Expert System for Decision Support in Agriculture

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1. Introduction

Agricultural production system has been evolving into a complex business system requiring the accumulation and integration of knowledge and information from many diverse sources. In order to remain competitive, the modern farmer often relies on agricultural specialists and advisors to get information for decision making. Unfortunately assistance of the agricultural expert is not always available when the farmer needs it. In order to alleviate this problem, expert systems were identified as a powerful tool with extensive potential in agriculture.

An Expert System (ES), also called a Knowledge Based System (KBS), is a computer program designed to simulate the problem-solving behavior of an expert in a narrow do main or discipline. The expert system could be developed for decision-making and location specific technology dissemination process. An expert system is software that attempts to reproduce the performance of one or more human experts, most commonly in a specific problem domain, and is a traditional application and/or subfield of artificial intelligence.[5]Expert systems helps in selection of crop or variety, diagnosis or identification of pests, diseases and disorders and taking valuable decisions on its management. The expert system which developed earlier were more of text based and could be utilized only by the extension officials and scientists.

Keeping the importance of ICT enabled interventions in agriculture and providing timely expert advise to farmers, the expert system on agriculture and animal husbandry was proposed and obtained as net work project from Indian Council of Agricultural Research. The

aim of the project is to develop expert system for agriculture (Paddy, Sugarcane, Banana, Ragi and Coconut) and animal husbandry for the three state in their respective languages ie., Tamil Nadu (Tamil), Karnataka (Kannada) and Kerala (Malayalam).

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2. Meaning, Importance and Early efforts

a. Expert system meanings

An Expert System is a computer program that stimulates the judgment and behaviour of a human (or) an organization that has expert knowledge and experience in a particular field. It is program that emulates the interaction a user might have with a human expert to solve a problem. An Expert System is a problem solving and decision making system based on knowledge of its task and logical rules or procedure for using knowledge. Both the knowledge and the logic are obtained from the experiences of a specialist in the area (Yogesh Kumar et al).

Expert System are recognized as an appropriate technology because they address the problem of transferring knowledge and expertise from highly qualified specialists to less knowledgeable personnel. In agriculture, this transfer is always taking place from research to extension, from extension to farmers, and even from farmers to farmers. Expert system present excellent tools for relieving the increasing pressure on the limited expertise available in developing nations. It must be recognized that knowledge, the very foundation of

expertise, is a scarce resource in developing nations. Expert System can help expand this vital resource by making available, in specific situations, vital knowledge that increase the effectiveness of less experienced personnel (Rafea et al ,1996).

The Expert System uses a hierarchical classification and a mix of the text description; photographs and artistic pictures. The system involves two main sub tasks, namely diagnosis and management. The system designed and developed using visual basic as front- end and Microsoft Access as back- end software (Vinod Kumar et al, 2008).

An Expert System is a computer program normally composed of a knowledge base, influence engine and user-interface. Expert system in the area of agriculture and describes the design and development of the rule based expert system, using the shell ESTA (Expert System for Text Animation). The designed system is intended for the diagnosis of common diseases occurring in the rice plant. ESTA programming is based on logic programming approach. The system integrates a structured knowledge base that contains knowledge about symptoms and remedies of diseases in the rice plant appearing during their life span (Shikhar et al)

An Expert System is defined as " a computer program designed to model the problem solving ability of a human expert " (Durkin,1994). It is also defined as "a system that uses human knowledge captured in a computer to solve problems that ordinarily require human expertise". Expert System increases the probability, frequency and consistency of making good decisions, additive effect of knowledge of many domain experts, facilitates real time, low – cost expert level decisions by the non-expert enhance the utilization of most of the available data and free the

mind time of the human expert to enable him or her to concentrate on creative activities. Expert System offers an environment where the good capabilities of humans and the power of computer can be incorporated into overcome many of the limitations (Mercy Nesa Rani et al,2011).

b. Importance of Expert System

The complexity of problems faced by the farmers are yield loses, soil erosion, selection of crop, increasing chemical pesticides cost, pest resistance, diminishing market prices from international competition and economic barriers hindering adoption of farming strategies.

Expert System are computer program that are different from conventional computer programs as they solve problems by mimicking human reasoning process, relying on logic, belief, rules of thumb opinion and experience.

In agriculture Expert System are capable of integrating the perspectives of individual desciplines such as plant pathology, entomology, horticulture and agricultural meteorology into a framework that best address the type of ad hoc decision making required of modern farmers. Expert system can be one of the most useful tools for accomplishing the task of providing growers with day to day integrated decision support needed to grow their crops.

c. List of Expert System in Agriculture

The works carried out on Expert System in agriculture and allied field and various software used to develop an Expert System by authors were collected worldwide and presented as follows.

S. No.	Authors	Name of ES	Utility	Software/ Shell used
1.	Fermanian *et al*. (1985)	PLANT/tm	Diagnosis of weed in turf	-
2.	Jones and Haldeman (1986)	CHAMBER	Management of environmentally controlled crop research facility	-
3.	Lemmon (1986)	COMAX	ES for cotton crop management	-
4.	Palmer (1986)	COMAX	Soybean crop variety selection	PROLOG
5.	Shroyer *et al.* (1987)	WHEAT WIZ	Cultivator selection tool	-
6.	Bennett and Sneed (1988)	COMAX	Planning, design and evaluation of irrigation systems	PASCAL

7.	Floris *etal.* (1988)	COMAX	Real-time operation; real-time meteorological data handling	PASCAL
8.	Getforth and Macvicer (1988)	OASIS	Operation of control structures; real-time meteorological data handling	PASCAL
9.	Haie and Irwin (1988)	EXSYS	Drainage diagnosis	PASCAL
10.	Halterman *et al*. (1988)	ES	Double cropping management	-
11.	Boggess *et al*. (1989)	FinsARS	Financial analysis for farm business management	-
12.	Stone and Toman (1989)	COT FLEX	Cotton crop management; coupled with SOYGRO model	PASCAL

13.	Batchelor *et al.* (1989)	SMART SOY	Soybean crop management	Insight 2+
14.	McClendon *et al.* (1989)	SMART SOY-IRRIG	Soybean irrigation	Insight 2+
15.	Morgan *et al*. (1989)	CUE	Crop variety selection	SELECT
16.	Hart *et al.* (1989)	CUE	Irrigation system selection	LISP
17.	Hershaeur et al. (1989)	CUE	Canal water distribution; canal network incorporated	LISP
18.	Bhatty (1990)	RESEXP	Reservoir operation; DP model integrated	PROLOG
19.	Helms et al. (1990)	CIRMAN	Crop insurance strategies	-
20.	McGregor and Thornton (1990)	CVSES	Wheat crop variety selection	CRYSTAL
21.	Oswald (1990)	TANK	Tank systems diagnostic analysis	PROLOG

22.	Han et al. (1991)	ES	Sprayer diagnostics	-
23.	Hasbini et al. (1991)	PUMP	Operational guidelines for center pivot systems	PASCAL
24.	King et al. (1991)	MKBS	Fertilizer and irrigation applications	Turbo C
25.	Nevo and Amir (1991)	CROPLOT	Multiple crop selection	Rabbi
26.	Srinivasan et al. (1991)	ESIM	Delivery system operation; canal network incorporated	EXSYS
27.	Clarke et al. (1992)	IRRIGATOR	Irrigation scheduling; ET method selection	PC PLUS
28.	Elango et al. (1992)	BDM-EXPERT	Drought management integrated with CASIMBOL model	IITM RULE
29.	Kumar *et al*. (1992)	KBS	Economic	Level 5

			feasibility of irrigation system selection	
30.	Nakamura and Tsukiyama (1992)	ES	Irrigation canal renovation project planning	-
31.	Plant *et al*. (1992)	CALEX/cotton	Cotton irrigation scheduling	CALEX
32.	Raman *et al.* (1992)	BDM-EXPERT	Crop planning under droughts; LP model inferencing	Insight 2+
33.	Bralts *et al.* (1993)	ES	Hydrologic analysis of micro irrigation system	=
34.	Mohan and Arumugam (1994)	CROPES	Multiple crop selection	IITM RULE
35.	Nevo *et al.* (1994)	CROPLAN	Optimal crop	PROLOG

			planning; LP model integrated	
36.	Pasqual (1994)	ES	Identification and control of weeds in wheat, barley and oats	-
37.	Arumugam (1995)	TANKES	Tans system operational guidelines; real-time operation	VP-EXPERT
38.	Mohan and Arumugam (1995)	ETES	ET estimation method selection	VP-EXPERT
39.	Nuthall and Bishop-Hurley (1996)	-	ES for animal feeding management	VP-EXPERT
40.	Yialouris *et al.* (1997)	VEGES	A multilingual Expert System for the diagnosis of pests and	AUA-ES

			diseases and nutritional disorders of six greenhouse vegetables	
41.	Ganesan (2002)	AGRES	Diagnosis of pests and diseases of major crops of Kerala	-
42.	Balasubramani(2004)	RUBEXS-04	Disease and Diagnosis in rubber plants	VB

The studies reviewed under this section clearly indicates that, various softwares were used by the researchers to develop computer-based Expert System and used as an effective tool in various fields of agriculture. The above observations suggests the need to develop a user friendly computer based Expert System considering the flexibility, simplicity, nature of problem and familiarity of the software to the student researcher.

d. Experiences in Using Expert System for Agricultural Development

Bundy (1984) stated that the application of Expert System generally falls under three classes, namely, Expert System proper, intelligent front-ends, and hybrid systems. An Expert System proper is a purely rule based system, relying on a sizable knowledge base. It is based on a qualitative, causal understanding of how things work. Such a system is more suitable under situation wherein not quantitative data are used. It is essentially conceptual and heuristic rule-based system. An intelligent front-end is a user-friendly interface to a software package, enables the user to interact with the computer using his/her terminology. It minimizes or avoids misuse of complex models by less experienced users. A hybrid system represents the integration of algorithmic techniques with Expert System concepts.

Cook *et al.* (1988) developed a microcomputer-based, graphics-oriented Expert System for use in the design of parallel terrace systems. It divides the design process into manageable activities: digitization of a contour map, input of field and machinery characteristics, definition of "watersheds" to be terraced, definition of the outlet system and waterway divides, placement of conventional terraces and placement of parallel terraces based upon a key terrace. The system is able to make design suggestions based on accepted practices and the programmed knowledge of recognized terrace system design experts.

Haie and Irwin (1988) stated that the Expert System was developed for use in land drainage decisions. It was designed to diagnose the causes of the drainage problems in the command area of an irrigation system. Factors such as water regime in the soil profile, presence of a cultivation pan or an impermeable layer below the topsoil etc., were

considered. Diagnostic Expert System is intended to identify the causal factors that are responsible for the poor functioning of an irrigation system.

Kurata *et al.* (1989) described on Expert Systems for tomato growers, farm machinery, troubleshooting and farm work scheduling. The tomato growing Expert System answers questions on greenhouse environment, disease and fertilization.. The farm machinery program collects information about problems in machinery operation and provides a scheduling system for sending a technician to the farm, depending on the diagnosis. The work scheduling Expert System consists of long, middle and short term scheduling programs for field operations. The number of working days for each farm, progress of operations, materials to use and requirements for a specific day's operation are some of the questions answered.

Morgan *et al*. (1989) described on Expert System for crop variety selection. They developed a system which was designed to consider the soil characteristics, water availability and prevalence of diseases. This system was developed for winter wheat in Scotland. This would allow agricultural extension officers to recommend varieties with confidence thereby reducing the demand for advice from specialist crop advisors.
Sprangler *et al.* (1989) observed that an expert's knowledge is the central and key component of developing an Expert System. Furthermore, it is more difficult component. At the end the knowledge acquisition must be

Regarded as much as an art as a methodical and scientific procedure. One approach, however, that often seems to be ignored is the collection, integration and use of research results, while an expert should clearly build research results into their expertise, it is also possible to

bypass the expert and use the published results in formulating rules in cases where the research provides a complete and logical answer.

Bhatty (1990) presented a hybrid Expert System for optimal operation of a reservoir system in Pakistan. This Expert System includes the cognitive and computational components involved in the reservoir operation. The reservoir operation has the objectives of irrigation and hydropower generation. This Expert System was mainly intended to maximize power production.

Oswald (1990) has studied the feasibility of using an Expert System for the tank diagnostic analysis. Diagnostic analysis is usually performed by experts who try to find the reasons for the malfunctioning of tank irrigation system and also to identify possible remedial measures. The limitation of the study is that the basic knowledge is derived from only two tank irrigation systems in south India. Hence, the general utility of this Expert System to other tank irrigation system is limited.

Batchelor *et al.* (1991) revealed that Expert Systems methodology has shown considerable promise as an information technology. However, limited knowledge of how current information technologies relate to the decision process impedes the adoption of Expert Systems. The significance of developing an economic theory of Expert Systems is substantiated with an empirical application investigating a soybean pest management decision process (SMARTSOY) based on experience with four insect pests causing damage to soyabeans in the southeastern USA. SMARTSOY is combined with SOYGRO (soyabean crop growth simulation model). Pest management recommendations from extension bulletins and the Expert System are compared with an expert's recommendations. Results indicate the potential improvement in

decision-making processes with the adoption of Expert Systems.

Elango *et al.* (1992) stated that the Expert System developed, is a management tool for dealing with water shortages. Apart from crop planning, the hybrid Expert System approach has also been employed to provide managerial assistance under water shortage situations. It is combined with an irrigation game model CASIMBOL (Computer Aided Simulation of Irrigation Management Below Outlet) for managing water deficits.

Raman *et al*. (1992) dealt with development and application of an Expert System for drought management. A linear programming model was used to generate optimal cropping patterns from past drought experiences as also from synthetic drought occurrences. These policies together with the knowledge of the experts were incorporated in an Expert System. Using this, one can identify the degree of drought in the current situation and its similarity to the identified drought events and be able to get the corresponding management strategy.

Rafea and Howard (1996) stated that the assessment of Expert System evaluates the climate, water and soil properties and provides the user with the advice on the feasibility of cultivating lime in this site. In the assessment of subsystem, there are two ways of integration with multimedia. The first one is through building the link to the media inside the knowledge base. The system one is dynamic and based on building the link to the media during the consultation time. Lime Expert System (LIMEX) was able to correctly assess 16 out of 20 cases and to provide excellent assessment of the lime cultivation feasibility in 12 out of 20 cases. These results suggest LIMEX as a significant and useful tool for lime cultivation.

Mohan and Arumugam (1997) developed and presented an Expert System for multiple crop types in large regions in South India. Availability of water and other resources, climate, soil characteristics and farmer related factors were comprehensively entailed in representing the domain knowledge. This Expert System was evaluated for two years using field data involving a group of farmers and specialists in practice. A good agreement was found between the decisions of the Expert System and the preference of the specialists. However, under similar circumstances, the preferences of the specialists are different from the decision of Expert System. This aspect owes to the fact that farmers educational status is poor and they are traditionally oriented. It is concluded that the application of the Expert System approach to irrigation management offers several advantages: a saving of the expert's time; increased understanding of the system; and useful training capability for the water managers. The spectrum of Expert System application is expected to expand in the future so that every decision-intensive task in irrigation management will have a corresponding decision which greatly relieved the dependence of water managers.

Ganesan (2002) stated that AGREX (Agricultural Expert System) is a user friendly computer based package which provide precise, up-to-date information, advises and suggestions to farmers regarding diseases and pests affecting plants and recommendations on the prevention/control measures against them, in the swiftest possible manner. AGREX consists of four modules such as FRS (Fertilizer Recommendation System), CPS (Crop Protection System), FARMWAT (Farm watering) and RICEDIAG (Rice Diagnosis). The module FRS recommends the fertilisers to be used, the quantity, the cost and also the proportion of each chemical in a

mixture. CPS suggests management measures for combating diseases and pests. FARMWAT tells the farmers the method of irrigating a plot, the quantity of water for each crop depending on the soil-crop evapo-transpiration and place, using the crop factor, crop coefficient and effective rooting depth of each crop and water holding capacity of the soil. RICEDIAG is an Expert System for diagnosis of the disease-affecting paddy. It follows forward and backward chaining methods.

Jayawardhana *et al.* (2003) developed a user friendly Expert System BESTCOMP: Expert System for Sri Lankan solid waste composting for better management of solid waste composting by local authorities in Sri Lanka. BESTCOMP Expert System mainly focussed on the behaviour of the physical, chemical and biological process in composting. The intention had been to provide distant users with scientific and techno-economic information using modern tools but at a much lower cost. This research has put very strong emphasis on allowing the user to browse around the knowledge that has being extracted from books, published research articles, reports, audio, video, Internet, case studies and the domain experts who involved in solid waste management activities, so the user can get an accurate and a real feel for the solid waste management subject.

Thomson and Willoughby (2004) revealed web-based Expert System was developed to advise on the relative efficacy of different herbicides for mixes of weed and crop species at different times of the year in a forestry or farm forestry setting. The system assumes that weed identification and impact assessment or prediction has already been accomplished and that there are no cost-effective non-chemical alternatives. The Expert System produces a relative suitability index for

each herbicide, as well as an English language discussion of the case.

Knowledge-based expert system technology has been applied to a variety of agricultural problems, since the early eighties. The following paragraphs present how expert systems were considered in agriculture in the eighties. The papers have been selected to represent different applications and to be easily obtained by interested readers.

The expert system applied to the problems of diagnosing Soybean diseases (Michalski t al., 1983) was one of the earliest expert systems developed in agriculture. A unique feature of the system is that it uses two types of decision rules: 1) the rules representing experts diagnostic knowledge, and 2) the rules obtained through inductive learning from several hundred cases of disease

POMME (Roach et al,, 1985) was an expert system for apple orchid management. POMME advises growers about when and what to spray on their apples to avoid infestations. The system also provides advice regarding treatment of winter injuries, drought control and multiple insect problems.

National Institute of Agricultural Extension Management (MANAGE) has developed an expert system to diagnose pests and diseases for rice crop and suggest preventive as well as curative measures. The rice crop doctor illustrates the use of expert-systems broadly in the area of agriculture and more specifically in the area of rice production through development of a prototype, taking into consideration a few major pests and diseases and some deficiency problems limiting rice yield.

The first Expert system software for use by the grape cultivators was developed by the Indian Institute of Horticultural Research Institute,

Bangalore. This spontaneous response for the product made them to

Undertake development of similar software for providing guidance to mushroom cultivators, which became extremely popular and a large number of growers started using it regularly for getting solutions to their problems.

Center for Informatics Research and Advancement, Kerala has prepared an Expert System called AGREX to help the Agricultural field personnel and give timely and correct advice to the farmers. These Expert Systems find extensive use in the areas of fertilizer application, crop protection, irrigation scheduling, and diagnosis of diseases in paddy and post harvest technology of fruits and vegetables.

Punjab Agricultural University, Ludhiana, has developed the Farm Advisory System to support agri-business management. The conversation between the system and the user is arranged in such a way that the system asks all the questions from user one by one and based on which it gives recommendations on the topic of farm Management.

3. Expert System Content Development

a. Content Generation

The relevant contents on the respective crops are very important for developing expert system using the appropriate soft wares. Accordingly, the contents on paddy, sugarcane, banana under precision system, Coconut, Ragi, Cattle & Buffaloe, Sheep & Goat and Poultry were scouted from the State Agricultural Universities namely Tamil Nadu Agricultural University and its research centres, University of Agricultural Sciences, Bangalore & Dharward, University of Horticultural Sciences, Bagalkot, University of Veterinary Sciences,

Karnataka, Kerala Agricultural University and all KVKs coming under Zone VIII.

The contents were scouted directly from the scientists, extension workers and other stakeholders through direct contact methods, group discussion, interactive meeting and brainstorming methods.

The images and Videos Contents were scouted from the universities, research stations, farmers' field and other recognized research institutions during critical stages of crop growth period. All the images scouted from direct field and research plots.

b. Content Validation

Content validation is very important for any content development and content authorization for uploading the same into any ICT platform. Hence, intensive exercises have been undertaken to validate the scouted contents with help of concerned scientists at TNAU and other partners. The contents validation team has been constituted based on subject matter specialists wises especially to validate the contents, photos and videos for getting authenticity and reliable contents. The content validation for English was carried out at TNAU, SBI Coimbatore, NRCB, Trichy, KAU, Thrissur, UAS Bangalore and ZPD, Zone VIII Bangalore. The Tamil content was validated at TNAU and KVKs of Tamil Nadu. The ZPD, Zone 8 has carried out the content validation for the Kannada languages with support of KVKs, UAS Bangalore and Dharwad and UHS, Bagalkot. The Malayalam languges validation was done with help of Kerala KVKs and KAU, Kerala.

c. Content Translations:

The C-DAC, Hyderabad has identified as content translators for

Tamil, Malayalam and Kannada languages for development of Expert system.

04. EXPERT SYSTEM SHELL DEVELOPMENT

An expert system is an interactive computer-based decision tool that uses both facts and heuristics to solve difficult decision making problems, based on knowledge acquired from an expert. An expert system is a model and associated procedure that exhibits, within a specific domain, a degree of expertise in problem solving that is comparable to that of a human expert.

An expert system relies on two components: a knowledge base and an inference engine. A knowledge base is an organized collection of facts about the system's domain. An inference engine interprets and evaluates the facts in the knowledge base in order to provide an answer. Typical tasks for expert systems involve classification, diagnosis, monitoring, design, scheduling, and planning for specialized endeavours.

Facts for a knowledge base must be acquired from human experts through interviews and observations. This knowledge is then usually represented in the form of "if-then" rules (production rules): "If some condition is true, then the following inference can be made (or some action taken)." The knowledge base of a major expert system includes thousands of rules. A probability factor is often attached to the conclusion of each production rule, because the conclusion is not a certainty.

An important feature of expert systems is their ability to explain themselves. Given that the system knows which rules were used during the inference process, the system can provide those rules to the user as

means for explaining the results. By looking at explanations, the knowledge engineer can see how the system is behaving and how the rules and data are interacting. This is very valuable diagnostic tool during development.

The expert system project is developed in Multi Lingual languages such as English, Tamil, Malayalam and Kannadam for the benefit of three State users.

5. EXPERT SYSTEM FOR AGRICULTURE

Components of the Expert system:

The home page of the expert system has three important components viz., Information System, Decision Support System, Diagnosing System (Crop Doctor) (Fig.1)

A. Information System:

Information system is web based static information wherein all the technological and complementary information from A to Z about the crop are pooled and loaded in this component. It is a ready reckoner and user-friendly navigation with image based presentation, up scaling and updating the content at any time. The static information system is highly useful for the extension officials, scientists, policy makers and administers.

B. Decision Support System:

¨ Decision support system is a computer-based information system including knowledge based system that support decision making activities. A decision is a choice between alternatives based on estimates of the values of those alternatives(Fig.2)

¨ Accordingly, the DSS has been contemplated and designed to get best possible options and decision by farmer themselves for the day today agriculture operation. Customized tools such as Menus, Pop-up Windows, Drop down Boxes or inter-related Multiple Combo Boxes, Video Plug-ins etc., were incorporated using Dot net programme.

¨ The Decision Support System is consisting of details about Season, Climate, Variety, Nursery Management, Cultivation Practices, Irrigation Management, Nutrient Management, Crop Protection, Farm Implements, Post Harvest Technology, Marketing, Institutions, Schemes and FAQ's.

C. Crop Doctor:

¨ Crop doctor is a vital component in the Expert system which acts as artificial intelligence. It is picture and image based 'if and then rule' based programme which has written using Dot net programme. It deals with diagnosing the pest, disease and nutritional disorders affecting the selected crops. The first obvious sign is given as thumbnail images in the Key Visual Symptoms (Primary Symptom) with multiple sub levels (Secondary Symptoms). Farmers by selecting the symptoms, they will make a conclusion on the causes for the damage, identification of pest or pathogens, nutritional disorders and control measures to be taken in the field.

¨ In crop doctor component of expert system, major pests, diseases and deficiency disorders were included.

¨ Regarding management, different control methods like cultural

methods, chemical methods, biological methods, preventive methods, ecofriendly methods and trap methods are given with suitable and relevant photographs.

¨ Nutrient management is the major and most important practice that is to be carried out in correct time with suitable methods.

¨ Deficiency detection is the very crucial part in managing nutrients for proper crop production. Crop doctor helps the user to decide the casual agent or reason behind the occurred symptom.

¨ After attaining the conclusion, different methods or choices to come out of the problem are given in this system that is the main and vital role to ward off the problems of cultivation.

¨ Video documentation of each and every method will guide the farmers to use the control measures in proper way and it will give exposures like hands-on trainings.

¨ It provides flexibility in management methods and gives autonomy state in the process of planning and execution of control measures. (Fig.3)

Segments of Crop Doctor:

¨ In crop doctor component of Expert System, three segments such as

¨ Symptoms of damage

¨ Identification of pest or pathogen

¨ Control measures

¨ are given after diagnosing the problem. The detail information about each segments were documented (Fig.4)

Symptoms of Damage:

In this part of crop doctor, real field symptoms of affected crop in

different angles were used for slide show. The symptoms are visualised both in close up view and long shot views. Attack of a single pest or disease may cause more than one symptoms. All the possible and occurring symptoms used for slide shows are real representatives of particular problem. Specific pest or disease may attack all the stages – seedling stage, growth stage, maturity stage of a crop. For this reason, symptoms have been visualised in stage by stage also. Infected or affected plant portions are used as identification tools. Real videos for field symptoms were also given with specific icon buttons. So, user can very well compare and conclude with his own field symptoms (Fig.5)

Identification of Pest or Pathogen:

In crop doctor component, after diagnosing the reason behind the problem, user may want to know the details about the casual agent. For this reason, morphological descriptions about pest or pathogen, its life stages, conditions favouring its multiplication, longevity, its resistance or susceptibility to a particular problem are documented both in words and as visuals(Fig.6)

Management of pest or pathogen:

This is the most valuable part of crop doctor. While developing management strategy, user has to select different methods that are readily available, economical and applicable at field level. To cater the needs of different critical stage of affected crop, various methods like cultural method, chemical method, biological methods, trap method, preventive method and ecofriendly methods are given in detail with relevant and suitable visuals. User can select a method according to the situation. By having the choices for control measures, selection of method may be

decided by pest economic status. This will help to reduce the cost of cultivation and thereby increase the farm income. Real videos and visuals for management of pest or pathogen were added with specific video icon buttons (Fig. 7 to 12)

Specialty of Diagnose Report:

¨ In recent years, need of the hour is launching an evergreen revolution in our farms which can help to improve productivity in perpetuity without associated ecological harms.

To meet this need in our diagnose report, we provided the technical guidance's with the latest information on the methods of bridging the gap

¨ between technical knowhow and field level do how of different management methods like cultural method, chemical method, biological method, preventive methods, ecof riendly methods and trap methods.

¨ Farm sector suffers due to inadequate ToT and there exists an incapability to cope up with latest technologies. Crop doctor removes this situation and it helps to empower the farmers to solve their field problems in crop protection and nutrient management.

¨ It ensures synergy between the farm activity and control measures to be taken **in time** i.e, particularly after the Economic Threshold Level (ETL).

¨ It advises to go for minimum cost techniques to the farmers synchronising with other farm operations like cultural practices.

How it can be used?

When you click pest and disease management, it opens a Form with **Primary Symptoms**. At present **specific problems** such as Rhinoceros beetle and Red palm weevil in coconut are being taken into account. Later the generic problems will be added to the form. The Primary Symptom Form will contain **15-16 thumbnail images**. To have a better view of the image, on mouse over event the image can be enlarged and on click event the farmer can see a video clipping which contains related symptom photos (it is in mpeg format)taken in different angles of the field. Farmer has to first click the radio button and then the NEXT button to proceed to the **Secondary Symptom Form**. This Form is similar to the Previous Form (Primary Symptom Form) but in addition to that farmers can either go for a **single or multiple symptom selection**. By clicking the **Diagnose** button it opens a **Diagnose Form** which in turn consists of Symptoms of Damage, Identification of Pest and Control Measures which relatively explains the causes with photos and video clips. To diagnose quickly, question mark shape [?] icon is given in the home page of doctor. If the user clicks that icon, user tips to quick diagnose will appear(Fig.13to15)

Importance of crop protection:

Crop protection plays a key role in safeguarding crop productivity against competitions from pests, diseases and deficiency disorders. Expert assessment reveals that loss potential may be varied from less than 50% to more than 80%. Hence, there is a need to reduce if not eliminating these losses by protecting the crop from different pest, diseases and deficiency disorders through proper techniques. At present

day the role of crop protection in agriculture is of great importance and a challenging process than before, as the so called resistance species should be brought under check. All other management practices of crop husbandry will be futile if the crop is not protected against the ravages of the pests, diseases and deficiency disorders. The entire effort of growing a crop will be defeated in the absence of crop protection resulting in financial loss to the grower. So the crop protection against various problems is a must in agriculture.

We have developed crop doctor module for Paddy, Coconut, Banana, Sugarcane and Ragi crops. Details of this crop doctor are given below

Paddy Doctor:

In Paddy doctor component of Expert system, major and destructives pests of paddy - Stem borer, Brown plant hopper, Green leaf hopper, Leaf folder and Ear head bugs, Diseases such as Blast, Tungro, Brown spot, Bacterial leaf blight, Sheath rot, Sheath blight and False smut and major Nutrient deficiency disorders such as Nitrogen, Phosphorus, Potassium and Zinc are included in the first page of key visual symptoms. Control measures available for the major pests, diseases and nutrient deficiencies are cultural, chemical, biological, trap, preventive and ecofriendly methods. Minor problems like Thrips, Yellow hairy caterpillar, Swarming caterpillar, Green horned caterpillar, Grasshopper, Gall midge, Whorl maggot, Hispa beetle, Skipper, Black bugs and mealy bugs, Grain discoloration, Udbatta, Bacterial leaf streak diseases, Grain discoloration, Udbatta, Bacterial leaf streak diseases, Boron deficiency , Calcium deficiency, Iron deficiency, Sulphur deficiency, Magnesium deficiency, Manganese deficiency are included in

the second page of the key visual symptoms form of paddy doctor. Non insect pests like Snail, Nematodes, Rat are also included in the paddy doctor page(Fig.16)

After diagnosing the problem, user can get detail information regarding symptoms of damage, identification of pest or pathogen and its control measures and also they can get report in printed form as recommendations. Video documentation of control measures for all pests and pathogen are included in this module.

Coconut Doctor:

In coconut doctor component of Expert system, Pests like Rhinoceros beetle, Red palm weevil, Eriophid mite, Black headed caterpillar, Termite, Skipper, White grub, Scale insect, Grasshopper, Coried bug, Nut borer, Mealy bug and Rat, Diseases like Leaf blight, Basal stem end rot, Stem bleeding disease, Bud rot, Root wilt and Leaf rot, Deficiency disorders such as Nitrogen, Phosphorus, Potassium, Boron, Manganese and Magnesium are included in the key visual symptoms page (Fig. 17)

Banana Doctor:

In Banana doctor component of Expert system, pests like Stem weevil, Corm weevil, and Aphids, Thrips and Nematodes, Diseases like Yellow sigatoka, Panama wilt, Bunchy top, Cigar end rot, Erwinia rot, Anthracnose, Banana mosaic virus and Bract mosaic virus, Deficiency disorders like Nitrogen, Phosphorus, Potassium, Calcium, Boron, Iron and Sulphur are included in the key visual symptoms page(Fig. 18)

Sugarcane Doctor:

In Sugarcane doctor component of Expert system, pests like Top borer, Early shoot borer, Internode borer, White flies, Mealy bug, White grub, Wolly aphid, Scale insect, Termite, Grasshopper and Nematodes, Diseases like Yellow leaf disease, Smut, Rust, Red rot, Ratoon stunting, Wilt, Sett rot and Grassy shoot diseases, deficiency disorders such as Nitrogen, Phosphorus, Potassium and Iron are included in the key visual symptoms page(Fig. 19)

Ragi Doctor:

In Ragi doctor component of expert system, pests like Pink stem borer, Cut worm, Grasshopper, Leaf folder, Earhead caterpillar, Aphids and Earhead bug, diseases like Blast, Seedling blight, Wilt, Smut and Mottle streak, deficiency disorders such as Nitrogen deficiency, Phosphorus deficiency and Potassium deficiency are included in the key visual symptoms page (Fig.20)

06. Expert System for Animal Husbandry

a. Cattle and Buffalo

In Animal Husbandry, doctor component of Expert system is named as **Health Adviser.** In Cattle and Buffalo Expert system, Diseases such as Foot and Mouth Disease, Mastitis, Traumatic Reticulo Peritonitis, The litis Abortion, Total uterine Prolapse, Downer cow syndrome and Milk Fever, Retained Fetal, Membranes, Actinimycosis, Bloat, Enteritis, Worm Load are included in the key visual symptoms of Health Adviser.

b. Poultry:

In Poultry Expert system, diseases such as NewCastle Disease or Ranikhet Disease, Mareks Disease, Infectious Bursal Disease, Infectious Bronchities, Avian Influenza, Colibacillosis, Infectious Coryza, Fowl pox, Ascariasis, Coccidiosis, Gout are included in the key visual symptoms of the Health Adviser component.

c. Sheep and Goat:

In Sheep and Goad Expert system, disease such as Blue Tongue, Plague disease or Peste-des-Petits Ruminants (PPR in Sheep and Goat), Sheep pox, Tetanus, Abortion, Anthrax, Contagious and Ecthyma are included in the key visual symptoms of the Health Adviser component

08. Future Research on Expert System

Expert System which was developed by e-Extension team comprised of land use planning, cropping strategy for farmers fields based on integrated information on soil, water, weather, nutrient and pest management models with how and where to get proper seeds, prices of farm equipments, agricultural produce, products and series of such set of information which can lead to high productivity and transform the livelihood of the farmers. But the content is **off-line**, in form of CD or it can be installed in a **Kiosk Centre** for the benefit of the farmers where information can be disseminated.

Expert Systems can be developed by using certain programming

languages such as Fortran, Pascal, C++, Visual Basic, Javascript, .NET and dbase. The languages like **Prolog** (Programming in Logic) and **Lisp** (List in Programming) are most significant and are used for designing Artificial Intelligence systems. There are **E**xpert **S**ystems

shells, which are ready made software packages, which facilitate designing of **E**xpert **S**ystem without writing complicated programs. They provide the inference engine and user interface commands. It has the facility to construct the rules in spoken English language and has a built in editor.

Web-Based Expert System

Farmers will make a query at any time particularly to his region specific. A **web portal** has to be developed with a **login screen**. As in AGRISNET he can give his survey number. Moreover GIS based project already running there can be incorporated to read the farmer input such as survey number using geo-spatial server. The end user has to give inputs in online form such as crop details, soil test result, fertilizer recommendation result etc. The knowledge bases from various sources can be integrated to answer the queries generated by the farmers and deliver customized farm recommendations which is powered by the **E**xpert **S**ystem in the background with server scripting language support such as **A**ctive **S**erver **P**ages, ASP.NET (the ES developed using .NET has to be re-engineered with ASP.NET), **J**ava **S**ever **P**ages, PHP (open source), ColdFusion, Python, Perl CGI etc.,

By this way, recommendations are tailor-made by the **E**xpert **S**ystem to deliver only relevant expert knowledge as and when required by the farmer throughout the crop growing period. This web portal has to be delivered in **local language** to enable user-friendliness. A **feedback form** needs to be created which can be used to send feedbacks and suggestions for improving or enhancing the **E**xpert **S**ystem.

The method we have followed is a **Forward Chaining** model, where we

explore the symptoms, farmer has to correlate with his field symptom and then he should go for the control measure. But in **Backward Chaining** model

we have to get the input from the farmer either in the form text which is in native language or in form of picture.

The use of multi-media content like colour images, videos showing symptoms of crop diseases has to be worked out for each and every pest and diseases and deficiencies. At least 5,000 photo images related to a particular symptom has to be stored in the knowledge base. **Image Processing** tools like **MATLAB** and **Simulink** will help in mapping the field image taken by the farmer to map with the photos stored in the database. Most image processing techniques involve in treating the image as a two dimensional signal and applying standard signal-processing techniques to it. The technical advancements such as high-resolution imaging, large scale databases, networking, interoperability and hand-held computer devices will help the farming communities to harness the power of Information and Communication Technology (ICT).

Audio Interface helps in easing for better understanding in local language.

When a new problem arises, the **D**ecision **S**upport **S**ystems algorithms for solving a problem with a pre-defined set of input data has to be changed. Periodical Govt. policies, supporting price policies, market demand forecasts, availability of high-yielding seeds, timely pest warnings and remedies has to be changed periodically to help the farmers.

Single Window Delivery System - AGRISNET, AGMARKETNET, TN Agricultural Automatic Weather Network has to be integrated. The development of GIS/RS will strengthen the **E**xpert **S**ystem.

Agricultural Data Warehouse consisting of Integrated Agricultural Data coupled with exploration tools like **OLAP** (On-Line Analytical Processing) and **Data Mining** helps in strengthening the ES.

Conclusion

Effective adoption of Information and Communication Technologies (ICT) now has a proven record in many parts of the world and a demonstrated potential to attain significant economic, social and environmental benefits at local, national and global levels. Likewise, The future is going to be virtual agricultural extension services where the owner of the farm may be sitting in some where distanced from their farm and would like to do agriculture by appointing contract labour and through mechanization. Besides, the availability of expert or extension workers would be limited for providing farm specific advisory services due to very low extension workers for growing farming community. To solve this problems, development of expert system for all crops is very important to provide farm specific advisory services in time and self diagnosis of farm problems. Hence, development of Expert systems (ES) are identified as powerful tool for farmers, extension workers and government officials.

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