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Wheat Midges and Thrips Information System: Decision Making in Central Germany

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1. Introduction

Wheat Midges and Thrips Expert System (WMTES) is constructive computer software, giving the users a recommendation based on pheromone and water traps catches as well as infestation levels. These results were collected from our field experiments which conducted in three locations in central Germany (Halle, Silstedt and Salzmünde) during three years 2007 to 2009. Computer programs can help in information recovery and decision support when dealing with pest problems. These decision support tools can provide farmers with easy, rapid access to accurate information that can help them to obtain the threshold to make adequate management decisions. Plans for future field testing and expert system implementation are also discussed. Using such as expert system for controlling wheat ear insects can be successfully applied to the solution of daily problems in plant protection programs for wheat producers. Finally, the obtained results would give a good guide for decision making which proved an efficient method of integrated plant protection for wheat ear insects as well as other insects in another crop.

An expert system is a computer program, which mimics behaviour of an expert in a particular area of knowledge. Expert systems (ES) have been developed and applied in many agriculture fields i.e. diagnose insects and diseases of various crops. Farmers across the world face problems like soil erosion, increasing cost of chemical pesticides, weather damage recovery, the need to spray, mixing and application, yield loses and pest resistance. On the other hand researchers in the field of agriculture are constantly working in Pakistan on new management strategies to promote farm success (Khan et al., 2008). Pest management is a highly challenging problem. Globally, annual losses from pests and diseases had increased year after year (Sharma, 2001).

The development of an agricultural expert system requires the combined efforts of specialists from many fields of agriculture, and must be developed with the cooperation of

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the farmers and extension officers who will use them (Chakraborty & Chakrabarti, 2008; ESICM, 1994). Expert Systems (ES) can be used by decision makers for predictions, such as on the needs for water, fertilizers and pesticides for a particular crop in the region given the area cultivated with such a crop. This generated information is important for different users: the traders, the exporters, the importers of these materials (Rafea et al., 1993; Rafea & Shaalan, 1996). Edrees et al. (2003) performed an expert system (NEPER) for wheat production dealing with all agricultural practices. This system are verified, validated, and, tested in the wheat fields in Egypt. There are some expert systems which are used in management systems, for example for aphids in Germany as reported by Freier et al. (1996); Gonzalez-Andujar et al. (1993); Gosselke et al. (2001) and in UK as recorded by Knight et al. (1992); Mann et al. (1986). ES is dealing also with development method for insects forecasting (Jörg et al., 2007) and diseases (Räder et al., 2007) on plants to optimize control. Up to date more than 20 met-data -based forecasting models have been developed and introduced into agricultural practice in Germany (Kleinhenz & Roßberg, 2000; Kleinhenz & Zeuner, 2007; Tiedemann & Kleinhenz, 2008).

Wheat ear insects are perceived as being of major importance. As a result, international surveillance schemes have been established, aimed at providing advance warning of pest outbreaks that will allow public and private sector agencies, including farmers for performing agricultural extension services, to make appropriate preparations for insect control (Sivakami & Karthikeyan, 2009). In Europe, wheat midge and thrips are two of the most important groups of insect pests (El-Wakeil et al., 2010; Gaafar, 2010; Gaafar & Volkmar, 2010; Gaafar et al., 2009, 2011 a,b; Volkmar et al., 2008, 2009) some species cause damage directly, through feeding, and indirectly from the fungi infestation. This work is aimed at providing the decision support tools for farmers with rapid access to accurate information that can help them to obtain the threshold to make adequate control decisions.

2. Model verification study (methodology)

Model verification was done at three sites; two research fields in Halle and Silstedt and one large scale field in Salzmünde, which were selected for detailed study in 2007, 2008 and 2009. The sites were chosen to cover a range of soil types and locations representative of the infested area of central Germany, and to be cover by meteorological stations.

S. mosellana males were monitored using pheromone traps and ear samples taken to assess the ultimate level of midge larvae infestation in all sites and in 2 growth stages; flowering (GS 65) and milky (GS 73) based on Tottman (1987) scales. White water traps were used to sample the migrated midge larvae to soil. For all of these sites the highest catch of male midges in pheromone traps was recorded. A correlation analysis was used to investigate the relationship between midge catches and the ultimate level of grain damaged. Levels of wheat midge infestation were relatively correlated with low/ high throughout the monitoring methods to use in the expert system.

The observations of variability in trap catch, and how it related to subsequent infestations, were very relevant when deciding how best to use the traps for wheat midge risk assessment and were used to develop a decision support model. With this in mind it has been kept as simple and user-friendly as possibly being based on a stepwise decision tree involving yes/no answers to questions (Fig. 1).

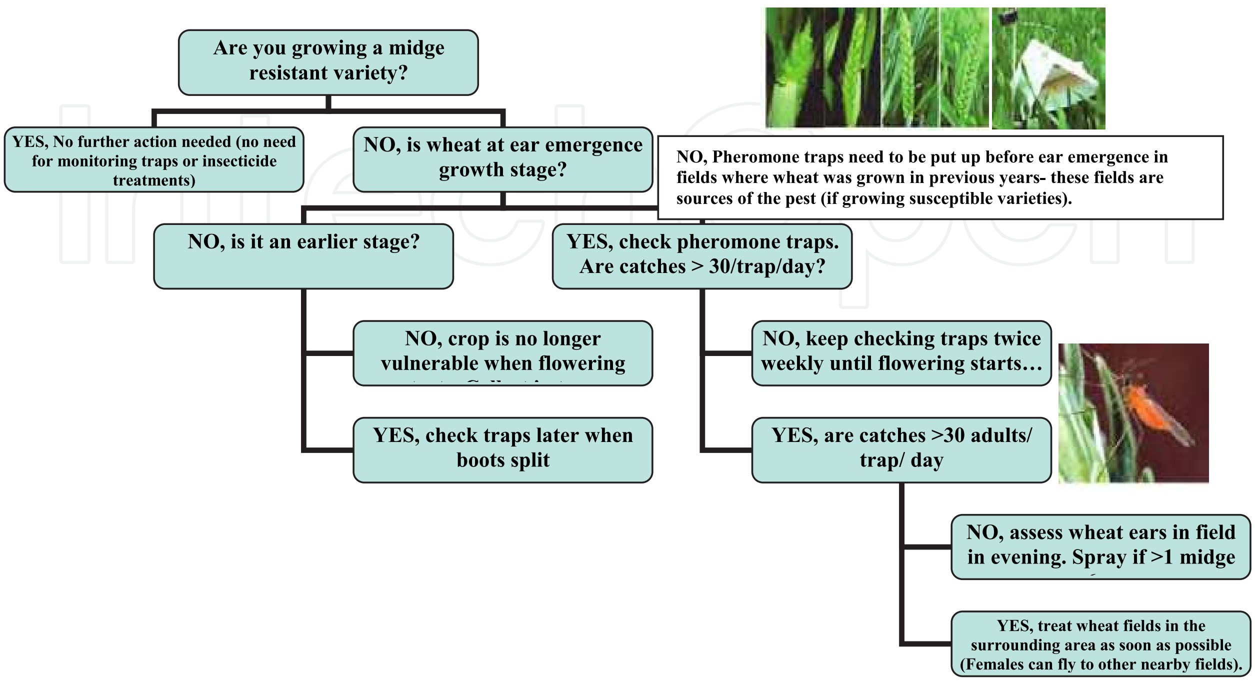

Fig. 1. Wheat midge decision support model (modified after Ellis et al., 2009).

3. Expert system development life cycle and structure

3.1 Development life cycle

The first step is creating the knowledge base and the first task in the creation of knowledge base is knowledge acquisition. Knowledge acquisition is considered as one of the most important phases in the expert system development life cycle. Knowledge acquisition is to obtain facts and rules from the domain expert so that the system can draw expert level conclusions (Gonzalez-Diaz et al., 2009). Some commonly used approaches of knowledge acquisition are interviews, observations, taking experts through case studies and rule induction by machines. Knowledge acquisition is crucial for the success of an expert system and regarded as a bottleneck in the development of an expert system (Saini et al., 2002). After the knowledge acquisition is done, the process of representing that knowledge begins. There are many approaches used for knowledge representation, for example rules, logic expressions and semantic networks. In rule-based expert systems Rules are made on the basis of the hierarchy and these rules lead to proper treatment that the user has to use.

The domain must be compact and well organized. The quality of knowledge highly influences the quality of expert system (Suo & Shi, 2008). The first step in the development of any expert system is problem identification. The problem here is a diagnostic problem aimed to identify ailments in the wheat using symptoms of insect pests. The problems occur frequently and the consequences on farmer's financial status are enormous. The demand for help is increasing rapidly. Diagnosis or diagnostic problem solving is the process of understanding what is wrong in a particular situation. Thus gathering of information and then interpreting the gathered information for determining what is wrong are of central importance in diagnostic problem solving (Lucus, 1997).

3.2 System structure

Figure (2) shows typical expert system structure we have created. Each of these blocks is explained below.

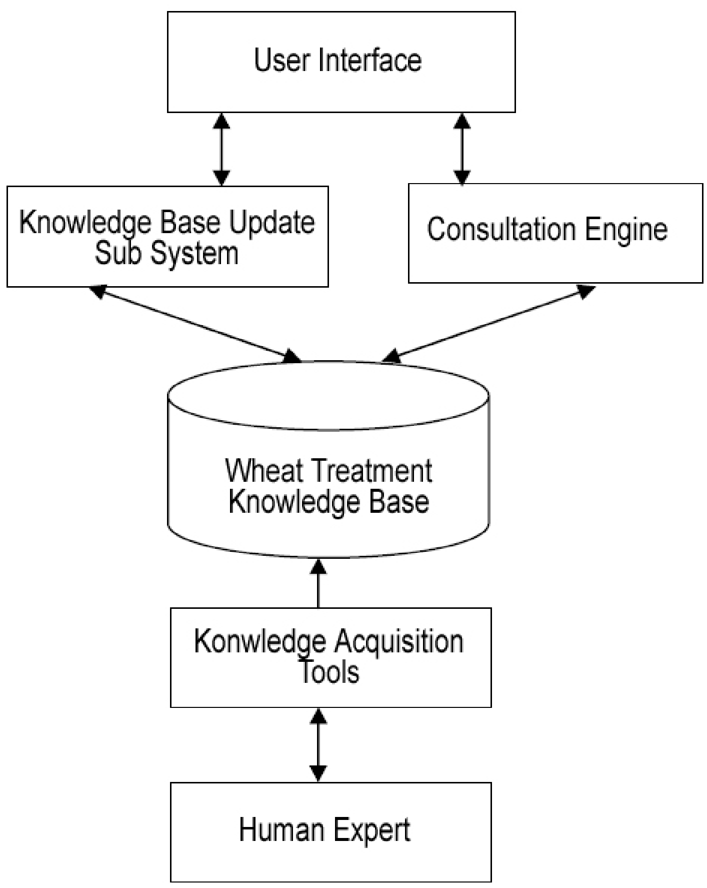

Fig. 2. Expert system structure of wheat ear insects (modified after Khan et al., 2008).

3.3 User interface

This is the interface the end user will use to interact with the system by providing parameters to it and having recommendations and consultation results out of it.

Knowledge base update sub system

As we know the utmost drawback of using expert system is that it has fixed knowledge base. If this base is not updated periodically, the results of consultation by time will be out of date. Thus, we developed this sub system to have the ability to update and enhance the knowledge base at any time easily and smoothly.

Consultation engine

Consultation Engine is the communication channel between the end user and the system; this is where user submits his consultation. Engine has 2 operation modes one is system wizard and the other is manual entry.

Wheat treatment knowledge base

This is the heart and the core of the system where it holds all the knowledge that we process to give the right decision to the user.

Knowledge acquisition tools

This is the ways we acquire knowledge from different sources and save it in the knowledge base.

Human expert

Everything in the end must return back to humans without the help of human expert we can not by any means have computerized expert system.

3.4 System user interface

Our system has 3 main modules:

1. System main data entry module
2. Knowledge base update module
3. Consultation engine module

3.4.1 System main data entry module: System main screen (fig. 3a)

Main Data Menu: (Fig. 3B)

Fig. 3A. System Main Data Entry Module.

Fig. 3B. Main Data Menu.

Crops Window

Here we can add, update and delete any kind of crops that we are dealing with now or may be in need to deal with in the future (Fig. 4A).

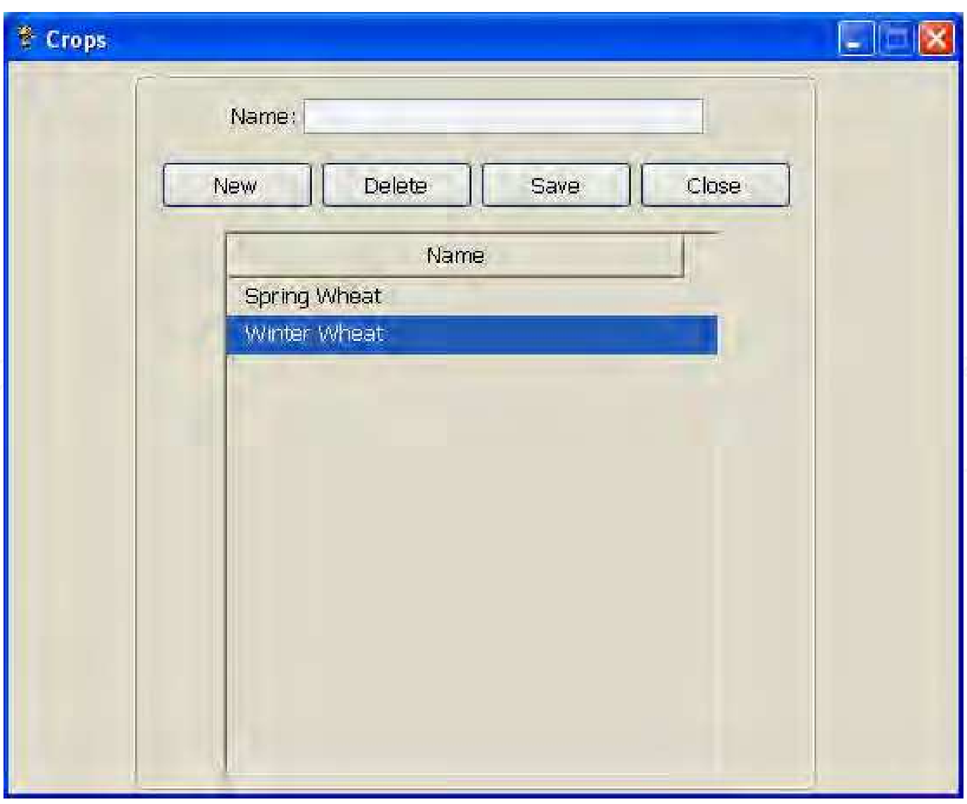

Fig. 4A. Crops window.

Insects Window

From this window we can add, update and delete any kinds of insects that we are dealing with now or may be in need to deal with in the future(Fig. 4B)

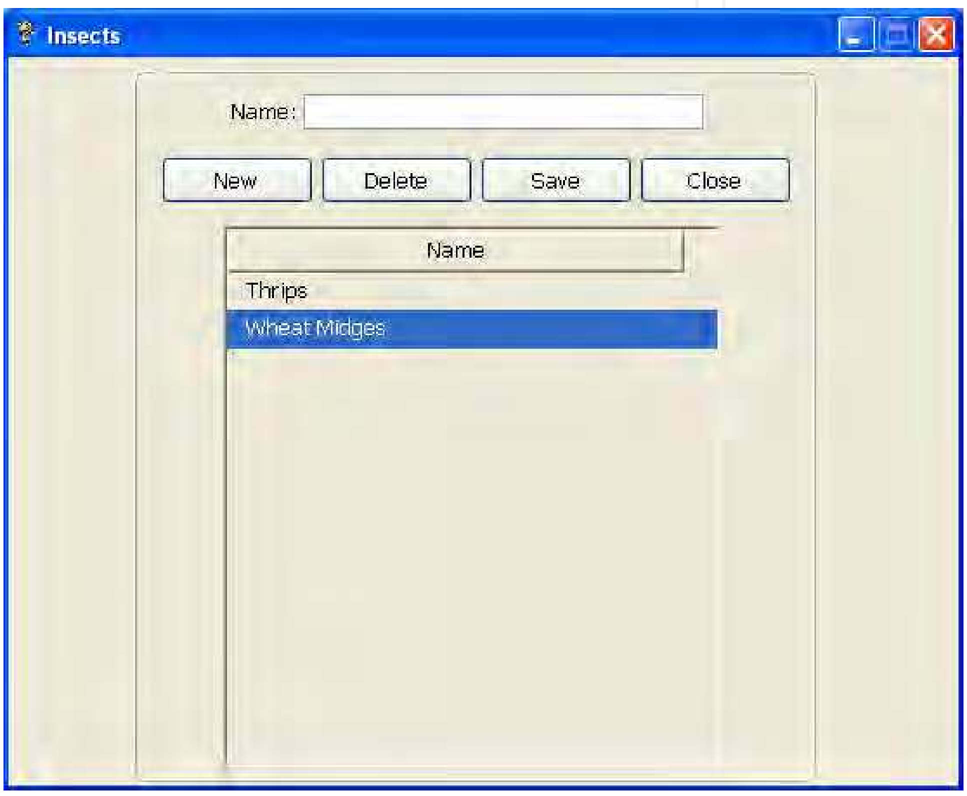

Fig. 4B. Insects window.

Locations Window

From this window we can add, update and delete any study locations that we are using now or may use in the future (Fig. 5A).

Weather Conditions Window

From this window we can add, update and delete any weather conditions that may be affected either on crop or insects (Fig. 5B).

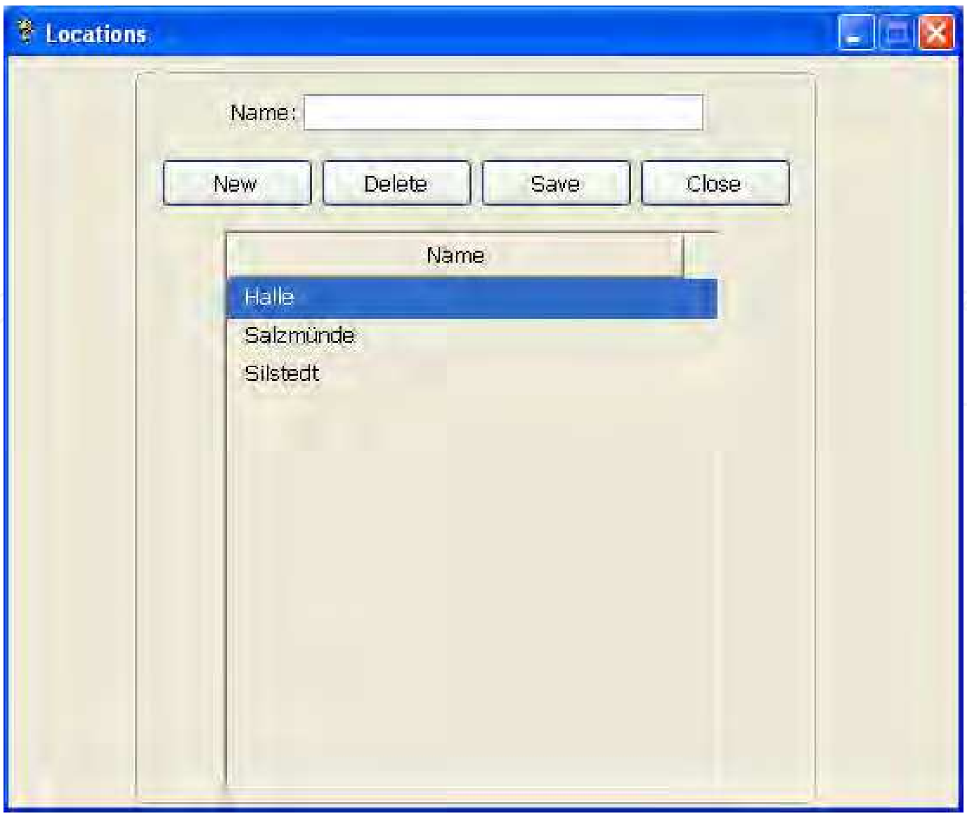

Fig. 5A. Locations window.

Fig. 5B. Weather conditions window.

Growth stages window

From this window we can add, update and delete any growth stages that we are interesting to study the population dynamic of insects (Fig. 6).

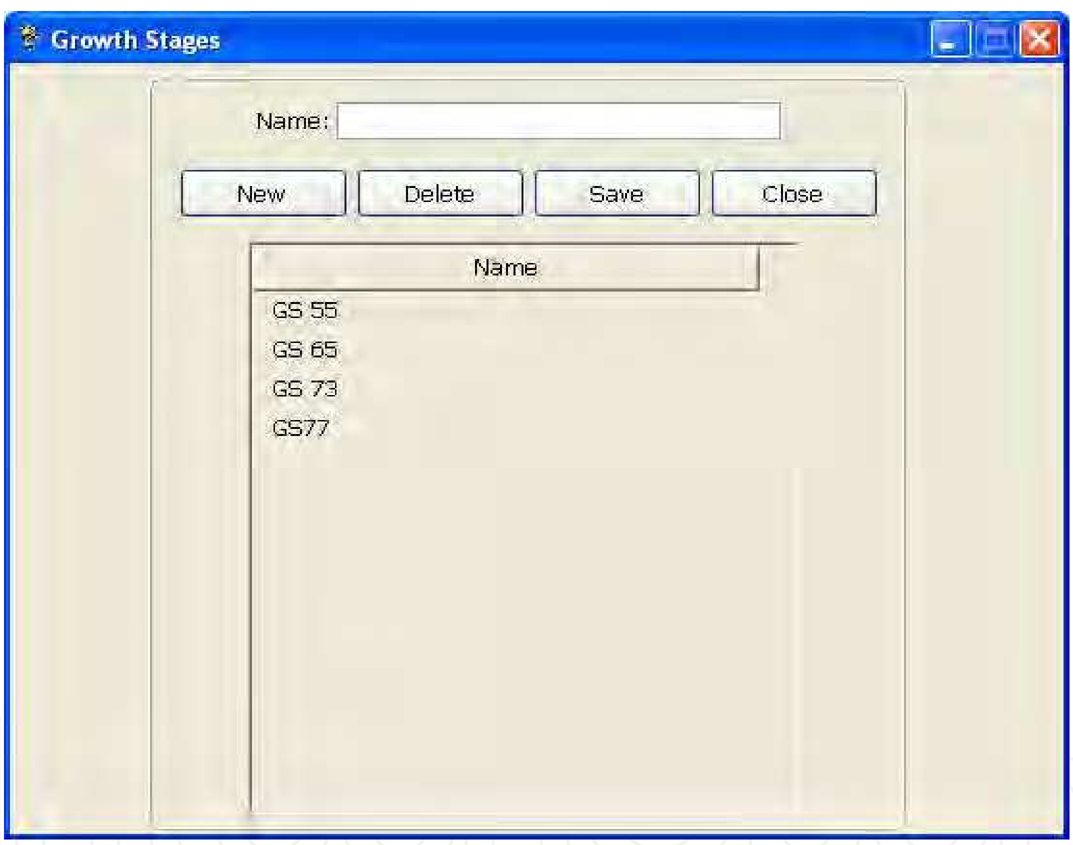

Fig. 6. Growth stages window.

3.4.2 Knowledge base update module

In this window we will be able to modify and update the knowledge base we have to be concurrent with the latest researches and results we got from different data acquisition techniques (Fig. 7).

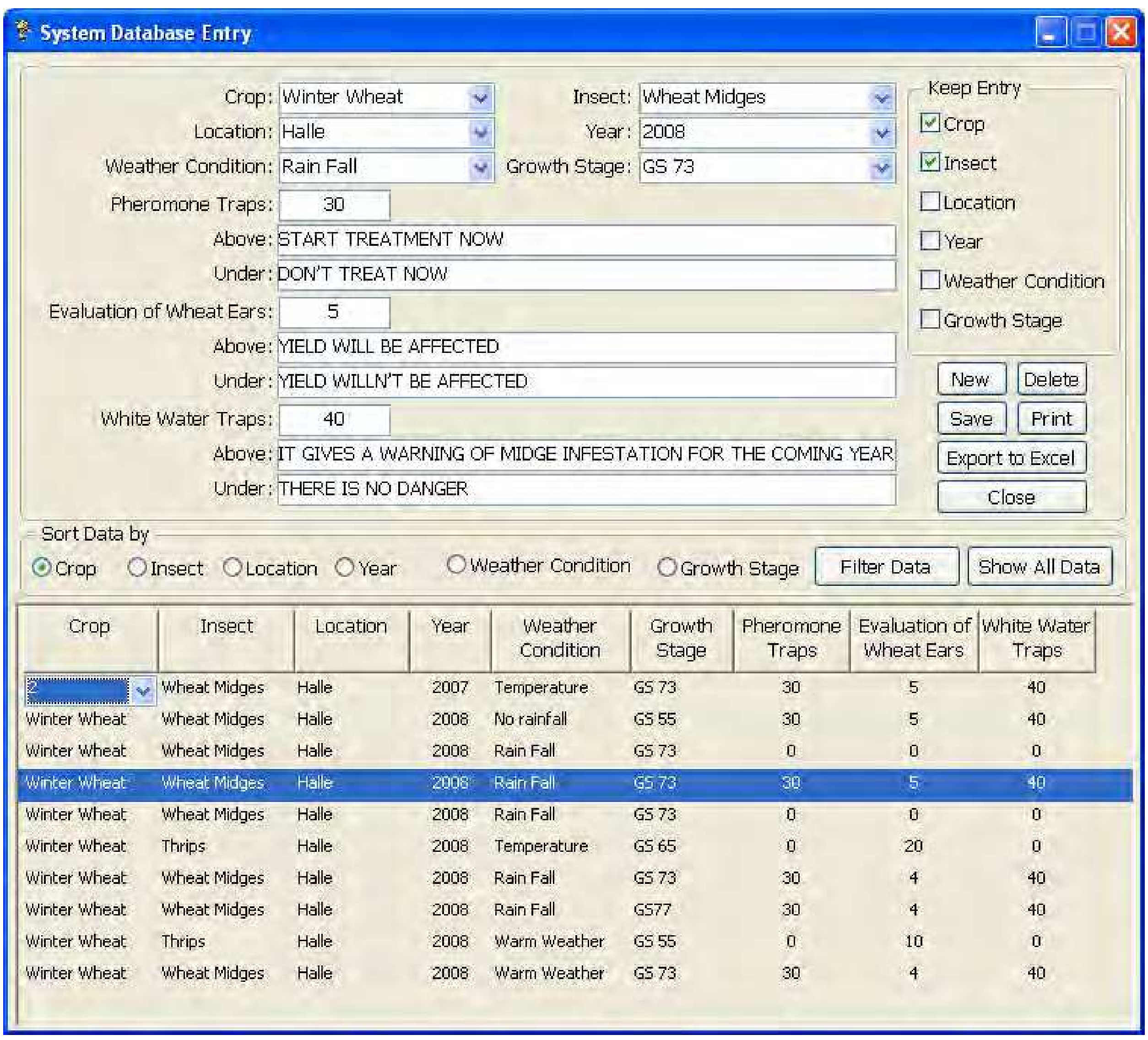

Fig. 7. Knowledge Base Update Module.

3.4.3 Consultation engine

System settings

In this window we can change the consultation engine setting by choosing the defaults of the system parameters and even saving it permanently in the system (if you click on save) or just change it for the current consultation session (if you click on apply) (Fig. 8).

Fig. 8. System Settings.

- Consultation Engine Menu

This menu contains menu items for System Wizard, Pheromone Traps, Evaluation of Wheat Ears and Water Traps

- System Wizard

In system wizard the system will keep asking questions to select insect species, year, location, growth stage and weather conditions for getting answers from user till it has all the required information to give right decision for the user (Fig. 9).

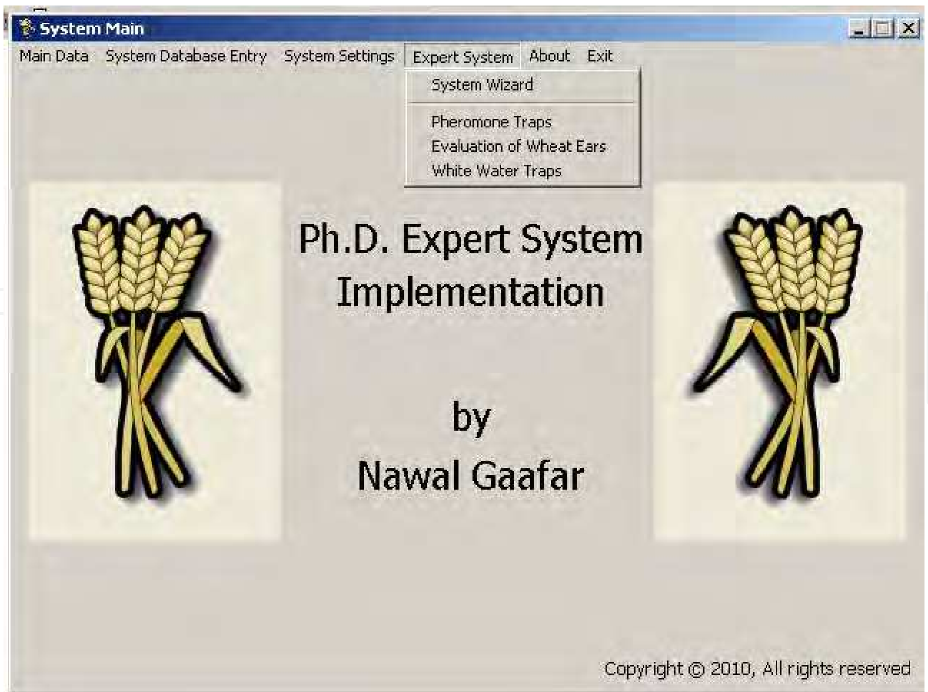

Fig. 9. System Wizard.

Summary window after gathering all the required information from the user (Fig. 10A)

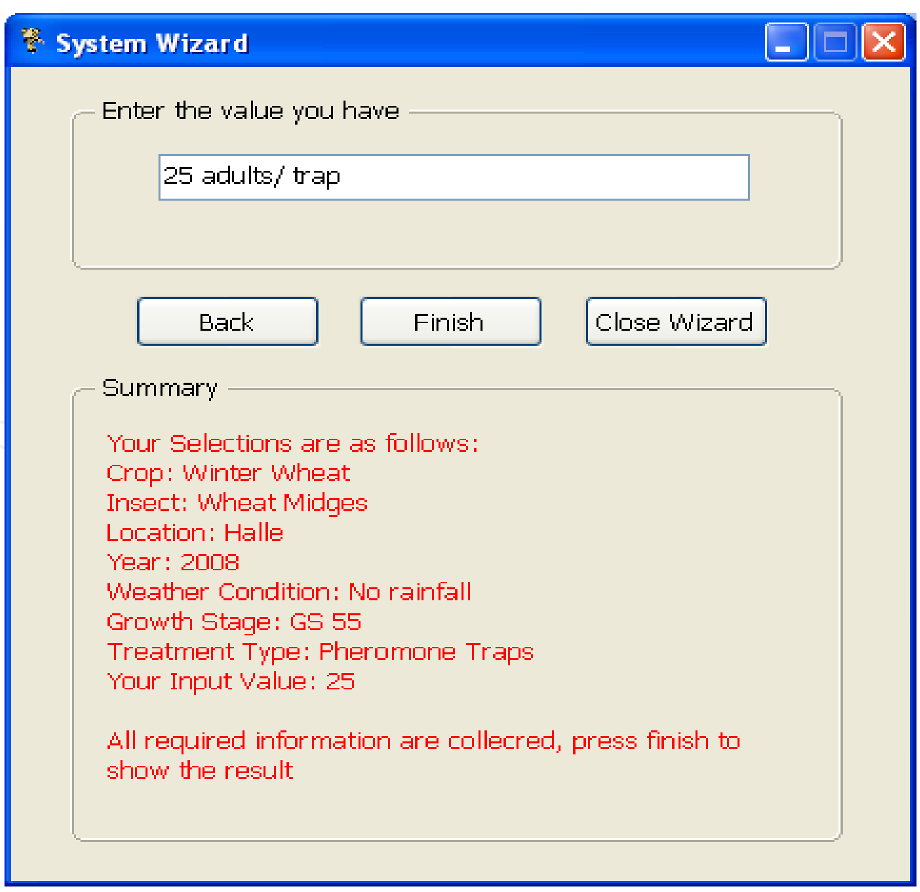

Fig. 10A. All the required information.

This is an example for the consultation result out of the system (Fig. 10B).

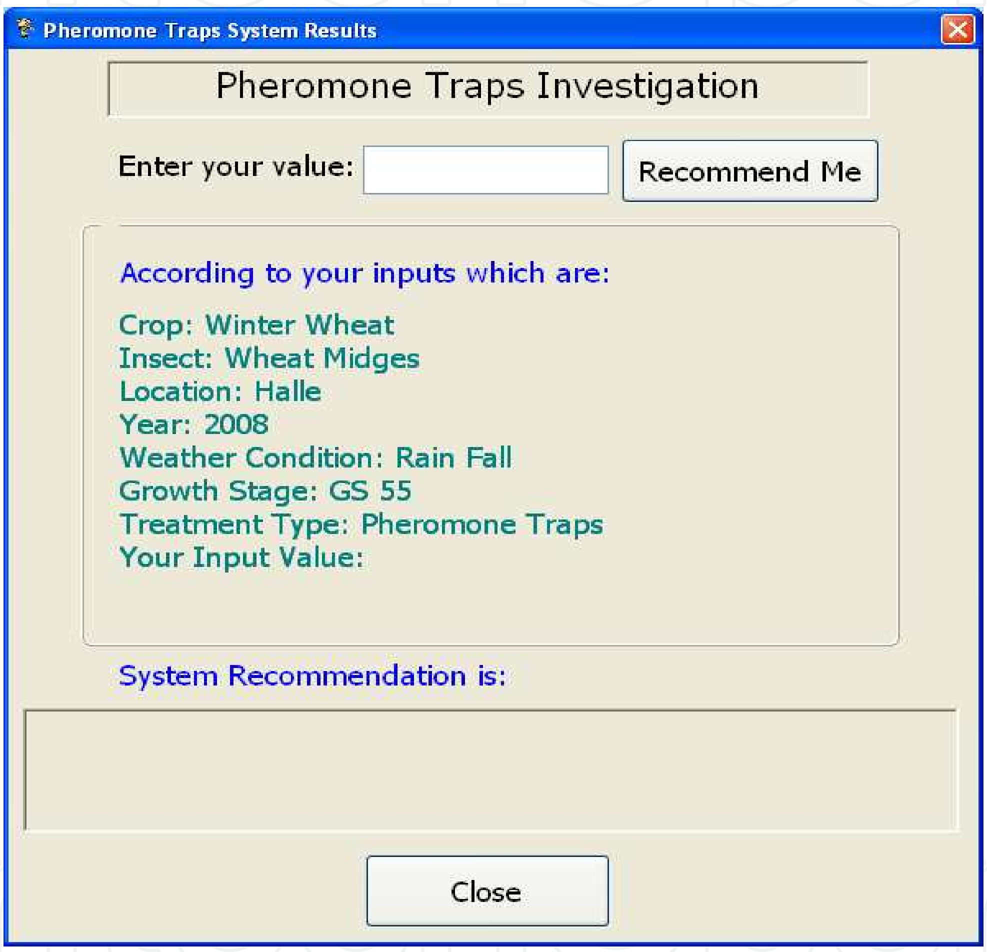

Fig. 10B. The consultation result out of the system.

Pheromone Traps: In this window system will use the defaults assigned in system settings in the consultation where user will only submit the OWBM value and click on recommend me and the system will process the value and give recommendation to user (Fig. 11 A&B)

Fig. 11A. Recommendation without treatment.

Fig. 11B. Recommendation with treatment.

Evaluation of wheat ears (wheat midges)

Here, this system will use the defaults assigned in system settings in the consultation where the user will only submit midge larvae value and click on recommend me and the system will process the value and give recommendation (Fig. 12 A&B).

Fig. 12A. Expectation without yield losses.

Fig. 12B. Expectation with yield losses.

Evaluation of wheat ears (thrips)

This system will use the defaults assigned in system settings in the consultation where the user will only submit thrips value and click on recommend me and the system will process the value and give recommendation to the user (Fig. 13 A&B).

Fig. 13A. Recommendation without treatment.

Fig. 13B. Recommendation with treatment.

White water traps

In this window, the system will use the defaults assigned in system settings in the consultation where the user will only submit the midge larvae value and click on recommend me and the system will process the value and give recommendation (Fig. 14 A&B).

Fig. 14A. Recommendation without danger.

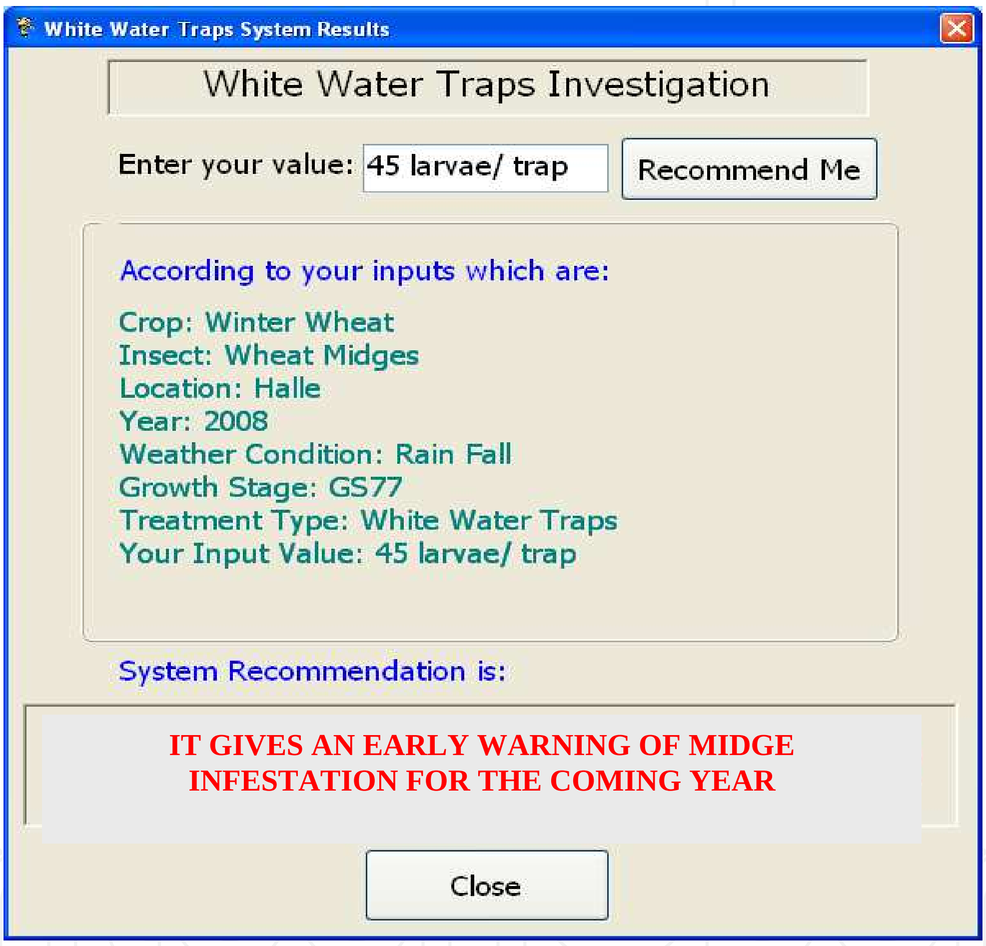

Fig. 14B. Recommendation with warning.

About

This is the about and copyright of the system (Fig. 15)

Fig. 15. The copyright of this system.

4. Testing and validation

WMTES field trials (based on crop samples) during 2007, 2008 and 2009 seasons, were done for the samples received from three different regions. As it is unwise to implement any ES from day one after completion of its development, parallel consultation from the IPM experts was found useful in improvement and validation of ES results. Also, real world ES need testing and validation in the real world environment i.e. field testing. Comparison of results produced from system as well as suggested by IPM experts has been used to improve the quality of inferences and consultation. Feedback forms have been used for preparation of validation case sheets.

5. Discussion

Pheromone traps monitor only male midge whereas it is female WBM that lay eggs from which the damaging stage of the pest emerges. Therefore, it is not possible to set a simple trap catch threshold above which economic damage occurs and below which it does not. A decision support model that can be used by farmers was developed using a stepwise decision tree involving yes/no answers to questions (Fig. 1). When growing a susceptible wheat variety pheromone traps need to be put out before ear emergence in fields where wheat was grown in previous years and provide a source of the pest. These traps should be monitored daily or at least twice weekly during the susceptible growth stage. When trap catches exceed threshold (30 midges/ day) crop inspections provide additional information to help decide whether to treat a field. It is advantageous that the pheromone traps are so sensitive and catch as many WBM as possible because they provide an early warning of midge flight during ear heading time and the suitable weather conditions, thus avoiding situations in which insecticide sprays are applied too late when they are needed. The threshold of midge larvae infestation is 3-4 larvae/ ear, where as in water traps, used to sample the migrated midge larvae is 30-40 larvae/ trap. Similar results were recorded by Ellis et al. (2009). The later should be also monitored carefully after the heavy rain, particularly at late milky stage; it gives an early caution of midge infestation for the coming year, especially intend cultivating wheat after wheat.

Midge infestation was higher in 2008 than in 2007 and 2009. The low levels of midge infestation hindered the verification of the decision flow tree as it was not possible to examine the impact of midge catches on infested ears. There can be some confidence in the proposed threshold of greater than 30 midges/ trap/ day to indicate a need to inspect crops for the pest as reported by Ellis et al. (2009).

The main objectives of WMTES have been met in allowing better data provision at all levels. However, the system can easily be changed and updated to meet new demands. For example, the current system automatically produces bulletins. This function could be developed further to produce automatically customized pest reports to include the interpretation of current pheromone or water traps data and to provide pertinent advice to growers and/or advisors. These could include comparisons between ear insect numbers in previous years and changes in the numbers between dates for specific regions, or a more forecast for weather conditions on the population dynamic of ear insect in any year. A knowledge base developed for a specific region in a problem can be tuned to make it more appropriate for other regions. Our results are consistent with Edrees et al. (2003) and Khan et al. (2008).

The current expert system has improved understanding of the WBM problem. Improving risk prediction: the decision flow chart proposes thresholds to help predict the need for insecticide treatment. The verification study suggested that this is a good basis for risk management. However, thresholds are based on data from a limited number of sites and years; further work is required to confirm the initial findings and improve the precision with which it is possible to predict the risk of pest attack. Risk of damage is also primarily dependent upon the coincidence among midge activity, the susceptible stage and weather conditions. Being able to predict the likely timing of the susceptible stage in relation to midge emergence would be a significant development, and help to limit unnecessary spray as stated by Freier et al. (1996).

The expert system will be used in training new experts. It will allow less experienced users to examine the reasoning process of an expert, to improve their understanding of how one takes control decision and to learn how to approach different situations to take the adequate decision. Agricultural extension services require more effective ways of handling, communicating, and using information. The program for the control of wheat ear insects is an example of one way that expert system technology can be successfully applied to daily problem solution in plant protection as recommended by Räder et al. (2007) and Suo & Shi (2008).

Much of the power and flexibility of expert systems are due to the fact that the knowledge base is separated from the inference mechanism (Rauscher, 1990; Waterman, 1985). The knowledge base can be modified without interfering with the operation of the system or the performance of other rules. In this way the program is now being enriched with rules for other insects, crops and sites, as well as by using of the user's feedback to improve the system. It is as important to develop the system as to maintain it. This task will be carried out for the extension services. WMTES is designed to enhance the quality and availability of knowledge required by decision makers in wheat insect management. It depends on a knowledge base that contains all the knowledge required to give useful, accurate and adequate consultations to wheat farmers.

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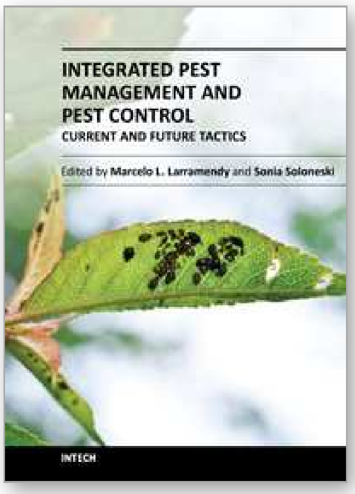

Integrated Pest Management and Pest Control - Current and Future Tactics
Edited by Dr. Sonia Soloneski

ISBN 978-953-51-0050-8
Hard cover, 668 pages
Publisher InTech
Published online 24, February, 2012
Published in print edition February, 2012

Integrated Pest Management is an effective and environmentally sensitive approach that relies on a combination of common-sense practices. Its programs use current and comprehensive information on the life cycles of pests and their interactions with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means and with the least possible hazard to people, property, and the environment.