° 20′ W)	7 May (3%) 15 May (10%)	21 May (25%)
Cloquet, MN (46° 42′ N, 92° 31′ W)	7 May (1%) 15 May (7%)	23 May (25%)
Ames, IA (42° N, 93° 39′ W)	7 April (1%) 15 April (6%)	26 April (25%)
Gothenburg, NE (40° 56′ N, 100° 10′ W)	1 April (1%) 7 April (7%)	13 April (25%)
Columbus, OH (40° N, 82° 53′ W)	1 April (2%) 7 April (7%)	19 April (25%)
Hillsboro, IL (39° 9′ N, 89° 29′ W)	15 March (0%) 1 April (9%)	7 April (25%)
Winfield, KS (37° 14′ N, 96° 59′ W)	7 March (2%) 15 March (11%)	22 March (25%)

Percentages in parentheses indicate frequencies of occurrence for the dates at which accumulations occurred.
[a] Based on early to midmonth decision guides.
[b] Based on 121°C DD accumulation analysis.

more often. However, by using the nominal calendar dates as a guide, unnecessary sampling would occur before egg hatch 89–100% of the time. In most situations in which nominal date recommendations are used, sampling would begin 1–2 wk before egg hatch. Consequently, the calculated dates provide more efficient decision recommendations for the initiation of sampling.

We used the 3 DD accumulations because they have been used to initiate sampling activities for alfalfa weevil in midwestern states. Differences in fall ovipositional patterns in different regions of the alfalfa weevil's geographical range lead to differences in the timing of egg hatch and larval populations the following spring. Studies of northern populations (specifically in eastern Ontario, Michigan, and Wisconsin) have revealed that adult weevils seldom oviposit in the fall because of cool temperatures (Casagrande and Stehr 1973, Litsinger and Apple 1973, Harcourt et al. 1977). Conversely, for southern populations (for example, in Oklahoma), ovipositional activity in the fall is more common (Berberet et al. 1980). In intermediate regions, such as Nebraska, Iowa, Illinois, Indiana, and Ohio, fall oviposition is variable depending on climatic conditions, with more fall oviposition at lower latitudes (Niemczyk and Flessel 1970, Hsieh and Armbrust 1974, Foster 1986, DeGooyer 1993). Therefore, specific degree-day accumulations most likely need to be used for different locations in the Midwest.

In this analysis, we only correlated degree-day accumulations to calendar dates for alfalfa weevil egg hatch in the Midwest. An important advantage to using ClimProb is that it can be adapted for numerous situations as they relate to pest management decision making. Users can input any degree-day accumulation for any phenological event. For example, for stalk borer, *Papaipema nebris* (Guenée), users can input degree day values for egg hatch (316°C DD) and 4th-instar development (760°C DD) (Lasack et al. 1987). Similarly, degree-day values have been calculated for every life stage of the alfalfa weevil, so values can be entered for the stage of interest.

Degree-day accumulations for several insect species, such as alfalfa weevil, begin on a specific calendar date. However, for other species, accumulations begin after specific life history events. For example, accumulations for green cloverworm, *Plathypena scabra* (F.), black cutworm, *Agrotis ipsilon* (Hufnagel), and European corn borer, *Ostrinia nubilalis* (Hübner), begin after significant moth flights (Hammond et al. 1979, Showers 1983, Kaster and Showers 1984). For black cutworm, accumulations begin after the 1st significant migratory flight. For green cloverworm, accumulations begin after the initial migratory flight and for each subsequent generation flight. For these situations, ClimProb can be used to correlate calendar dates to accumulated degree-days because the user can input the date of moth flight instead of a fixed calendar date.

Real-time degree-day accumulations are the most accurate predictors for egg hatch and other life-history events for alfalfa weevil. Therefore, real-time degree-days should be used when possible. However, results from this study indicate calendar dates from which sampling can be initiated when real-time degree-day accumulations are not available. Moreover, calendar dates and corresponding locations can be presented graphically.

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References Cited

Baker, D. G., E. L. Kuehnast, and J. A. Zandlo. 1985. Climate of Minnesota part XV: normal temperatures (1961–1980) and their application. University of Minnesota Agric. Exp. Stn. AD-SB-2777.

Berberet, R. C., K. M. Senst, K. E. Nuss, and W. P. Gibson. 1980. Alfalfa weevil in Oklahoma: the first ten years. Oklahoma Agricultural Experiment Station Bulletin, B-751. Oklahoma State University, Stillwater.

Casagrande, R. A., and F. W. Stehr. 1973. Evaluating the effects of harvesting alfalfa on alfalfa weevil (Coleoptera: Curculionidae) and parasite populations in Michigan. Can. Entomol. 105: 1119–1128.

DeGooyer, T. 1993. Phenology and population dynamics of the alfalfa weevil, *Hypera postica* (Coleoptera: Curculionidae), in central and southcentral Iowa. M.S. thesis, Iowa State University, Ames.

Foster, D. E. 1986. Scouting for and managing the alfalfa weevil. Iowa State University Cooperative Extension, IC-428, Ames.

Hammond, R. B., F. L. Poston, and L. P. Pedigo. 1979. Growth of the green cloverworm and a thermal-unit system for development. Environ. Entomol. 8: 639–642.

Harcourt, D. G., J. C. Guppy, and M. R. Binns. 1977. The analysis of intrageneration change in eastern Ontario populations of the alfalfa weevil, *Hypera postica*, (Coleoptera: Curculionidae). Can. Entomol. 109: 1521–1534.

Herbert, D. A., T. P. Mack, R. B. Reed, and R. Getz. 1988. Degree-day maps for management of soybean insect pests in Alabama. Alabama Agricultural Experiment Station Bulletin 591, Auburn University, Auburn, AL.

Higley, L. G., and R.K.D. Peterson. 1994. Initiating sampling programs. *In* L. P. Pedigo and G. D. Buntin [eds.], Handbook of sampling methods for arthropods in agriculture. CRC, Boca Raton, FL.

Higley, L. G., and W. Wintersteen. 1987. Using degree days in an integrated pest management program. Iowa State University Cooperative Extension, Pm-1296, Ames.

Higley, L. G., L. P. Pedigo, and K. R. Ostlie. 1986. DEGDAY: a program for calculating degree-days, and assumptions behind the degree-day approach. Environ. Entomol. 15: 999–1016.

Hsieh, F., and E. J. Armbrust. 1974. Temperature limits of alfalfa weevil oviposition and egg density in Illinois. J. Econ. Entomol. 67: 203–206.

Lasack, P. M., W. C. Bailey, and L. P. Pedigo. 1987. Assessment of stalk borer (Lepidoptera: Noctuidae) population dynamics by using logistic development curves and partial life tables. Environ. Entomol. 16: 296–303.

Litzinger, J. A., and J. W. Apple. 1973. Oviposition of the alfalfa weevil in Wisconsin. Ann. Entomol. Soc. Am. 66: 17–20.

Kaster, L. V., and W. B. Showers. 1984. Modeling black cutworm (Lepidoptera: Noctuidae) field development in Iowa. Environ. Entomol. 13: 384–389.

Meyer, S. J., S. A. Ameri, and K. G. Hubbard. 1994. User's guide: ClimProb 3.1—software for assisting climate-related decision making. High Plains Climate Center, Report 94-5, University of Nebraska-Lincoln, Lincoln.

Niemczyk, H. D., and J. K. Flessel. 1970. Population dynamics of alfalfa weevil eggs in Ohio. J. Econ. Entomol. 63: 242–247.

Poston, F. L., L. P. Pedigo, and S. M. Welch. 1983. Economic injury levels: reality and practicality. Bull. Entomol. Soc. Am. 29: 49–53.

Showers, W. B. 1983. Management of the European corn borer. North Central Regional Publication 22. Iowa State University, Ames.

Wedberg, J. L., W. G. Ruesink, E. J. Armbrust, D. P. Bartell, and K. L. Steffey. 1980. Alfalfa weevil pest management program. Illinois Cooperative Extension Service Circular 1136, Urbana-Champaign, IL.

Whitford, F., and S. S. Quisenberry. 1990. Population dynamics and seasonal biology of the alfalfa weevil (Coleoptera: Curculionidae) on alfalfa in Louisiana. Environ. Entomol. 19: 1443–1451.

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