International Journal of Bio-resource and Stress Management 2013, 4(2):192-200

Expert System for Integrated Stress Management in Jute (*Corchorus olitorius* L. *and C. capsularis* L.)

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Article History

Manuscript No. c613
Received in 23rd April, 2013
Received in revised form 3rd June, 2013
Accepted in final form 6th June, 2013

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Keywords

Corchorus spp., biotic stress, abiotic stress, management

Abstract

Jute (*Corchorus olitorius* L.= tossa jute and *C. capsularis* L.= white jute) is a traditional crop of nearly 300 years old with annual commercial value and provides livelihood to more than 5 million rural farm-families mostly located in the eastern part of India. A web-based expert system has been developed with the aim of improving decision-making by jute growers and other users. Knowledge was obtained from the literature and experts. The knowledge was then represented in the knowledge base of the expert system in a series of rules and heuristics. The system is a client-server application supported by a data base containing information of two domains-fibre production and seed production. Both the domains contain management information involving diagnosis and treatment to reduce losses due to weeds, diseases, insect-pests (biotic stress) and hydric stress (logging and drought), respectively, responsible for 22, 12.9, 11 and 25% of the total fibre crop loss of 23% annually in India. This integrated stress management is a part of the crop management system for judicious utilization of all components. The system is enhanced by photographs and drawings to assist the user in stress management of jute crop at the farm level. This user-friendly expert system can be helpful as a decision tool for farmers, technicians and policy makers towards early identification of the harmful agents and hydric stresses, their economic management and for education purpose as well.

1. Introduction

Jute (*Corchorus olitorius* L.=tossa jute and *C.capsularis* L.= white jute) is a traditional crop of 300 years old mostly located in the south-east part of Asia. In India its cultivation is spread over 0.91 m hectares to produce 11.57 m bales jute fibre with productivity of 22.83 q ha^{-1} (Chakraborty et al., 2013 and Directorate of Economics and Statistics, 2012) though the potential yield is more than 32 q ha^{-1}. It provides livelihood to more than 5 million farm-families mostly located in the eastern part of India. In spite of steep competition from polymer it is still reigning in India, contributing 62% of the world production with an annual turnover of around US$ 1 billion. Though the area under jute in India is steadily shrinking because of socio-economic interference, its production is sustained due to its commercial value, the role it plays in the rural economy and its eco-friendliness. It is predominantly a rainfed crop sown during *pre-kharif* season (1st April to 15th July) depending highly on uncertain north-western monsoon and harvested during *kharif* season (16th July to 15th November). Yield and quality of fibre is severely hampered by weeds, insect pests, diseases (biotic stress factors) and water logging and drought (abiotic stress factor). Skewed distribution of rainfall in the last decade (2000-2010) adversely affected crop growth due to 177 mm water deficit in the first 70 days and 193 mm surplus water in the last 50 days during *pre-kharif* season. Diseases, insect pests and weeds are responsible for yield reduction and quality deterioration of jute. Often due to water scarcity retting of harvested jute crop becomes difficult. About 25% of the Indian jute acreage is under low-lying situation (Ghorai et al., 2008a). The degree and duration of waterlogging varies widely depending on many factors associated with poor drainage. Contribution of weeds, pests, diseases and hydric stress-logging and drought contributed 22, 12.9, 11 and 25% respectively to the total fibre yield loss of 23% (Pandit et al., 2004; Ghorai et al., 2008b).

One effective way to increase crop productivity and quality is the reduction of losses due to stress factors by rational management of crop production. A concept in crop management is integrated stress management, i.e. a systematic concept to keep the crop damage due to stress factors below the economic injury level thereby minimize crop loss by improved crop management (protection from stress factors by judicious use of one or more of physical, chemical, biological and agronomic manipulations) that uses increased crop information and improved decision-making paradigm to reduce inputs and improve economic and social conditions in the farm ecosystem. Usually human experts are needed to provide the diagnostic knowledge; however, in some areas, domain experts are not readily available or scarce and experts may not have sufficient time to handle all diagnostic requests during the cultivation period or crucial moments. As the diagnosis and management may also be performed by an expert system (ES) it could play an important role in speeding up the crop production management system.

Application of ES in agriculture is not new. Although many applications (Rajkishore et al., 2002) have been developed for crop production and pest management system in other crops, this is the first attempt for jute crop. Rapid access to all the possible information may help them to take fast decisions to manage their crops efficiently and effectively.

In this paper, a web-based expert system is proposed for jute crop to provide growers and technicians with information for proper identification and management of harmful organisms (weeds, diseases and insects) and abiotic damages, i.e. water logging and drought commonly found in the jute tracts of India. The system can be useful for training as well as for education purposes. Moreover, the prototype system can be extended to other allied fibre crops with minor changes in the system design to make it applicable to pest management and risk assessment in other agro-ecosystem as well.

2. Materials and Methods

The study was based on biotic and abiotic stress factors standing in the way of realising full potential jute fibre yield. JAFexpert is developed during 2007-13 using SQL server for database management and ASP.NET (2.0) C# as programming language. It is a web-based Client-Server application. In this application object oriented methodology and heuristic method is followed having hierarchical organization of classes, sub-classes and solution classes. The subclasses are mutually exclusive and inherit discriminative features. Solution classes are enumerated, and hierarchy involve different types of classifications. In a stepwise hierarchical classification process, suitable classes towards final diagnosis/solution process is selected by proper data use.

The dynamic forms, tables, frames are applied in the JAFexpert which has enhanced security of data, easy and faster user interaction and accommodated heuristic knowledge of the experts. In developing the ES, four steps were followed: knowledge acquisition (KA), knowledge representation (KR), Interface for JAFexpert operation, and system evaluation.

2.1. Knowledge acquisition

Knowledge acquisition (KA) is the process of transferring knowledge from the knowledge source to the knowledge base. To acquire the required knowledge, we followed the KA procedure discussed in Rafea et al. 1993. A critical aspect of building an expert system is formulating the scope of the problem and gleaning from the source expert the domain information needed to solve the problem. The reliability of an ES depends on the quality of knowledge contained in the knowledge base.

Knowledge has been acquired from up to date published refereed sources, technical bulletins, manuals for advisers and other workers in jute and from the domain experts of CRIJAF, Barrackpore. Mostly, knowledge was acquired from domain experts and the personal experience of the authors. Conventional interviewing with the experts facilitated better understanding of the problem and its further representation. The knowledge was provided by five experts on crop protection (two plant pathologists, three entomologists) and one expert on crop production for weeds and hydric stress management. To fulfil the set functional objectives, the conceptual analysis and goal analysis were done to determine the required phases and components of the system. Unstructured and structured interview with experts helped conceptualize, clarify specific goals in the domains, and to gather the knowledge how the domain experts reached conclusions. The experts themselves recognized the expert whose decision must be followed and conflicts were resolved by consensus.

2.2. Knowledge representation

Knowledge representation is the problem of getting knowledge and expertise into the computer in a form that is easy to access and use in solving problems. The stress factors of jute that are included in the expert system are given in Table 1.

The following methods were applied in the JAFexpert to represent the KR for different domains.

In the ES, tables and production rules are used for knowledge representation. Information of questionnaire on pest identification have been represented in the form of five database tables (viz. m_pest, p_images) for storing all the data and images needed for insect-pest identification and management in jute crops. These tables have been designed in MS-SQL Server. Figure 2 shows table structures and relationship among different tables. Figure 3: depicts an example showing the structure of a rule for identifying pest in jute crop. The structure of rules for identifying particular pest makes use of textual as well as pictorial identification in the form of conditions. These

Table 1: Stress factors of jute included in the expert system.

Weeds	Common Name	Scientific Name
Narrow Leaved	Goose grass	*Acrachne racemosa*
	Doob	*Cynodon dactylon*
	Egyptian grass	*Dactyloctenium aegyptium*
	Crabgrass	*Digitaria sanguinalis*
	Viper grass	*Dinebra retroflexa*
	Sanwa	*Echinochloa crusgalli*
	Sanwa	*Echinochola colonum*
	Crowfoot grass	*Eleusine indica*
	Kanki, rye-grass	*Lolium multiflorum*
	Bandra	*Setaria faberi*
	Bandra	*Setaria gluca*
	Bandra	*Setaria lutescens*
	Green bristle grass	*Setaria viridis*
Broad Leaved	Kanta Note	*Amaranthus spinosus*
	Cholai	*Amaranthus spp.*
	Pig weeds	*Amaranthus viridis*
	White cockies comb	*Celosia argentina*
	Day Flower	*Commelina benghalensis*
	Kundra	*Digera arvensis*
	Dudhia	*Euphorbia hirta*
	Hazardana	*Phyllanthus niruri*
	Common purselane	*Portulaca spp*
	Rasvari	*Pysalis minima*
	Black Nightshade	*Solanum nigrum*
	Desert horsepurslane	*Trianthema portulacastrum*
Sedges	Mutha	*Cyprus rotondus*
	Yellow nutsedge	*Cyprus esculentus*
	Bindi mutha	*Cyperus difformis*
	Jal mutha	*Cyperus iria*
Diseases	Black band	*Botryodiplodia theobromae*
	Sooty mould of pods	*Cercospora corchori, Corynespora cassicola, Alternaria* spp.
	Anthracnose	*Colletotrichum corchorum; C. gloeosporioides*
	Tip blight	*Curvularia subulata*
	Stem rot	*Macrophomina phaseolina*
	Root knot nematode	*Meloidogyne incognita, M. javanica*
	Powdery mildew	*Oidium* sp.
	Stem gall	*Physoderma corchori*
	Hooghly wilt	*Ralstonia (=Pseudomonas) solanacearum*
	Soft rot	*Sclerotium rolfsii*
	Yellow mosaic	*Virus*
Insect-pests and mites	Cut worm	*Agrotis ipsilon*

Continue

	Jute semilooper	*Anomis sabulifera* Guenee
	Jute apion or stem weevil	*Apion corchori* Marshall
	Thrips	*Ayyaria chaetophora* Karny
	Mealy bug	*Ferrisia virgata* Ckll.
	Indigo caterpillar	*Laphygma exigua, Spodoptera exigua* Hübner
	Grey-weevil	*Myllocerus discolor* Boheman
	Jute girdler	*Nupserha bicolor postbrunnea* Dutt
	Red mite	*Oligonychus coffeae* Nietner
	Yellow mite	*Polyphagotarsonemus latus* Banks
	Bihar hairy caterpillar	*Spilosoma obliqua* Walker
Hydric stress	Drought	
	Waterlogging	

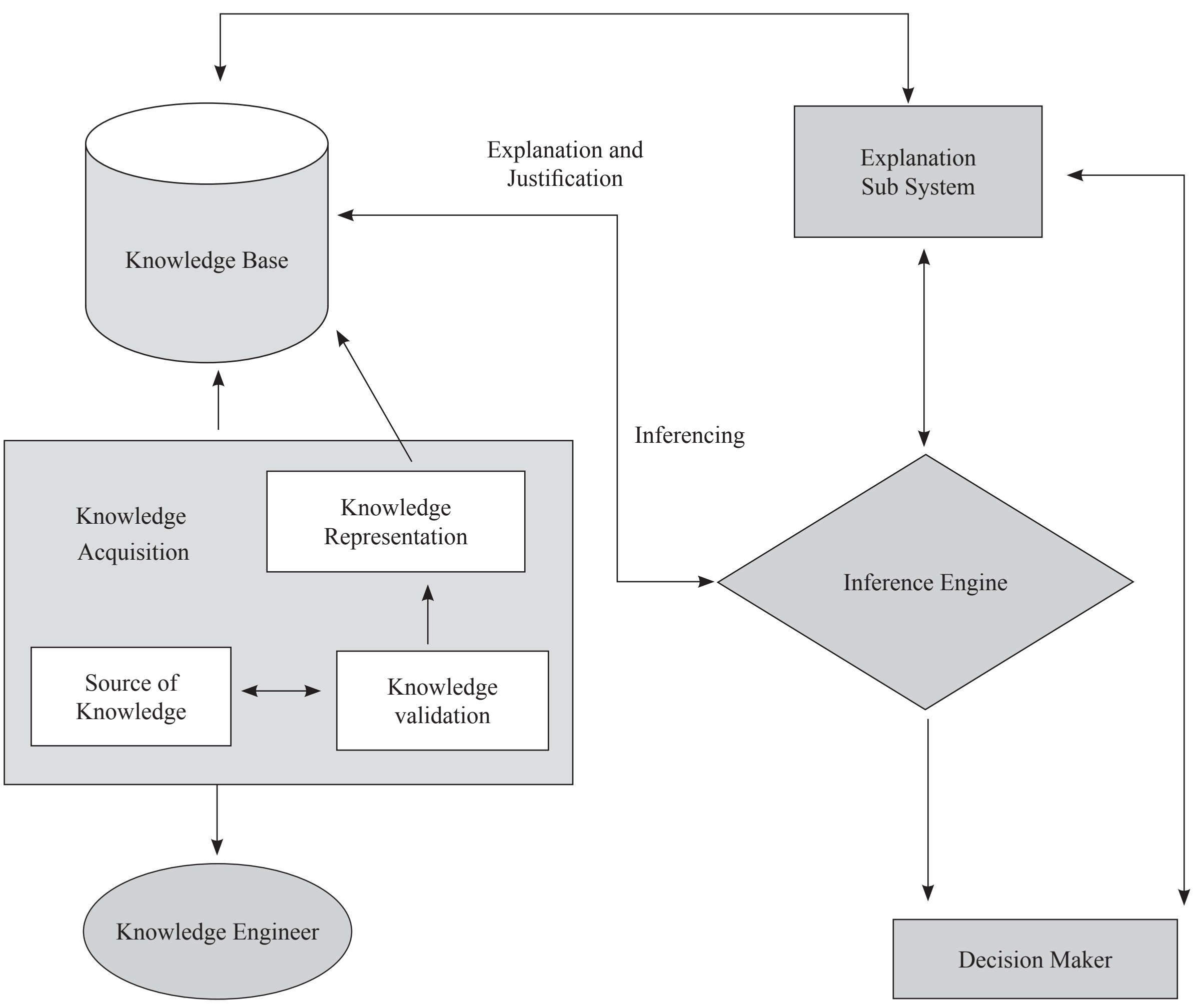


Figure 1: Architecture of Jute Expert System

conditions are connected through the logical operators.

2.3. Interface for expert system in operation

At the beginning of each session, the user is prompted to select the particular module that are fed with related rules corresponding to weeds, diseases, insects, water logging or drought stresses. Figure 4 illustrates the way data flows between three layers, namely, presentation layer, logic layer, and data access layer.

Farmers and domain experts interact with the system through the interface to get the results of their queries or to view the knowledge (Gonzalez-Diaz et al., 2009). One of the important feature of Jute Expert System is that the system follows the principle of "minimum work" to reach a conclusion (Jones et al., 1993). It requires very limited and simple knowledge in the form of answers to multiple choice questions to guide the users on their crop related queries. The user operates the system through browser or graphical user interface (GUI). A sample screen shot of home page of JAFexpert is presented in Screen 1. The entire process involved in the diagnosis of stress factors and their management in three phases: preliminary diagnosis, final diagnosis and management. The system records the decision made at each level as *Question & Answer Session*. It is helpful to user with respect to the questions asked by the system and answers given by the user at each level. All extra knowledge in the form of suggestions given by the user / farmer in the feedback form can be accommodated further to modify the knowledge base with the consultation of domain experts.

Few examples for the identification of stress factors and their management are illustrated through displays in Screen 2 (selection of the type of weed management step by step for long duration crop in post emergence), Screen 3 (weed management solution page for mechanical control in post emergence for long duration crop), Screen 4 (Question & Answer session for the identification of insect-pests through multiple choice question based on users' answer), Screen 5 (pictorial symptoms and management of identified insect-pest), Screen 6 (Decision tree for diseases diagnosis), Screen 7 (disease details and management), Screen 8 (drought management) and Screen 9 (waterlogging), respectively.

2.4. System evaluation

The evaluation process of the expert system was carried out in two steps: verification and validation (Mahaman et al., 2003).Verification refers to building the system right, i.e., substantiating that a system correctly implements its specifications; while Validation refers to building the right system i.e., substantiating that a system performs with an acceptable level of accuracy. During the Jute Expert verification phase, the system was tested by five domain experts on crop protection (two plant pathologists, three entomologists) and one expert on crop production for weeds and hydric stress

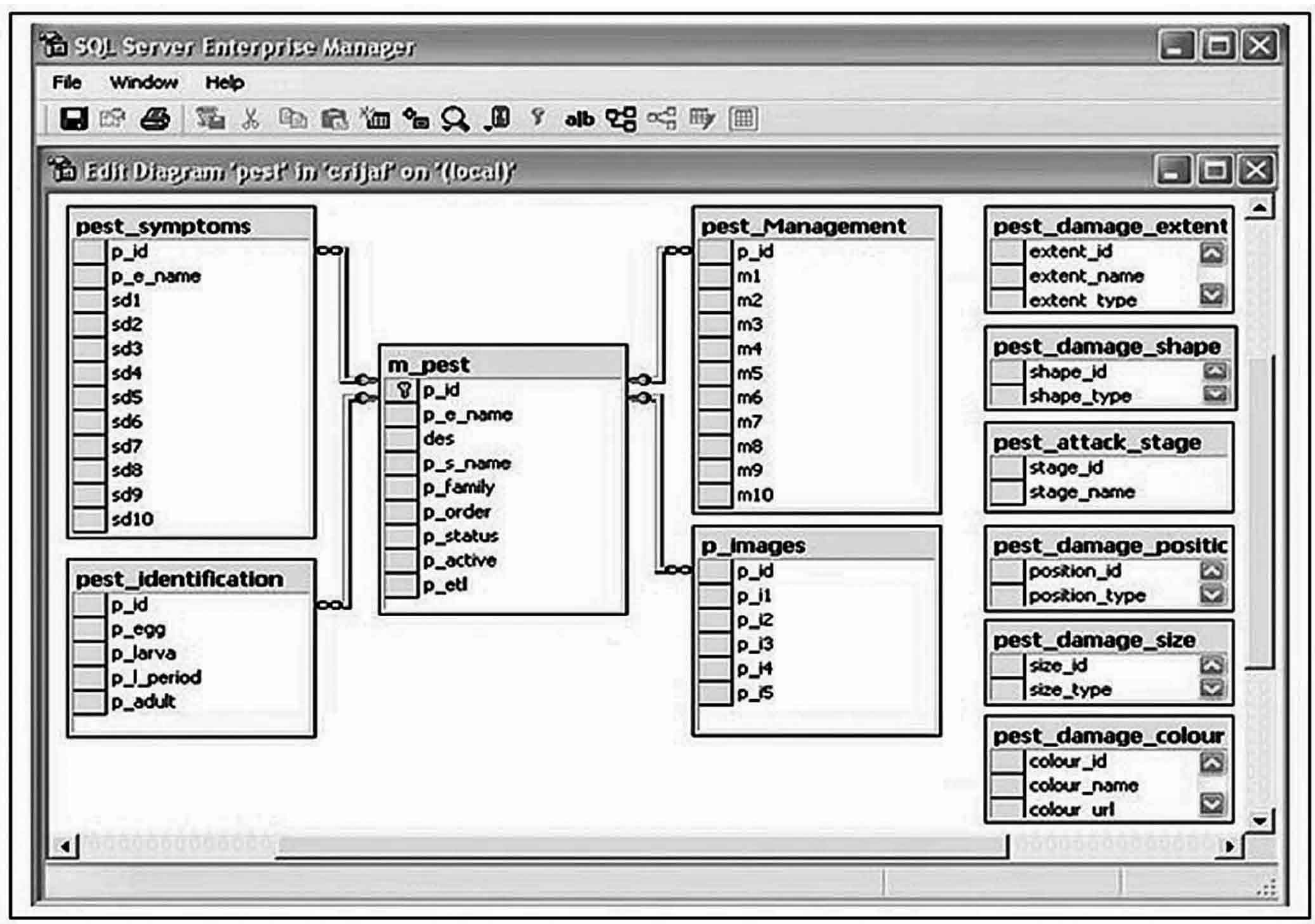


Figure 2: Table structure and relationship between tables in the pest identification and management

Crop Name: Jute
Textual Condition:
IF The Crop age is in harvesting stage and
The Affected part of the plant is leaf
THEN Select Pictorial condition
Pictorial condition: (image3)
IF The shape of the damage is cut/chewed and
The cut type is serrated diagonal cut and
The damage occurred in apical leaves and
The other symptom is plant defoliation
THEN Final Identification:
IF True
THEN The pest is: Jute Semilooper

Figure 3: An example showing the structure of a rule for pest identification

management within the Central Research Institute for Jute and Allied Fibers (CRIJAF). They have checked whether it could actually help in stress management. Functionality tests, performance test, configuration test and documentation tests were carried out by project developer to check if the system satisfied the functional requirements as documented in the System Requirement Specification (SRS) document. To evaluate performance of the JAFexpert, test cases corresponding to different stress factors and their related advice were performed. So many test cases corresponding to diseases, pests and weeds were prepared manually by the knowledge engineer. Each of the domain experts as well of the jute Expert solved the test cases independently. It was also observed by tracing all pathways that the system is running properly. Jute Expert was run many times giving all the combinations and the result of each consultation was verified by the experts and the developer.

During the validation process, particular attention was paid to the system performance in carrying out the diagnosis and management. All the participants used the system either on their own or with some help and evaluated the system performance. Their comments and suggestions on system performance were received through the feedback form. Feedback form had following criteria's: user friendliness, clarity of questions asked, level of correctness of the system in identifying the diseases pest and completeness of the database.

3. Conclusion

JAFexpert is developed to provide online help to jute growers and extension workers to access the knowledge of multiple experts on diagnosis of stress factors and their management.

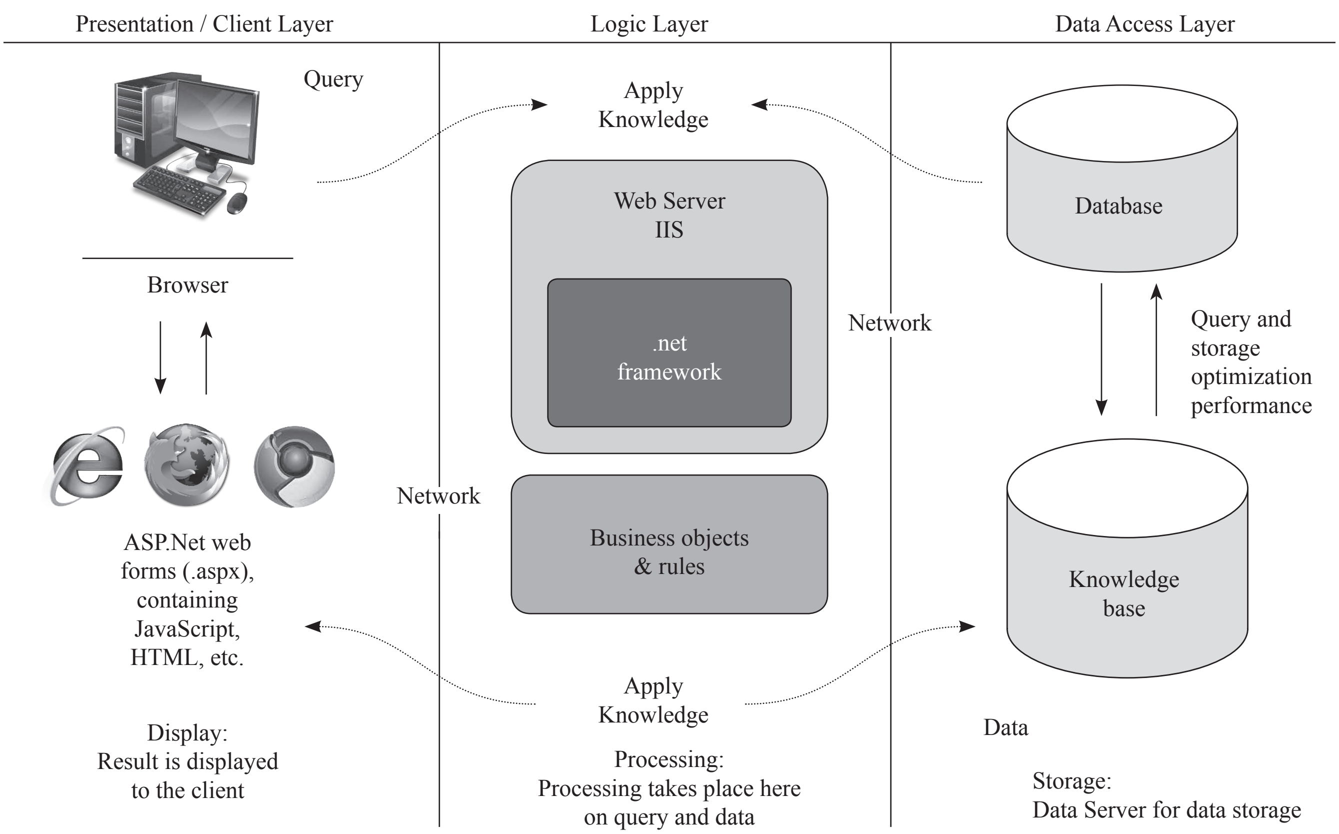
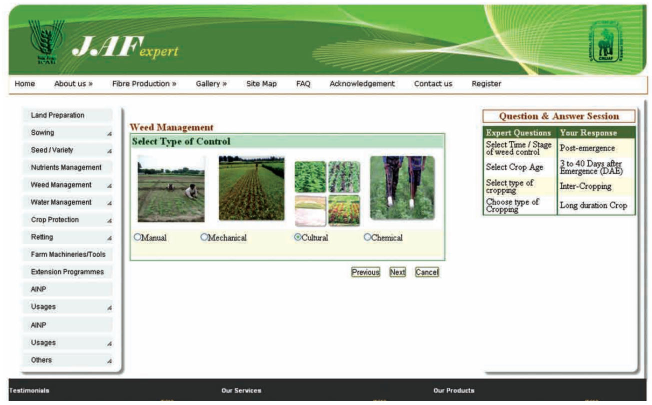
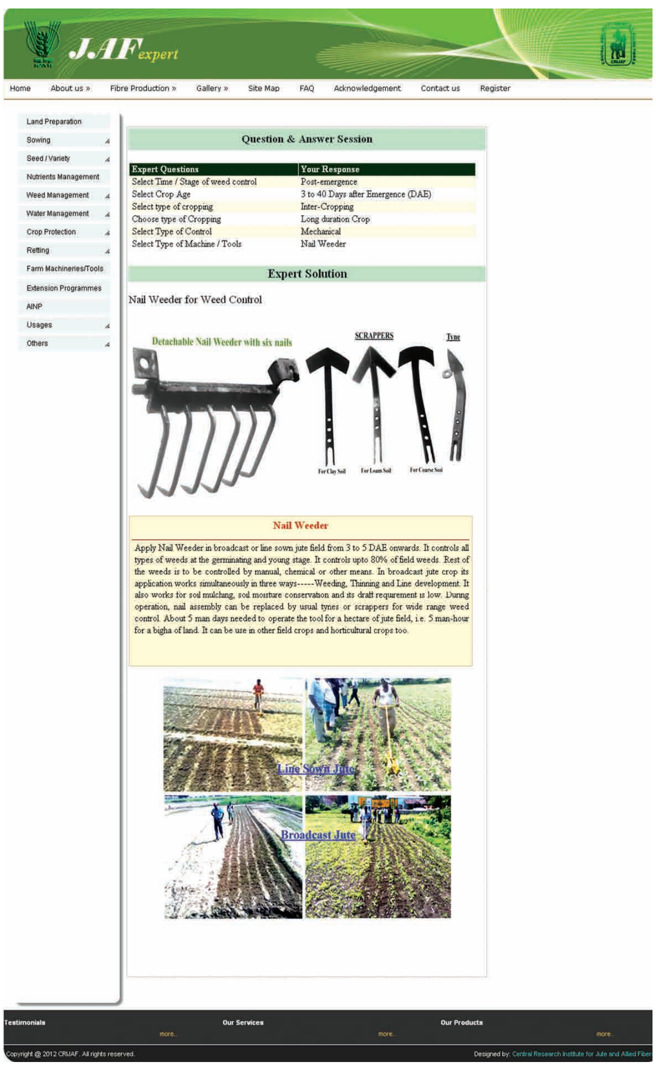


Figure 4: Pictorial representation of data flow between layers in JAFexpert

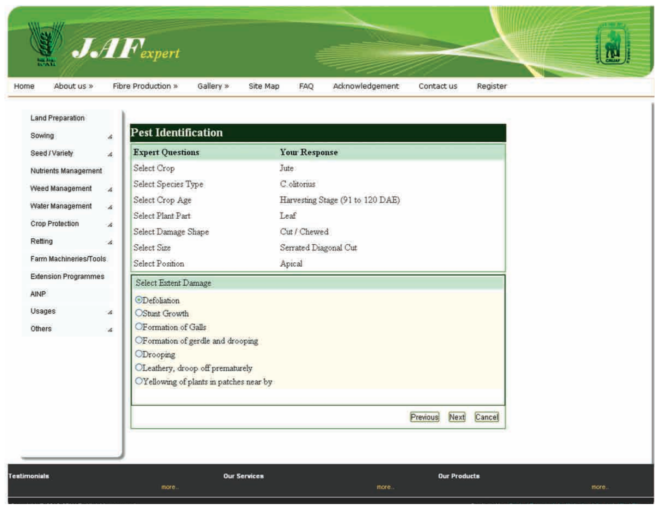
Screen 1: Home page of JAFexpert



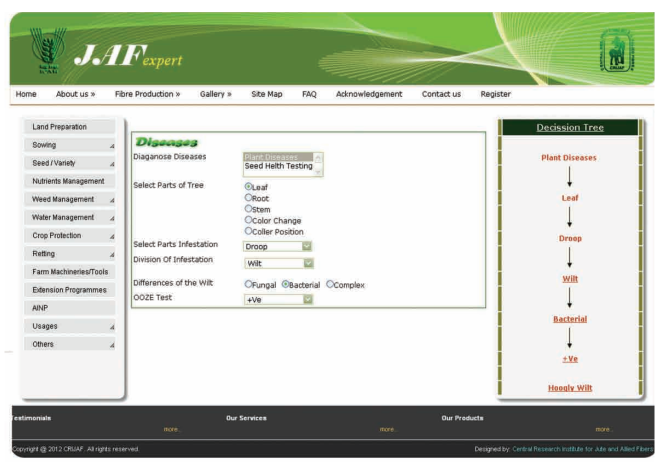
Screen 2 :Question & Answer session



Screen 3: Solution page for weed



Screen 4: Insect-pest identification

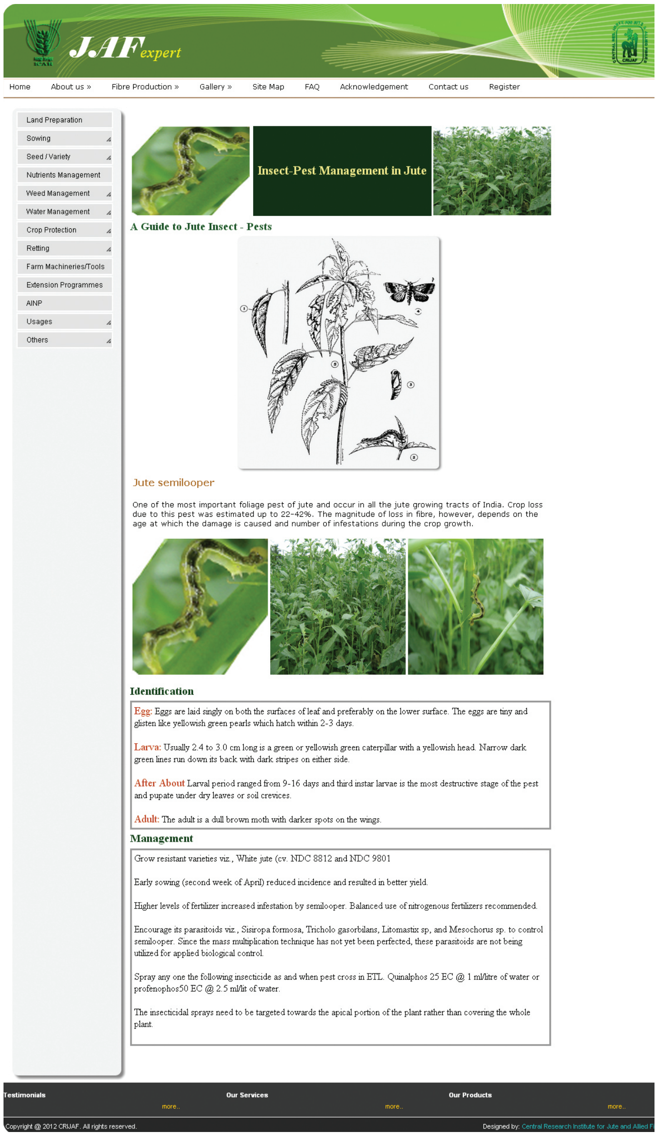


Screen 6: Decision tree for disease

The inference engine of JAFexpert automatically matches facts against conditions to determine which rules are applicable.

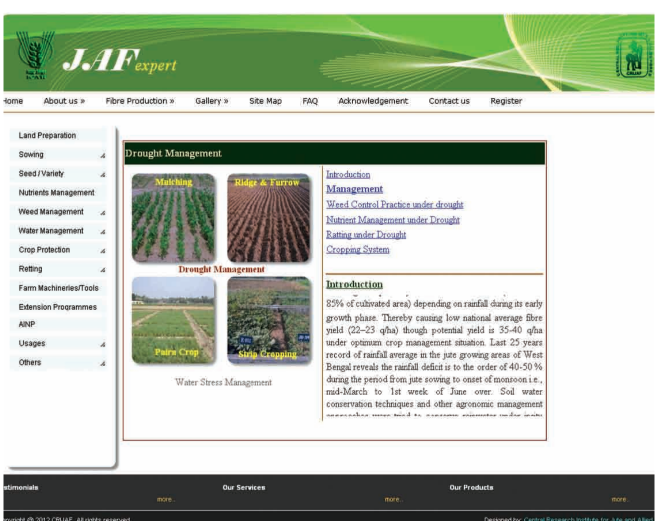
4. Further strategy

For further improvement of the system adoption of new cases,

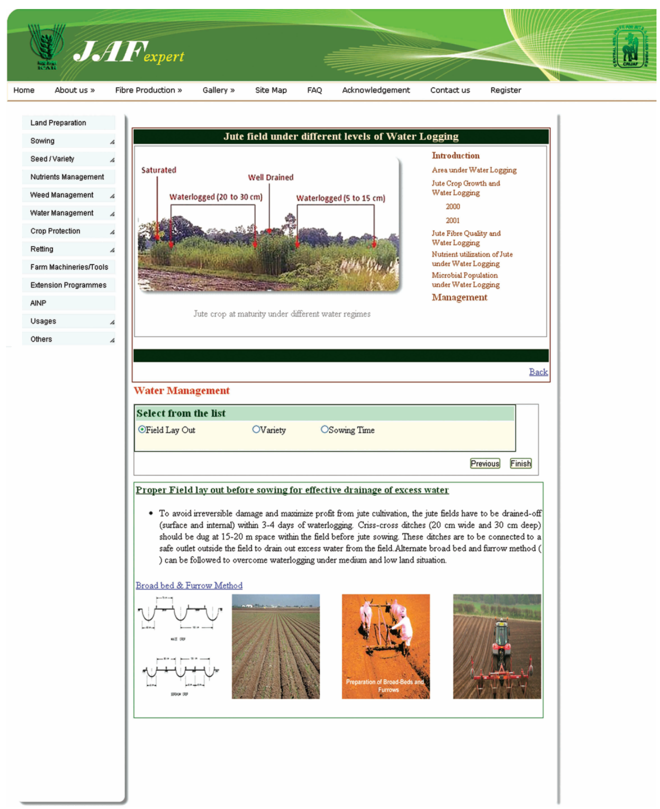


Screen 5: Details of identified insect-pest and management

Screen 7: Disease details



Screen 8: Drought management



Screen 9: Waterlogging management

technologies and programming methodology are useful, likewise the suggestions received through the 'User Feedback' form. This work can be extended for other allied fibre crops and developed in other languages for better communication.

5. Acknowledgement

The authors are immensely grateful to Dr. B. S. Mahapatra, Director, CRIJAF, Barrackpore for support and encouragement and Ministry of Textiles, Government of India for the financial grant in pursuing the project work under Technology Mission on Jute. The authors are indebted to the domain experts especially Dr. S. Satpathy, Dr. K. Selvaraj, Dr. R. K. Mandal and Dr. N. C. Pandit for their cooperation and support during knowledge elicitation for the Jute Expert System. The assistance of scientists, field staff and farmers in evaluation of the JAFexpert is also gratefully acknowledged.

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