A Web-Based Decision Support System for Managing Greenbugs in Wheat

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Abstract

The greenbug (Schizaphis graminum (Rondani)) is the key insect pest of winter wheat (Triticum aestivum L.) in much of the Great Plains. Crop consultants, extension personnel, and wheat producers attempt to manage greenbugs with minimal economic loss. However, environmental conditions, control costs, and grain value vary widely over time and alter the optimum treatment threshold. Several types of information are needed to successfully manage greenbugs. We developed a web-based decision support system for greenbug management utilizing four modules: Apid Identification, Economic Threshold Calculator, Insecticide Selection, and Natural Enemy Identification. The greenbug threshold calculator calculates damaging populations for a region using weather data, and derives an economic threshold by comparing the monetary value of the lost yield to the cost of applying an insecticide. The user can print appropriate data forms for use in field sampling. Other modules in the system help with insecticide selection and identification of cereal aphids and their natural enemies. A tutorial on the use of the system is also included on the website. The modular structure makes it easy to periodically revise and incorporate new pest management information. To access the system go to the Entomology and Plant Pathology at Oklahoma State University homepage and select "Agricultural Models" and "Cereal Aphids Pest Management."

Introduction

Approximately 18 million acres of winter wheat (Triticum aestivum L.) are planted in the southern and central Great Plains of the United States each year. The greenbug, Schizaphis graminum (Rondani), commonly infests winter wheat in much of the region, and is a particularly important pest in Texas, Oklahoma, and Kansas. The economic losses it causes in the region exceed $100 million in some years (1). Localized infestations of greenbugs in winter wheat occur almost every year in the region and widespread outbreaks occur every 5 to 10 years (1,2).

Insecticides are widely used to control greenbugs in winter wheat, and are applied to millions of acres of winter wheat during severe outbreaks (2). Natural enemies of the greenbug such as the parasitoid Lysiphlebus testaceipes (Cresson) and lady beetles are sometimes effective at controlling greenbug infestations (3,4,5). However, insecticides often are applied without adequate knowledge of cost-benefit relationships or whether natural enemies will exert effective control. A significant body of information has been assembled on the ecology and management of greenbugs in winter wheat, which could be valuable for pest management purposes. Unfortunately, much of this information does
not exist in a form that is readily accessible to producers, crop consultants, and other crop managers who make control decisions.

Computer-based pest management decision-making tools are valuable in both high and low value crops whenever several interrelated variables must be evaluated in decision-making (6,7). Decision support systems may be particularly important in winter wheat production because the margins that exist between profit and loss are small, so accurate decisions and efficient resource allocation become all the more imperative (6).

In this paper we describe the design, development, and implementation of a web-based system for greenbug pest management decision-making in winter wheat. The system incorporates the current state of knowledge on greenbug pest management in an easily accessible, understandable, and useable form. The system is highly adaptable and can easily be modified and updated to incorporate new information as it becomes available.

**System Design Features**

Effective greenbug management decision-making requires several types of information. Obviously, a manager must confirm that the aphid species infesting the field of interest is actually the greenbug. This might seem a trivial matter, but farmers and managers sometimes mistake other less damaging aphid species for greenbugs. This can lead to unnecessary expenditures if insecticides are applied to treat the infestation. Natural enemies can, under some circumstances keep, greenbug infestations below the level at which economic losses occur (3,4,5). However, our experience is that many producers are unfamiliar with the important natural enemies of greenbugs and do not know how to estimate their control potential. Readily accessible tools that help growers identify natural enemies and estimate their impact on greenbugs are needed.

Once a manager is certain that the field is infested with greenbugs, it must be determined if the infestation is serious enough to warrant an insecticide application, i.e., that it exceeds the economic threshold. The economic threshold is defined as the pest density at which economic injury will occur in the future if management action is not taken to control the pest in the present. Economic injury is the level of damage or pest activity at which the cost of applying measures to control the pest (usually an insecticide application) equals the value of the yield that will be lost if control measures are not applied (8). Implicit in the economic threshold concept is the idea that the pest population grows over time and, as it grows, it continues to reduce crop yield. Yield loss and greenbug population growth models are necessary for the decision support system to function in real time.

The best way to know whether a greenbug infestation requires treatment is to sample the field for greenbugs. Efficient methods for sampling greenbugs for pest management decision-making have been developed (9). Providing managers with easy access to resources required to sample wheat fields is another valuable feature of the system.

If results of sampling indicate that the greenbug infestation exceeds the economic threshold, an insecticide should be applied to suppress the infestation. Not all insecticides are labeled to use for greenbug control in winter wheat, and those insecticides that are labeled have various restrictions on use that may be important in particular circumstances. Providing such up-to-date information on the web helps growers choose the most economical and effective insecticide for their particular circumstance.

**System Development and Implementation**

The basic structure and components of the greenbug decision support system are illustrated in Fig. 1. The user interface is an HTML web page that displays when the user executes the system via the appropriate link on the Oklahoma State University Department of Entomology and Plant Pathology web site (Fig. 2). The user interface contains URLs to a tutorial and to all system modules. Furthermore, all modules including the user interface can be reached via URLs embedded in the modules.
**System Tutorial.** The tutorial consists of a series of HTML web pages that describe the steps required to determine the economic threshold, and locate and print Glance 'n Go sequential sampling forms to be used for sampling wheat fields. The tutorial was adapted from a training manual used in educational programs for Oklahoma county extension personnel and others involved in insect pest management in wheat (10).

**Aphid Identification Module.** The aphid identification module consists of a series of HTML web pages with images and descriptions of the aphids that might be mistaken for the greenbug. There are few enough aphid species likely to be encountered in wheat fields in the Great Plains that a dichotomous key or similarly elaborate tool is not needed for aphid identification. Rather, all that is required are images and descriptions of species that can be browsed and compared one against the other to determine the species. The descriptions accompanying images of each aphid species also give rudimentary information on recommendations for control and provide links to additional information, such as on-line extension fact sheets. For example, the web page describing the corn leaf aphid notes that insecticide application is never recommended to control this aphid (Fig. 3).

**Natural Enemy Identification Module.** The natural enemy identification module also consists of a series of web pages with images and descriptions of natural enemies of the greenbug. Guidelines are provided that outline the circumstances under which natural enemies will effectively control greenbug infestations. They are rudimentary at the present time, but are consistent with current extension recommendations regarding greenbug control by natural enemies (3,5). The natural enemy identification module will be expanded in future versions of the system as results of recent research on greenbug biological control (e.g., 4) are recast in a form useful for pest management decision-making.
Economic Threshold Calculator. The greenbug economic threshold calculator is an expert system developed using the expert system development software CORVID (Exsys, Inc. Albuquerque, NM). Under CORVID, applications are web enabled and run as a Java runtime applet embedded in a default or user supplied HTML web page. The economic threshold calculator uses standard economic evaluation functions (8), a simple model for simulating population growth of greenbugs (N. C. Elliott, S. D. Kindler, and K. L. Giles unpublished), and a model for wheat yield loss resulting from greenbug infestation (11). These economic and biological functions and models are combined with a historical database of monthly average minimum and maximum air temperatures for 30 years obtained from selected NOAA weather stations in the southern and central Great Plains. Using CORVID, the greenbug economic threshold calculator was developed in a format that was easily integrated with the rest of the system.

Many factors contribute to greenbug population growth, but temperature often predominates (12). The average minimum and maximum daily air temperatures serve as input to the greenbug population growth model and are accessed by clicking the mouse on the approximate location of the field on a map of the state in which it is located (Fig. 4).

Currently, the system contains weather data for Oklahoma, Kansas, eastern Colorado, and northern Texas. When a mouse click is made on the map, NOAA weather data for the station nearest the location of the mouse click are used to run the greenbug population growth model. The user must enter at the console insecticide and application cost information and an estimate of the price per bushel that the grower expects to receive for the harvested grain. The calculator then determines the population density of greenbugs that would reduce yield enough to equal the cost of insecticide treatment, i.e., the economic injury level. This estimate of population density is then projected backwards in time four days using the population growth model. The resulting population density is the economic threshold for the field. Four days represents a reasonable time frame for a grower to treat a field with insecticide once a treatment decision is made.

Pest management experts feel that yield loss caused by greenbugs can increase rapidly for infestations of approximately 12 greenbugs per tiller or greater (T. A. Royer and S. D. Kindler, personal observation). Thus, practitioners are uncomfortable advising growers not to treat when infestations reach levels greater than 12, even though economic thresholds of greater than this level can be calculated. Thus, the current version of the decision support system truncates the economic threshold at 12 greenbugs per tiller. If the system calculates an economic threshold greater than 12 greenbugs per tiller, the economic threshold is reduced to 12 greenbugs per tiller by the greenbug calculator. If future experimental studies provide a firmer basis for economic thresholds above 12 greenbugs per tiller, future versions of the system will be modified to reflect the new knowledge.
Once the economic threshold has been determined, the corresponding Glance 'n Go sequential sampling form (13,14) can be generated and printed by a mouse click on the highlighted text on the screen. By using this form to sample the field growers can save money because an insecticide treatment will be recommended only if needed to protect the wheat crop from economic loss. The probabilities associated with Glance 'n Go sampling are conservative in the sense that fields with greenbug infestations approaching the threshold are sometimes classified as needing treatment (15). This type of error is generally preferable to the alternative of not treating fields where greenbugs slightly exceed the economic threshold.

**Insecticide Selection Module.** The insecticide selector is also an expert system developed using CORVID. It was designed to help managers choose an appropriate insecticide for the circumstances under which it will be applied. The insecticide selector asks questions of the user and uses the answers to eliminate insecticides that, if used, would violate a particular circumstance. For example, if the insecticide were to be applied using ground equipment, the system would eliminate from the list of acceptable products any insecticide for which U.S. Environmental Protection Agency regulations require application by aircraft. Also included are guidelines on environmental conditions that affect insecticide efficacy if reliable published data exist to discriminate between products with respect to the particular variable. For example, methyl parathion is eliminated from the list when ambient temperatures are less than 50°F because studies have shown that this product has limited effectiveness below that temperature (16).

The logic for selecting insecticides within the expert system is stored in a spreadsheet containing use restrictions for each insecticide and other information that could affect the choice of insecticide. Insecticide price is not considered by the insecticide selector because it is highly variable, both among locations and over time, and therefore cannot be reliably assessed and stored in the database. The spreadsheet is accessed via CORVID logic blocks called Metablocks. The final output of the insecticide selector is a list of all insecticides registered for use in winter wheat that meet the criteria specified by the user.

**Summary**

A web-based decision support system for pest management recommendations has been developed for greenbug management. This guide provides information about identity, pest management, and biological thresholds for this important pest. The decision support system considers the highly variable abiotic, biotic, and agronomic conditions under which winter wheat is grown. The weather database in the system includes data for Oklahoma, Kansas, eastern Colorado, and northern Texas. The system has a modular structure to permit easy revision and expansion as new information and tools of value for pest management decision-making become available. The system is maintained on-line by Oklahoma State University. To access the system, use a web browser to go to the Entomology and Plant Pathology at Oklahoma State University homepage then select "Agricultural Models" and "Cereal Aphids Pest Management," or visit the mirror site hosted by the USDA-ARS. The greenbug economic threshold calculator is a module that derives an economic threshold for greenbugs based on data on the costs associated with the lost yield caused by greenbug infestation compared with the cost of insecticide application (11). It also allows the user to print Glance 'n Go sampling data collection forms for the appropriate economic threshold, which can be used to sample several fields (13,14). The economic threshold calculated by the system incorporates historical weather data to predict the growth rate of the greenbug population at the geographic location of the particular field and time of year during which sampling is to be undertaken. The system also has modules to help in insecticide selection, cereal aphid identification, and natural enemy identification. These modules will be revised periodically to incorporate new pest management information as it becomes available.
Acknowledgment

We thank Tim Johnson, who used his artistic and HTML programming talent to create the web pages in the system. Justin Spurlin created the aphid drawings. The work described in this paper was partially supported by a grant from the Oklahoma Center for Applied Science and Technology. Mention of trade names or commercial products in this article is solely for providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

Literature Cited