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Development of Disease/ Insect-pest Diagnosis and Treatment Knowledge base for Pulse Crops

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A B S T R A C T

Pulses are grown globally reached a volume of 90.48 Million Tons in 2020 and is further expected to 114.49 Million Tons by 2026. Amongst different pulse producing countries, India ranks first of the global pulse production. Over a dozen pulse crops are grown in the country and among these, Chickpea, Pigeonpea, Mungbean, Urdbean, Lentil and Pea are the major important pulse crops in the country grown together in more than 80% of the total area under pulses and contributing around 70% grain yield. Although these crops have yield potential of above 2000 kg/ ha, the all India average productivity of chickpea is only 950-1000 kg/ ha and of pigeonpea is a meagre 800-850 kg/ ha only. Among the major problems limiting their yield, biotic stresses are the most important. Under biotic stresses, insect pests and diseases are considered more important than other factors. Around 26-30% crop is annually lost due to diseases and insect pests causing nearly Rs. 4500 crores loss to the national exchequer. If this huge loss could be prevented, there would be no pulse shortage in the country in the years to come. Thus, it is a great challenge to the Scientists, who are supposed to tackle it, have to contemplate that how to reduce this unprecedented loss which can be answered by proper and timely diagnosis at a very initial stage and follow up proper, timely, cost effective and eco-friendly management practices by the resource poor pulse growers. Each disease and insect-pest has its own symptoms or characteristics. Farmers do not know about these symptoms, so farmers and extension workers need rapid access to diagnose the disease damaging a particular pulse crop. In order to have a successful pulse crop and remain competitive, the modern farmers often rely on agricultural specialists to assist them in decision making. Unfortunately, pulse specialists are not always available for consultation at the nick of the time. To solve this problem, Knowledge-Based System (KBS) may become powerful tools and a dire need of the day to the farmers, extension workers and Government officials. On same line the present work was initiated for designing and developing a Knowledge base for identification and control of diseases/ insect-pests in pulses.

Keywords: Knowledge-Based System, Pulse, Diseases/ Insect, Diagnosis

Introduction

Knowledge base is a database of specific domain knowledge that may contain rules, facts, judgments, experiences and is represented in an unambiguous form so that it can be easily and effectively used by a Knowledge-based System (Mundankar et al., 2007). Mainly it stores a large body of facts called declarative knowledge and rules i.e., procedural knowledge to manipulate the facts in the database. Disease/ insect-pest diagnosis and treatment knowledge base contains information on disease type, crop location, disease/ insect-pest symptoms (textual as well as pictorial), morphology of insect-pests, crop conditions, weather conditions, disease/ insect-pest diagnostic rules in the form of tables and control measures for disease/ insect-pest treatment and prevention (Adams, et al., 2008). The whole process of knowledge base development is carried out in the two steps: knowledge acquisition and knowledge representation. In the phase of knowledge acquisition, initially the knowledge engineer tries to collect all the problem domain related knowledge from different sources using different tools. In the present work, the knowledge is collected from published literatures and entered by human expert/knowledge engineer using an automatic knowledge acquisition system.

Present system mainly uses tables and production rules to represent the domain specific knowledge. Since knowledge base is created through automatic knowledge acquisition system which allows the knowledge engineer to add more knowledge, view and update existing knowledge in the knowledge base without creating any inconsistencies. The details of each type of knowledge base are presented in the following subsections.

It can be further divided into two knowledge bases: one for diseases/ insect-pest diagnosis knowledge base and other as diseases/ insect-pest treatment knowledge base.

Diseases/ insect-pest Diagnosis Knowledge Base

Diseases/ insect-pest diagnosis knowledge base for pulse crops was created through an automatic knowledge acquisition system where data was fed by domain expert/ knowledge engineer. The structure of the knowledge base was designed after consulting a variety of literature surveys, different domain experts, extension workers and on-field farmers (Chakrabarti et al., 2007; Gonzalez-Diaz et al., 2009). The identification of various possible symptoms, diagnostic rules and constraints was done with the help of a team of domain experts (i.e., pathologists, entomologists and plant breeders). For pulse crops diseases/ insect-pests diagnostic domain, we have broadly identified four major parameters viz., crop parameters, field parameters, symptom parameters and visible pictorial parameters describing all the plant damage symptoms that may occur in the crop/ plant at different stages. Based on the identified parameters, a logical, clear and easy-to-answer crop-wise questionnaire was designed for four major pulse crops (viz., Chickpea, Pigeonpea, Mungbean and Urdbean). These questionnaires were distributed among farmers/users to get more subjective and pictorial information needed during the pulse disease/ insect-pest diagnosis process. To start with, a set of basic questions for each disease/ insect-pest was designed with the help of experts by the knowledge engineer and then more questions were added by the experts while entering the data through automatic knowledge acquisition system. Some questions were common for more than one diseases/ insect-pest. Each question contained multiple answers and user/farmer had option to choose any one of them (Adams et al., 2008). Pictorial symptoms in the form of different photographs were collected with the help of domain experts and other sources like literatures, farmers, extension workers, etc. These photographs were stored in the knowledge base in the form of images using JPEG format. The images allowed a more effective communication with the users/ farmers to help in diagnosing the diseases/ insect-pest correctly (Gonzalez-Andujar, 2008; Koumpouros et al., 2004; Gonzalez-Diaz et al., 2009).

To better meet the needs of user, questionnaires surveys and interviews were carried out with 25 farmers and 10 experts. Each participant was asked to answer all the questions for a particular diseases/ insect-pest and the control options he would consider. On the basis of the answers received, an initial decision tree was formulated. This was then circulated among the experts and from their responses and subsequent interviews, it was possible to decide that by asking relevant questions in some order, the diagnosis can be made for a particular pulse crop. Each expert also assigned a reliability estimate for each question in terms of options like 75-100% certain, 50-75% certain, 25-50 certain and 0-25% certain. Reliability estimate attached to a question represents the importance of the question in identifying the particular diseases/ insect-pest.

For building pulse crops knowledge base, we collected a large pool of data describing plant damage symptoms (textual as well pictorial) of major diseases (viz., wet root rot, stem rot, wilt, dry root rot, collar root rot, ascochyta blight, botrytis grey mold, phytophthora blight, alternaria blight, sterility mosaic, yellow mosaic virus, cercospora leaf spot, powdery mildew and anthracnose) and 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) (Nene

et al., 1991; Singh et al., 1998; Reed et al., 1989; Dhar et al., 1998; Singh et al., 1998). Table 1 and 2, summarize major diseases and insect-pests, respectively for which the pulse crops knowledge base contains the data. From these tables, it is obvious that some diseases and insect-pests are common to two or more pulse crops and some diseases and insect-pests are infecting only one of them. It can be observed that some symptoms of the different diseases/ insect-pests are common for a pulse crop.

Questionnaire sets for symptom identification which gives information about the affected stage of the crop, affected part of the plant, crop sowing time, crop location, environmental conditions and the disease symptoms (presence or absence of spots, colour and morphology of the infected or infested crop, stage of the insect-pest, its feeding habit, damage caused, etc.) (Devraj et al., 2006). In these questionnaire sets, the headings (Q_1, Q_2, Q_3) represent the question list, which form the conditions for the diagnosis. Each question is followed by the possible answers and a reliability estimate.

Table 1.Diseases Pulse Crops Considered in the Knowledge Base

S. No.	Diseases	Pulse crops			
		Chickpea	Pigeonpea	Mungbean	Urdbean
1.	Wet root rot	✓			
2.	Stem rot	✓			
3.	Wilt	✓	✓		
4.	Dry root rot	✓			
5.	Color root rot	✓			
6.	Ascochyta blight	✓			
7.	Botrytis grey mold	✓			
8.	Phytophthora blight		✓		
9.	Alternaria blight		✓		
10.	Sterility mosaic		✓		
11.	Yellow Mosaic Virus (YMV)			✓	✓
12.	Cercospora leaf spot			✓	✓
13.	Powdery mildew			✓	✓
14.	Anthracnose			✓	✓

Table 2.Insect-pests Considered in the Knowledge Base

S. No.	Insect-pests	Pulse crops			
		Chickpea	Pigeonpea	Mungbean	Urdbean
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			✓	✓

The structure of a rule for identifying Wilt disease in Chickpea crop. The structure of rules for identifying particular diseases/ insect-pest makes use of the conditions having textual as well as pictorial symptoms. These conditions are connected through the logical operators.

Question 1. What is the crop stage at the time of infestation? (Reliability estimate: 75-100% certain)

- Seedling
- Flowering
- Podding
- Maturity

Question 2. Which portion of the plant is affected? (Reliability estimate: 50-75% certain)

- Roots
- Stems
- All aerial parts
- Leaves

Question 3. What was the sowing time? (Reliability estimate: 25-50% certain)

- Early sown
- Late sown
- Normal sown

Diseases/ Insect-pest Treatment Knowledge Base

The diseases/ insect-pest treatment knowledge base having the database of control measures is created separately. It contains cost effective, environment friendly and up-to-date control measures, which are composed of cultural practices as well as of chemical controls. Knowledge regarding the control measures includes the use of resistant varieties, cultural practices, chemical controls (fungicide name, dose and time of application), disease damaging multiple crops, multi-disease treatment, multi-crop disease management and farmers indigenous practices. The knowledge was acquired in the same way as we did in the diseases/ insect-pest diagnosis knowledge base. Due to the ease of use of the knowledge acquisition system, the diseases/ insect-pest treatment system could be regularly updated without interfering the diseases/ insect-pest knowledge base. Fig. 3 shows an example showing the structure of a rule for controlling Wilt disease in Chickpea crop.

Conditions

If Crop name = 'Chickpea' and
Disease type='disease' and
Disease name='Wilt'

Treatment

Cultural practices
Deep ploughing in summer
Three years crop rotation

Knowledge Representation

Knowledge Representation (KR) is the subsequent translation of acquired knowledge into a machine usable format (Zetian et al., 2005). KR is the problem of getting knowledge and expertise into the computer in a form that is easy to access and use in solving problem (Mahaman et al., 2003). Although different KR techniques exist (rules, frames, logic, O-A-V triplet semantic nets, etc.), No single knowledge representation method is by itself ideally suited for the acquiring and retrieving knowledge as well as subsequent reasoning (Turban et al., 2002). In pulse crops knowledge base, tables and production rules are used for knowledge representation.

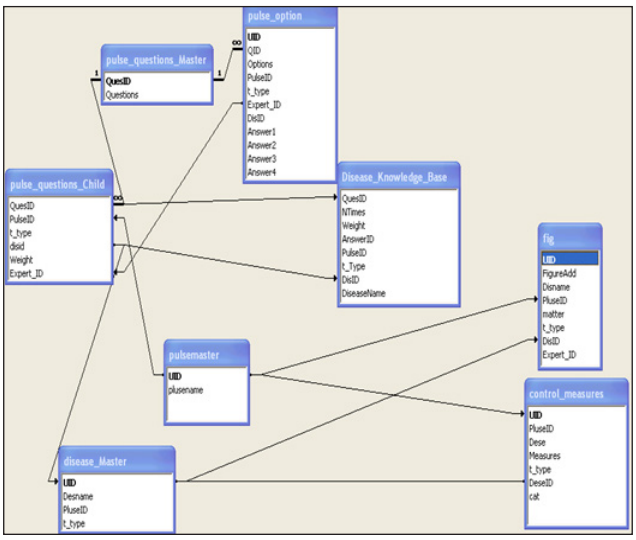

Figure 1.Table Structure and Relations in the Diseases/ insect-pest Diagnosis and Treatment Database

All the information of questionnaire for symptom identification have been 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) for storing all the data and images needed for diseases/ insect-pest diagnosis and treatment in pulse crops. These tables have been designed in MS-ACCESS 2000. Figure 1, shows table structure and relations in the different database tables. The relationship among different tables helps in retrieving the appropriate knowledge in a specific situation (Devraj et al., 2004; Morrison et al., 1991). Information about crop (PulseID and pulse crop name) is stored in pulsemaster table. The disease, Master table includes dis ID (Disease ID) Desname (disease name), pulseID and type (disease type- D: disease; I: Insect-pest) . The pulse, questions, Master table consists of two fields i.e., QuesID (Question ID) and questions (textual symptoms). Information about QuesID, pulseID, t_type, disID, weight (confidence factor), Expert_ID is stored in pulse_questions_Child. The pulse_

option table consists of AnsID (answer ID), QuesID, pulseID, t_type, Expert_ID, disID, Answer 1, Answer 2, Answer 3, Answer 4. Pulse diseases/ insect-pest diagnostic criteria is stored in the Disease_Knowledge_Base table which include QuesID, Ntimes (frequency), weight, AnsID, pulseID, t_type, disID, Desname. The fig table includes figID (image ID), FigureAdd (path of the image), matter (pictorial symptoms) Desname, pulseID, t_type, disID, Expert_ID. Information on diseases/ insect-pest treatment and prevention is kept in control_measures table. It consists of pulseID, Desname, measures (control measures), t_type, disID, cat (category: cultural practices, chemical controls). Figure 2 and 3, shows some database examples used in the diseases/ insect-pest diagnosis and treatment subsystem of pulse crops knowledge base.

UID	PulseID	Questions	t_type	disId	Weight	Expert_ID
1	1	What is the crop stage at the time of infestation?	D	1	50	1
1	1	What is the crop stage at the time of infestation?	D	2	50	1
1	1	What is the crop stage at the time of infestation?	D	3	50	1
2	1	Which portion of the plant is affected?	D	1	50	1
2	1	Which portion of the plant is affected?	D	2	50	1
2	1	Which portion of the plant is affected?	D	3	50	1
2	4	Which portion of the plant is affected?	D	27	20	1
3	1	What was the sowing time?	D	1	5	1
3	1	What was the sowing time?	D	2	5	1
3	1	What was the sowing time?	D	3	5	1
4	1	What was the temperature (in degree Celsius) at the time of disease appearance?	D	1	5	1
4	1	What was the temperature (in degree Celsius) at the time of disease appearance?	D	3	5	1
5	1	What was the soil moisture level in the field?	D	1	20	1
5	1	What was the soil moisture level in the field?	D	3	20	1
7	1	What is the planting space of the crop?	D	2	35	1
7	1	What is the planting space of the crop?	D	3	35	1
1	1	What is the crop stage at the time of infestation?	D	1	50	2
1	1	What is the crop stage at the time of infestation?	D	2	50	2
1	1	What is the crop stage at the time of infestation?	D	3	50	2
1	3	What is the crop stage at the time of infestation?	D	15	50	2
1	3	What is the crop stage at the time of infestation?	D	16	50	2
1	3	What is the crop stage at the time of infestation?	D	17	50	2
1	3	What is the crop stage at the time of infestation?	D	18	50	2
2	1	Which portion of the plant is affected?	D	1	35	2
2	1	Which portion of the plant is affected?	D	2	35	2
2	1	Which portion of the plant is affected?	D	3	35	2
2	3	Which portion of the plant is affected?	D	15	50	2
2	3	Which portion of the plant is affected?	D	16	50	2

Figure 2.A Sample of Pulse Questions Database

UID	QID	PulseID	t_type	Expert_ID	DisID	Answer1	Answer2	Answer3	Answer4
1	1	1	D	1	1	Seedling			
2	2	1	D	1	1	Roots			
3	3	1	D	1	1	Early sown			
4	4	1	D	1	1	20-25			
5	5	1	D	1	1	Excess			
6	6	1	D	1	1	NWPZ			
7	1	1	D	2	1	Seedling			
8	2	1	D	2	1	Stems			
9	3	1	D	2	1	Normal sown			
10	5	1	D	2	1	Normal			
11	6	1	D	2	1	CZ			
12	7	1	D	2	1	Normal spacing			
13	1	1	D	3	1	Seedling			
14	2	1	D	3	1	Roots	Stems		
15	3	1	D	3	1	Early sown	Normal sown		
16	4	1	D	3	1	20-25	25-30		
17	8	1	D	3	1	Same pulse crop			
18	6	1	D	3	1	CZ	NWPZ		
19	1	1	D	4	1	Seedling			
20	2	1	D	4	1	Roots	Stems		
21	3	1	D	4	1	Early sown			
23	6	1	D	4	1	CZ	NWPZ		
24	9	1	D	4	1	75-80			
25	1	1	D	1	2	Podding			
26	2	1	D	1	2	Roots			
27	3	1	D	1	2	Any sown			
28	7	1	D	1	2	Close spacing			
30	6	1	D	1	2	NWPZ			
31	1	1	D	2	2	Podding			
32	2	1	D	2	2	Stems			
33	3	1	D	2	2	Normal sown			
34	7	1	D	2	2	Close spacing			

Figure 3.A Sample of Pulse Options Database

The production rules in the knowledge base are made up of 'Questions', 'Diagnosis' and 'Answers'. A Diagnosis is a final conclusion of the system (e.g. Wilt, Wet root rot, etc.). Questions form the conditions that must be met for individual diagnosis. Answers are used to receive user inputs in the form of text or image.

Example

If

The crop name is pigeonpea,
The crop stage is podding,
The affected plant part is pod,
Feeding habit is biting and chewing type,
Pest identification symptom is a white legless larva, brown puparia and black adult fly.

Then

The IF part of a rule contains the disease symptoms or the pest description (question and answers) and the then part of rule, the diseases/ insect-pest itself (diagnosis). This is very similar to a human way of thinking. Indeed, while performing a diagnosis, human doctors observe the symptoms (or conditions) first and then identify or diagnose the problem. 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. 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. For example:

Cultural Practices

Late sowing in the first fortnight of November in irrigated areas, lower seed rate, wider row and plant spacing, erect and tall varieties.

Chemical Controls

- Seed treatment with a combination of Bavistin + Thiram (1:2), Dithane M 45, Bavistin @ 3g/kg seeds, Thiobendazole @ 2g/kg seeds, Ravral and Ronilan @ 4 g/kg seeds
- For the control of secondary infection Dithane M 45 @ 350 g/ha, Thiobendazole or Bayleton @ 200 g/acre in 100 litres of water should be sprayed.

Conclusion

Diseases/ insect-pest Diagnosis and Treatment Knowledge base is created through an automatic knowledge acquisition system where data was fed by domain expert/knowledge engineer. The structure of the knowledge base is designed after consulting a variety of literature surveys,` different domain experts, extension workers and on-field farmers. The identification of various possible symptoms, diagnostic rules and constraints was done with the help of a team of domain experts (i.e., pathologists, entomologists and plant breeders). For pulse crops diseases/ insect-pests diagnostic domain, four major parameters (viz., crop parameters, field parameters, symptom parameters and visible pictorial

parameters) describing all the plant damage symptoms that may occur in the crop/plant at different stages were identified. Based on the identified parameters, a logical, clear and easy-to-answer crop-wise questionnaire was designed for all major pulse crops (viz., Chickpea, Pigeonpea, Mungbean, Urdbean, Lentil and Pea). Pictorial symptoms in the form of different photographs are collected with the help of domain experts and other sources like literatures, farmers, extension workers, etc. These photographs are stored in the knowledge base in the form of images using JPEG format. The knowledge entered by experts is automatically represented into database in the form tables and production rules so that it can be accessed easily. The tabular representation of knowledge provided a convenient way to organize the knowledge base. New symptoms (i.e. textual as well as pictorial) can be easily added, modified and old ones can be deleted allowing the system to be easily alter or update without changing structure of the database. The system is designed to be almost automated, interactive but at the same time user-friendly also. The developed system has the following characteristics:

- System easily allows the expert to enter the textual and pictorial symptoms
- It captures the knowledge of an expert through interactive sessions, distills the knowledge and automatically generates tables and rules used in decision making
- System enables the domain expert to input, view, modify and delete the information contained in the database
- Direct involvement of the domain expert results in increasing the accuracy of the knowledge by minimizing the error possibilities due to the communication gap between developer and expert

The entire process involved in the diseases/ insect-pest diagnosis and treatment knowledge base can be explained in three phases:

Phase-I. Preliminary Diagnosis: This gives preliminary idea about the diseases/ insect-pests or group of diseases/ insect-pests on the basis of textual symptoms such as crop stage affected, plant part affected, crop profile (crop location, crop sowing time, crop planting space), feeding habits of insect, stage of the insect, environmental conditions (temperature, humidity, rainfall etc.), status of soil moisture, and status of diseases/ insect-pest in previous crop sown in the field.

Phase-II. Final Diagnosis: Preliminary diagnosis is confirmed/ rejected by taking into account the pictorial symptoms. Every pictorial symptom in the knowledge base has at least one picture associated with it. These pictures assist the user/farmer in diagnosing diseases/ insect more correctly. The user/farmer is shown all the pictures related to all the symptoms because each identified diseases/ insect-pest has damaged symptoms on some plant parts like leaves, stems, roots, flowers, buds, pods etc.

Phase-III. Suggesting Control Measures: Once the system gets a final diagnosis, the resultant diseases/ insect-pest is used to query the control measures database. Depending upon the diseases/ insect-pest confirmed, the control measures are presented to the farmer/ user to control the diseases/ insect-pest in the field. The system searches and displays a recommended treatment, which are composed of cultural practices, varietal resistance and chemical controls.

Knowledge base of pulse crops, like any other dynamic system needs to undergo updating, testing and refinement. This research has demonstrated a useful automatic knowledge acquisition system in the development of a knowledge-based system for pulses which can be quite powerful in tackling the huge and enormously wide knowledge acquired from multiple sources related to the common problems in pulse agriculture (i.e., diseases/ insect-pest diagnosis and treatment).

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