Expert System for the Management of Insect-Pests in Pulse Crops

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Abstract* - *The paper describes the design, development and implementation of a specialized system for the management of insect-pests in pulse crops. It is a web-based system that facilitate "farmers/extension workers" to diagnose insect-pests of major pulse crops viz., Chickpea, Pigeonpea, Mungbean and Urdbean (highly consumed pulse crops) and recommends the suitable treatments. Knowledge acquisition sub - system of the system offers online interface for entering, storing and structuring the domain specific knowledge to the domain experts. This paper also presents a methodology to develop an integrated knowledge base which combines the knowledge fed by the multiple experts in the framework of knowledge. The system holds an integrated knowledge base that incorporates information for the diagnosing of 20 major insect-pests of pulses emerging right from seedling to ripening. The presented work provides user-friendly interface that is able to asks the textual as well as pictographic symptoms in the outline form of multiple-choice questionnaire. Based on given answers, system identifies the pulse crop insect-pests along with its confidence factor and recommends most suitable treatments. The system's performance was found good and comparison between recommendations of human experts and system itself showed 92% agreement.

Keyword* - *automatic knowledge acquisition system, textual symptoms, pictographic symptoms, production rules, reliability estimate, confidence factor

I. INTRODUCTION

In India, the pulse crops are mostly grown in rainfed conditions and require less farm resources such as fertilizers, irrigations, labours, pesticides, insecticides, etc. and also the total cost of cultivation is less as compared to the cereal crops. Therefore, the farmers of the country can get high return in growing the pulse crops. India stands in the top most positions for consumption of pulses. The cultivation for these crops cover 23.47 million hectares with the production of 18.31 million tones (2012-13). The usual yield of pulses in the nation is approximated 600 kg/ha in comparison of the average global yield of 860 kg/ha.The major pulse crops such as Chickpea (Chana or Bengalgram), Pigeonpea (Arhar or Tur or Redgram), Mungbean (Moong or Greengram) and Urdbean (Urd or Blackgram) are grown under various agro-climatic situations in the country. This contributes nearly 90% of production of the total pulse production. Amongst the biotic stresses, the insect-pests problems is a major concern in pulse production due to enormous loss incurred in different production systems (Dhar et al., 2004). Along with all the advances made in crop protection technology there is 18-20% pulse crops are yearly lost due to the damage of insect-pests, costing nearly Rs. 3000/= crores to the "nationalized exchequer" (Chaudhary, 2004 and Singh *et al.,* 2004). Pulse crops are vulnerable to attack by a outsized number of insect-pests right from seedling to ripening and in storage space. Some of the insect-pests impose serious yield losses. If we are capable to control only these pests, it may augment the overall pulse production by a large proportion.

In the absence of an expert system, the major tasks of pulse crop management like insect-pests diagnosis and their treatments are mostly carried out by crop experts/entomologists on the basis of their experiences. Different pulse crops require completely different management techniques and cropping schemes. Farmers lacks on the information on production and protection technology, so they require quick access to all the potential information and should take prompt conclusion to handle their crops proficiently and effectively. In order to raise a successful pulse crop and remain always competitive, the modern farmers of the country often rely on pulses production specialists to assist them in arriving at the timely decision. Unfortunately, pulse specialists are not always available for consultation at the nick of the time. To solve this problem, an Expert System (ES) may become a powerful tool which is a dire need of the day for farmers, extension workers and Government officials. ES can provide on-line information on crop management issues like diagnosing and controlling noxious and commonly found insect-pests.

Many specialized systems have been created for diagnosis of crop insect-pests (Saini *et al.,* 2002; Mansingh *et al.,* 2007; Mahaman *et al.,* 2002; Jones *et al.*, 1993; Prasad *et al.,* 2006; Kaloudis *et al.,* 2005; Kramers *et al.*, 1998; Koumpouros *et al.*, 2004; Lopez-Morales *et al.,* 2008; Prasad *et al.,* 2002) and it has been drawn that farmers are getting better yield with the help of such systems. Most of them have been developed using conventional type of knowledge acquisition and representation methodologies. However, the proposed work has significant and unique feature of automatic knowledge acquisition system which helps the system to develop and enhance dynamically. Other added features of proposed system are its complete, consistent, and modular knowledge base that can be expanded to additional crops with no need to rephrase the current knowledge base.

The recommended design, development and implementation of an specialized system provides information for an early diagnosis and treatment of harmful insect-pests commonly found in pulse crops to the farmers and extension workers. Knowledge base for stated 4 chief pulse crops is build with the contribution of multiple domain experts (plant entomologists from Indian Institute of Pulses Research, Kanpur) which uses automatic knowledge acquisition system. The involvement of domain experts enhances the correctness of the knowledge base by reducing the error possibilities because of communication gap among the developer and the experts.

II. METHODS

A. *Knowledge acquisition*

The most promising model illustrates: the knowledge engineer collects the knowledge driven by expert, encodes it for the knowledge base, and then certify it in collaboration with the expert to acquire the resultant knowledge base (Rafea *et al.,* 2001). Once such a knowledge base is formalized then without the assistance of same knowledge engineer, it becomes complex for the user/expert to add/update the knowledge (Kolhe *et al*., 2007). To conquer such type of setback, an automatic knowledge acquisition system is developed providing ease to the user/expert for entering the knowledge directly for the formation of knowledge base. To grow this automatic system, knowledge engineer used the manual approach of knowledge acquisition which identifies the types of knowledge required for the system. Knowledge engineer scrutinize the content based information (i.e., books, journal, bulletins, databases, etc.), confer with the domain experts and farmers. Then after abstraction, recognize the type of knowledge (i.e., attributes, relationships, decisions, goals, etc.) that will be useful for pulse crop insect-pest diagnostic domain. Along with the classification of different potential causes, the organization of indicative rules and restriction were also conferred with the domain expert team (i.e., entomologists) prior to the development of the automatic knowledge acquisition system (Devraj *et al*., 2007). For example, in pulse crops insect-pest diagnostic domain, four major parameters viz., crop parameters, field parameters, symptom parameters and visible pictographic parameters were recognized and on the foundation of the identified parameters, a provisional listing of questionnaire for filling of online data is designed which helps the user/expert.

The system allows multiple experts to enter the knowledge for pulse crop. The system integrates all the information entered by experts. Thus, generates an integrated knowledge base for the particular pulse crop. The whole process is automatically executed to drive the result. Each domain expert fill out the reliability estimate. Reliability estimate connected to a question symbolizes the significance of the question in recognizing the stated pest. The knowledge for each crop is expertly stored in the database. System integrates pest-wise knowledge for a particular pulse crop. Reliability estimate helps to prioritized knowledge which builds a comprehensive knowledge base for identifying the pulse crop insect-pest.

For building expert system, we collected a large pool of data describing plant damage symptoms (textual as well pictorial) of major insect-pests (*viz., gram pod borer, cutworm, termites, spotted pod borer, pod flies, leaf binder, pod weevils, blister beetles, pod bugs, hairy caterpillar, thrips, stem flies and white flies*) occurring in some of the important pulse crops (*viz.,* Chickpea, Pigeonpea, Mungbean and Urdbean) (Reed *et al.,* 1989). Table 1 summarize major insect-pests, for which the knowledge base of the system includes the data. From this table, it is obvious that some insect-pests are common to two or more pulse crops and some insect-pests are infecting only one of them. It can be observed that some symptoms of the different insect-pests are common for a pulse crop.

TABLE I. Insect-pests considered in expert system.

S. No.	**Insect-pests**	**Pulse crops**			
		Chick pea	Pigeon pea	Mung bean	Urdb ean
1.	Gram pod borer	✓	✓		
2.	Cutworm	✓			
3.	Termites	✓			
4.	Spotted pod borer		✓		
5.	Pod flies		✓		
6.	Leaf binder		✓		
7.	Pod weevils		✓		
8.	Blister beetles		✓	✓	✓
9.	Pod bugs		✓		
10.	Hairy caterpillar			✓	✓
11.	Thrips			✓	✓
12.	Stem flies			✓	✓
13.	White flies			✓	✓

B. *Knowledge representation*

Knowledge representation (KR) is the subsequent conversion of gathered knowledge into a machine executable format (Zetian *et al.,* 2005). KR deals with the problem of receiving and gathering knowledge and specializing the computer in a way that provides ease of access and utilize in resolving problems (Mahaman *et al.,* 2003). There are different K-R techniques that are present (rules, frames, logic, O-A-V triplet semantic nets, etc.), but no individual knowledge representation technique is suited for acquiring and retrieving knowledge along with succeeding reasoning (Turban *et al.,* 2002). The work represents tables and production rules which are used for knowledge representation.

The information inferred from questionnaire that identifies symptom which are represented in the form of eight database tables (***viz. pulsemaster, disease_Master, pulse_questions_Master, pulse_questions_Child, pulse_option, Disease_Knowledge_Base, fig and control_measures***). These database tables stores all the data and images needed for insect-pest diagnosis and treatment in pulse crops.

The production rules in the system are made up of 'Questions', 'Diagnosis' and 'Answers'. A Diagnosis is a final conclusion of the system (e.g. Gram Pod Borer, Podflies, Pod Bugs, Termites, etc.). Questions are designed according to the conditions that satisfies individual diagnosis. User inputs are the drivers for the Answers . It can be in the form of text or image.

Example:

IF

The crop name is **pigeonpea**, *and*

The crop stage is ***podding*****,** *and*

The affected plant part is ***pod*****,** *and*

Feeding habit is ***biting and chewing type***, *and*

Pest identification symptom is a ***white legless larva, brown puparia and black adult fly***

THEN Insect-pest – **Podflies**

IF criteria of a rule includes the symptoms or the pest explanation (question and answers). The part under the THEN criteria is of a rule which states the insect-pest itself (diagnosis). The process is analogous to human thought process. Certainly, while performing a diagnosis, firstly the symptoms (or conditions) are observed by doctors and then problem is categorized and diagnosed. In the above example**,** crop name**,** crop stage, affected plant part, feeding habit and pest identification symptom represent the questions**,** ***pigeonpea, podding, pod, biting and chewing type and white legless larva, brown puparia and black adult fly*** are the answers and **Podflies** is the diagnosis**.**

Knowledge base also contains pictorial data. It is represented in the form of images and stored in the database in JPEG format. Total 110 images have been included in the database. After preliminary diagnosis using textual data, final diagnosis is done on the basis of another set of rules containing pictorial knowledge. Some hypertext (html) files are also called upon to give more textural and graphical information.

C. Inference Engine

The Inference Engine is designed after building knowledge base through automatic knowledge acquisition system. The engine is devised to formulate proper reasoning mechanism for searching the knowledge base. It guarantees the appropriate order of questions being asked from the user (*e.g.* avoids asking the same and irrelevant questions) (Jayawardhana *et al*., 2003). The engine uses forward chaining scheme which guide the search for selection of questions, rules and results (Tocatlidou *et al.,* 2002). The mechanism of the system begins through an interface where user can enters his/her choice about the pulse crop and type of disease. Thereafter, the inference engine for insect-pest findings and handling is invoked. Different steps of the inference engine flow are illustrated in Fig. 1.

III. USER INTERFACE

For any changes i.e. to update information or to view the knowledge and to get the results for their queries, the only way that Farmers and domain experts can interact with the system is via user- friendly interface. (Gonzalez-Andujar, 2008; Gonzalez-Diaz *et al.,* 2009). The foremost and important feature of the proposed system focuses on the principle of "minimum work" to reach a conclusion. The system needs minimal and simplified knowledge in the form of answers of multiple-choice questions which guide the farmers about their crop related queries. The process of insect-pest diagnosis and treatment comprises of three phases: Preliminary diagnosis, Final diagnosis and Suggesting treatments. The system records the choice made at each level. At the end of each diagnosis session, system is facilitated to display/print summary report. This report is verified to be helpful for user/farmer in accordance with the questions asked by the system and answers given by the user at each level. A feedback form about the system performance is displayed at the end of each consultation. The additional knowledge collected from the feedback form of the users can be used to adapt the knowledge base after consulting with domain experts. This individually-produced feedback is an inherent part of the developed system. It helps in detecting the new symptoms, new insect-pests, latest treatments along with modern chemicals and forbidden chemicals. So with the help of collected feedback, suitable changes can be made in the database. The knowledge updates itself, preserving state-of-the-art knowledge (Itoga *et al.,* 1990).

The overall process of identification and treatment of insect-pest in a pulse crop is presented in Fig. 2.

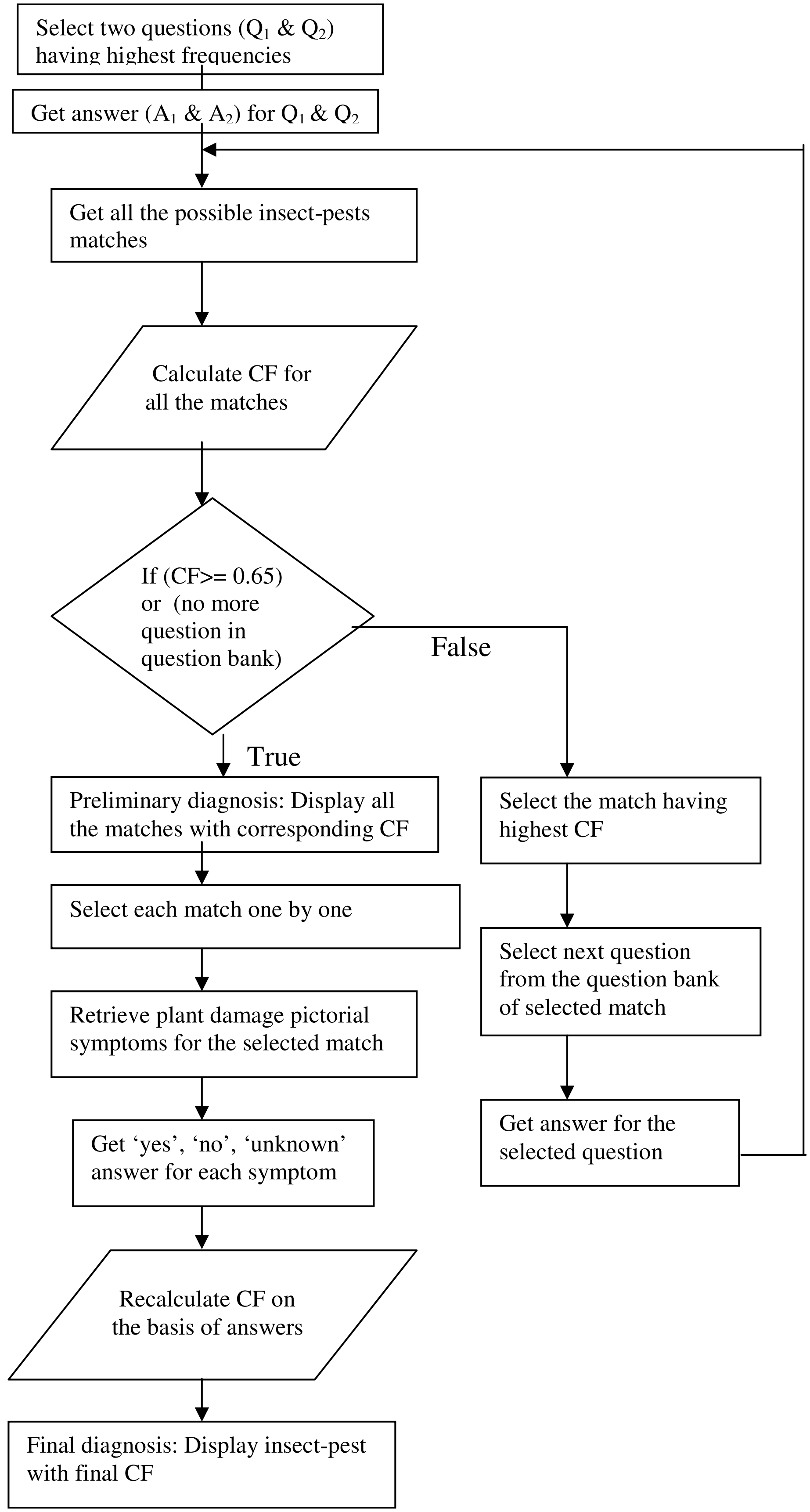

Fig. 1. Inference engine flow for the insect-pest diagnosis.

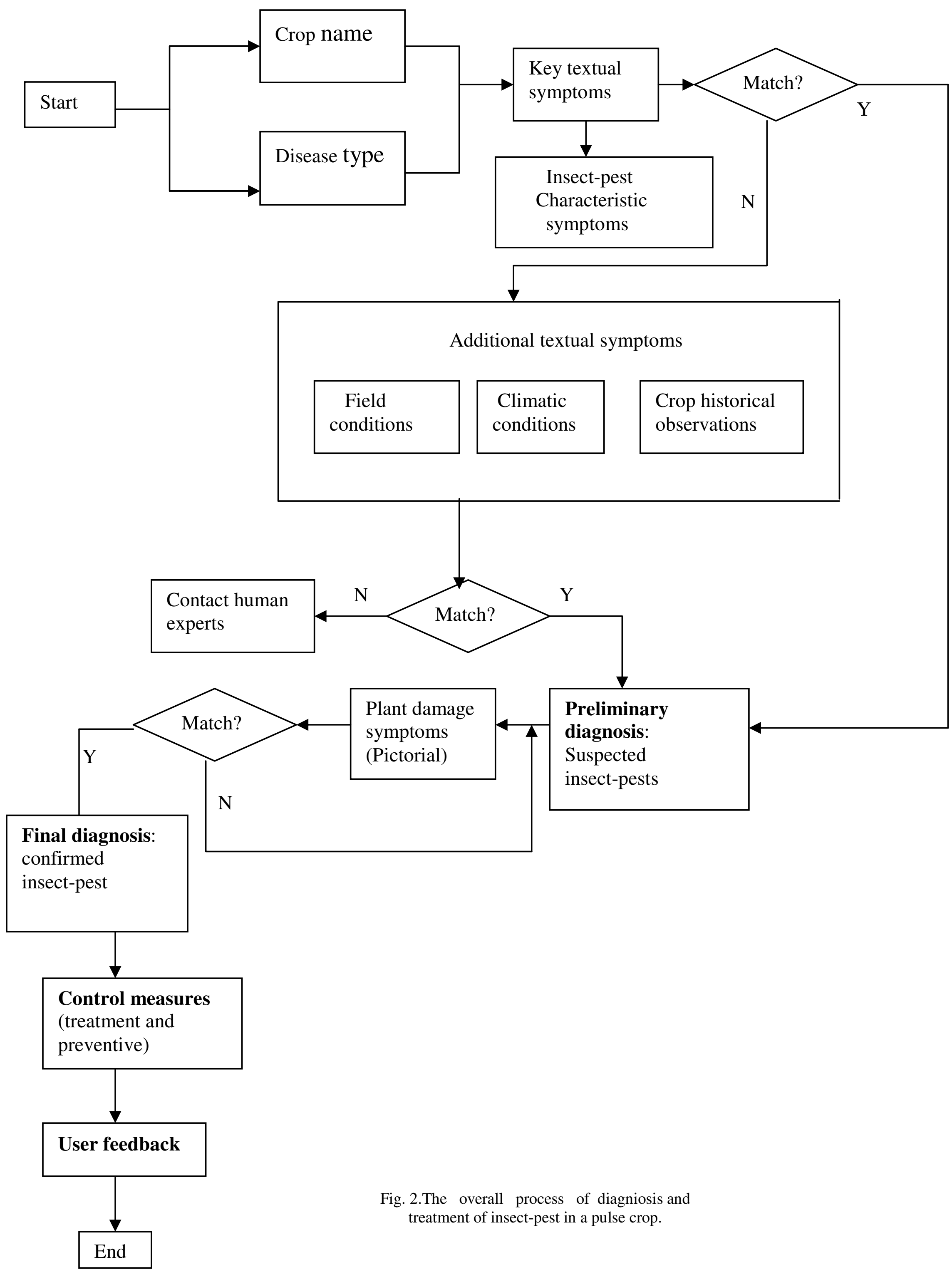

Fig. 2.The overall process of diagniosis and treatment of insect-pest in a pulse crop.

IV. CONCLUSION AND FUTURE DIRECTION

In order to provide online help to pulse growers and extension workers of the nation, an specialized system for the diagnosis of insect-pests in pulse crops is designed, developed and implemented. For ease of use to domain experts for conducting important operations, the system provides user-friendly interface. The system integrates all the information entered by experts. Thus, generates an integrated knowledge base for the particular pulse crop. The whole process is automatically executed to drive the result. The engine uses forward chaining scheme which guide the search for selection of questions, rules and conditions and determines which rules are applicable. The order of the multiple-choice questions should be in accordance of the user response. User performance, problems and suggestions are collected through the 'User Feedback' form. The image illustrations proves to be useful in final diagnosis. The evaluated results (farmers as well as State Agriculture Officers) depicts that the strength of the system is good and it can be implemented at the farmer's field.

The system is suitable for implementation in Hindi and other regional languages so that all the farmers of the country can use it. The future work will cover the larger aspects of knowledge base for all the cereal crops.

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