INSECT PHENOLOGY AND INTEGRATED PEST MANAGEMENT

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Abstract. Success of any pest management program requires knowing when to apply a treatment. Due to year to year weather variation, the calendar method is the least precise. Plant phenology is a more precise way to time treatments but it is subject to years when insect and plant development are not well synchronized. Pheromone trapping can be very precise but few tree and shrub insects have had their pheromones analyzed or synthesized. Insect phenology, the direct relationship of insect development to weather, can be precise and has been adapted for computer application. Lower developmental threshold, degree day, cumulative degree days, model, normal temperatures, and observed temperatures, terminology used in computer-generated predictions of insect development, are defined. One computer program created by the University of Minnesota Extension Service for predicting insect development and developing custom models is briefly described.

Résumé. Le succès de tout programme de gestion des insectes et des maladies requiert des renseignements quand il faut appliquer un traitement. Dû aux variations climatiques d;une année à l'autre, la méthode du calendrier est la moins précise. La phénologie de la plante est une voie plus précise pour programmer les traitements dans le temps mais elle est assujettie aux années quand les développpements de l'insecte et de la plante ne sont pas correctement synchronisés. Le piégeage aux phéromones peut être très précis mais peu d'insectes d'arbres et d'arbustes ont eu leur phéromone analysée ou synthétisée. La phénologie de l'insecte, relation directe entre le développement de l'insecte avec le climat, peut être précise et la été adaptée pour des applications sur informatique. Le seuil de développement minimal, le degré-jour, les degrés-jours cumulatifs, le modèle, les normales de temperature, les températures observées et la terminologie utilisée dans l'ordinateur de génération de prédictions du développement de l'insecte sont définis. Un programme informatique créé par l'Extension Service de l'université du Minnesota pour la prédiction du développement de l'insecte et le développement de modèles pratiques est brièvement décrit.

Timing is critical for successful insect control. Insects are not equally vulnerable in all stages of development and pesticides are active for relatively short periods of time (a few days to a few weeks). For these reasons, it is important that chemicals be applied in a way that puts the active chemical in contact with the insect at the right time. The same applies to using biological control organisms whose release must be timed to coincide with specific life stages of the pest insect.

Several techniques can be used to decide when to begin control measures but these vary in their precision and usefulness. The least precise approach involves using the calendar method. An arborist may routinely treat for a given insect at the same time each year. However, spring weather conditions can change considerably from year to year (6) with some springs being very early and others very late. The tremendous variation in spring weather means that applications will be timed incorrectly much of the time when we rely on the calendar to establish treatment schedules.

Plant phenology, the relationship that exists between weather and plant development, is a more precise way to time treatments. Since plant-feeding insects have evolved along with the plants that serve as their food, there is often a strong relationship between plant development and insect development. We can take advantage of this relationship by using plant cues (flowering, petal fall, lilac bloom, etc.) as indicators of insect development (15, 12). While this technique often works it, too, is subject to years in which plants and insects are not well synchronized and control decisions are incorrect. In addition, different individuals of the same plant species may vary in their development.

Pheromone traps are also being used to time insect control treatments (10, 9). Many insects communicate via chemical odors called pheromones. One group of these chemical odors (sex pheromones) are produced by females to attract males for mating. Some sex pheromones have been synthesized (16, 11) and used in a trapping system to precisely monitor insect activity (17, 5). Commercially available traps with lures (eg. Pherocon Insect Monitoring Systems, Scentry Monitoring Products) are being used to time chemical treatment for some insects (eg. ash borer, *Podosesia syringae;* rhododendron borer, *Synanthedon rhododendri;* lesser peachtree borer, *Synanthedon pictipes;* Nantucket pine tip moth, *Rhyacionia frustrana).* This technique, while very accurate, suffers from the fact that very few of the insects we wish to control have had their pheromones analyzed or synthesized.

Insect phenology, the direct relationship of insect development to weather, is also a precise method to establish treatment timing. It works on the assumption that, as cold-blooded creatures, insect growth and development is directly related to weather conditions of which temperature is normally the most influential. The time it takes for an insect to develop from one point in its life cycle to another (egg laying to egg hatch, larvae to adult) will likely depend on temperature. When temperature is optimal for the insect, development is rapid since temperature determines speed of development. Understanding these relationships allows one to predict insect activity by evaluating current weather conditions, in particular temperature. Computer programs have been developed to predict insect development using daily minimum and maximum temperatures (1, 7). Putting computer programs to use for predicting insect development requires familiarity with certain terms. These include:

- *Lower Developmental Threshold* (sometimes called threshold temperature, (or base temperature) is the temperature above which growth and development occurs for a selected organism towards some life cycle event. One example is the presence of first mines for the birch leafminer. The birch leafminer will continue to develop whenever the temperature exceeds 50°F (lower developmental threshold). There is no development whenever the temperature is below 50°F.
- *Degree Day* (sometimes known as heat unit or day degree) is a unit for measuring the length of time that the temperature exceeded the lower developmental threshold for each 24 hour period. One degree day is produced for each degree the average daily temperature is above the lower developmental threshold. No degree days occur when the temperature is below the lower developmental threshold. For example, if the average daily temperature is 75°F and the lower developmental threshold is 50°F then 25 degree days are produced (75 minus 50 = 25). If the average daily temperature was only 45°F, no degree days would be produced since 45 is below the lower developmental threshold of 50°F.
- *Cumulative Degree Days* (also called accumulated degree days or growing degree days) is the total number of degree days above the lower developmental threshold necessary for an organism to reach the selected developmental stage. Using the birch leafminer in Minnesota, 312 degree days above a lower developmental threshold of 50°F are needed for the mines to become apparent and treatment to begin.
- *Model* is the information that lets us predict timing of a biological event. When using Forecaster (1) it consists of the pest name, the event of interest, lower developmental threshold, and cumulative degree days. For example, birch leafminer, appearance of first mines, 50°F lower developmental threshold, and 312 cumulative degree days would comprise a model for predicting presence of first mines of birch leafminer.
- *Normal Temperatures* are the low and high temperatures that would be expected in a normal (average) year for a specific day. For example, the normal temperatures for Jun 8 in Minneapolis, Minnesota are: normal low = 54°F, normal high = 74°F.
- *Observed Temperatures* are the actual low and high temperatures that occurred on a specific day in a specific year. For example, the observed temperatures for Jun 8, *1988* in Minneapolis, Minnesota were: low = 56°F, high = 93°F, for Jun 8, *1989:* low = 44°F, high = 75°F.

The simplest use of a computer program for predicting insect events involves getting available information on the lower developmental threshold temperature, cumulative degree days for the pest insect, and the normal and observed temperatures for your area. The lower developmental threshold and cumulative degree-days you need for a particular event may already be available (2, 14, 3, 4, 8, 9). Sources for information about the pest include professional journals, university extension services, university departments of entomology, or experiment stations, and trade journals or newsletters. The National Weather Service or local weather stations can provide temperature data.

Once the appropriate data are entered into a program, the program should calculate the date when the insect is expected to be in the desired stage of development. Rerunning the program with more current observed temperature data will improve the accuracy of the forecast.

Unfortunately, the same insect may not behave in the same way from one geographical area to the next (13). This means that you may not be able to rely on published data and that your program model may have to be customized for your area. A unique aspect of *Forecaster* (1) allows for creation of models for specific circumstances. The steps in developing your own model are: 1) select the pest and event of interest; 2) observe the insect in the field in your area; and 3) record the date, and year when the event took place. Do this for at least two seasons. You can then use this information to generate a custom model through *Forecaster* by producing a series of lower developmental threshold temperature/cumulative degree day combinations generated from your recorded field observations. Use the combination shown by the computer to have the smallest variation from year to year to create the custom model. Finally use the custom model to predict the insect event in the current year, then check the accuracy of the prediction through field observation of the event. If the custom model does not meet your needs repeat the process including the new field observation.

Precise methods for predicting insect development are becoming very important as interest increases to maximize insect control with reduced pesticide use. Computer-generated forecasting systems represent the direction that these pest control programs will be taking in the coming years.

Even if you don't anticipate using a computer generated forecasting program, I strongly encourage all practitioners to begin taking notes on the dates when important insect events take place in your area. You will find these data invaluable references for future pest manangement programs regardless of what system you use to predict insect development.

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Acknowledgements. I thank Roger D. Moon, Department of Entomology, University of Minnesota, for his assistance in preparation of this manuscript and James G. Hermann, Minneapolis Park and Recreation Board, for his useful and constructive comments. Article number 18,353 of the Minnesota Agricultural Experiment Station.

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