A CLIPS EXPERT SYSTEM FOR DETECTING AND MANAGING *EMPOASCA FABAE* HARRIS ON *MEDICAGO SATIVA* L.

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Abstract: The potato leafhopper (*Empoasca fabae* Harris) is the most serious insect pest on alfalfa (*Medicago sativa* L.) during late spring and early summer in Indiana.   Since the potato leafhopper is a sucking insect, its damage often goes unnoticed resulting in reduced forage quality and yield.   A CLIPS (C Language Integrated Production System) expert system has been developed for use by alfalfa producers, extension specialists, and other agricultural advisors to detect early damage and to help them manage the potato leafhopper.   Management considerations of the potato leafhopper and the sequence in which they were built into the CLIPS expert system were time of year, identification of nymphs and adults, damage symptoms, losses caused by the potato leafhopper, detecting a potato leafhopper problem, economic thresholds for spraying, and insecticides.

INTRODUCTION

An expert system for selecting alfalfa (*Medicago sativa* L.) varieties was developed in 1988 (Rhykerd, *et al.,* 1988a).   As this expert system was being developed, it readily became apparent that the expert system could be expanded to include other management decisions that must be made at the time of seeding including lime requirement, phosphorus and potassium fertilization, weed control, and method and rate of seeding (Rhykerd, *et al.,* 1988b, 1989a-b).   This expert system worked well in making management decisions at the time of seeding alfalfa, but the costs associated with the purchase of commercial software and runtime fees prohibited its use by agricultural consultants, extension specialists, and alfalfa producers.

The recent development of CLIPS (C Language Integrated Production System) by the Artificial Intelligence Section at NASA/Johnson Space Center has eliminated most of the costs associated with commercial shells, since CLIPS is neither copyrighted nor licensed (Giarratano and Riley, 1989).   The alfalfa establishment expert system built on the PC Plus™ expert system shell from Texas Instruments (Rhykerd, *et al.,* 1989b) has been successfully converted to CLIPS (Engel, *et al.,* 1990; Rhykerd, *et al.,* 1990).   The conversion to CLIPS not only eliminates costs associated with commercial expert systems but also permits mathematical calculations which are difficult to make in the commercial expert system shell.   The CLIPS alfalfa establishment expert system is able to recommend a seeding rate based on pure live seed, provided the alfalfa producer knows the percent germination and purity of the alfalfa seed to be sown.

The management considerations for Indiana and the sequence in which they were built into the CLIPS alfalfa establishment expert system were as follows (Rhykerd, *et al.,* 1990):

1. Soil drainage (*Phytophthora* resistance);
2. Soil pH;
3. Soil P test;
4. Soil K test;
5. Use of crop;
6. Weed control;
7. Expected longevity of stand (*Anthracnose* resistance);
8. Variety recommendation;
9. Method and rate of seeding;
10. Pure live seed (% germination and purity provided by user).

Insect pests were not considered in the development of this expert system. However, the value of the alfalfa establishment expert system for alfalfa producers in Indiana would be increased considerably, if the CLIPS expert system could be expanded to include the major alfalfa insect pests in Indiana. The two major insect pests of alfalfa in Indiana are the potato leafhopper and the alfalfa weevil. Consequently, the following study was initiated to develop a CLIPS expert system for detecting and managing the potato leafhopper (*Empoasca fabae* Harris), Indiana's most destructive insect pest of alfalfa. This potato leafhopper CLIPS expert system will later be incorporated into the CLIPS alfalfa establishment expert system. Hopefully, an alfalfa weevil (*Hypera postica* Gyllenhal) CLIPS expert system can be developed and added at a later date.

DEVELOPING AND REFINING THE POTATO LEAFHOPPER EXPERT SYSTEM
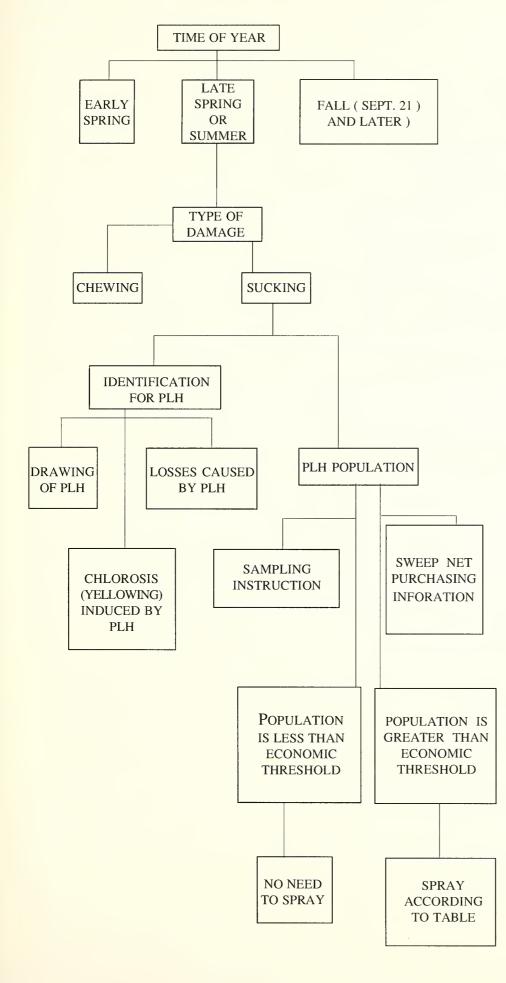
The decision tree used as the knowledge base in building the potato leafhopper expert system is presented in Figure 1. The domain experts for this potato leafhopper expert system were M.C. Wilson and C.L. Rhykerd, and the knowledge engineers were L.M. Rhykerd, B.A. Engel, R.L. Rhykerd, and C.L. Rhykerd, Jr..

Time of Year: The first question posed to the alfalfa producer is "time of year". The potato leafhopper does not overwinter in Indiana. It is brought into Indiana by warm southerly winds in early- to mid-May. Generally, potato leafhoppers are not a problem on the first cutting of alfalfa in Indiana, providing the first cutting is harvested by mid-May. Most of the damage to alfalfa occurs on the second and third cutting. Therefore, the alfalfa producer is asked whether the insect damage occurs in early spring, late spring or summer, or fall (September 21 or later). The expert system proceeds only if the alfalfa producer selects late spring or summer as the time of year that the damage occurs.

Type of Damage: Insects are broadly grouped in this program as chewing or sucking insects. The potato leafhopper is a sucking insect. Therefore, the alfalfa producer must select "sucking" as the type of damage, if the expert system is to continue.

Identification of the Potato Leafhopper: Additional information is provided to the alfalfa producer so that the sucking insect can be positively identified as a potato leafhopper. The alfalfa producer can ask to see a drawing of the potato leafhopper, information on the chlorosis caused by the potato leafhopper, or the losses caused by the potato leafhopper.

Figure 1. Potato leafhopper (PLH) decision tree used for building the knowledge base.

Potato Leafhopper Population: The economic threshold for potato leafhoppers is dependent upon the height of the alfalfa and the population of potato leafhoppers (Wilson, *et al.*, 1980). Information is provided on the proper method for sampling an alfalfa field for potato leafhoppers. In addition, information is provided for purchasing a sweep net, if the alfalfa producer does not have access to one.

If-Then rules concerning alfalfa height and potato leafhopper population are posed to the alfalfa producer. If the potato leafhopper population exceeds the economic threshold for the height of the alfalfa producer's alfalfa plants, spraying with an insecticide is recommended. A table listing suggested insecticides is included in the expert system, so that the alfalfa producers can study the insecticides suggested for controlling potato leafhoppers.

A typical example of a CLIPS rule in the potato leafhopper expert system is time_of_year_1. This rule informs the user that there is no potato leafhopper problem in early spring and displays an appropriate message:

```
(defrule time_of_year_1.
    (time early_spring)
    =>
    (assert (message 0 show "The potato leafhopper does not overwinter in Indi-
        ana but is brought into Indiana in early-to mid-May by warm southerly winds.")))
```

CLIPS uses rules and facts. Facts can be used to describe parameter values and properties. Parameter information is used to interact with the program user. The following is an example for the declaration of the parameter time:

```
(time
    prompt "What time of year is it?"
    expect early_spring late_spring_or_summer fall-Sept21_or_later
    help "Choose the current time of year.  Select the appropriate time of year,
        then  press the return key."
    why "The population of potato leafhoppers on alfalfa in Indiana is dependent
        on the time of year.  The potato leafhopper migrates north during May.
        Therefore, it is only a problem during the late spring and summer months."
    value
    value-type SINGLEVALUED
    default
    range
    certainty-range
    unknown
    gprompt ghelp gwhy)
```

The development of the potato leafhopper expert system is now in its final stage, the testing stage. The expert system will be revised, if necessary, until the expert system provides consistent and correct expert-level solutions. It will then be incorporated into the CLIPS alfalfa establishment expert system to assist the Indiana alfalfa producers in coping with their most serious insect pest.

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