



Selection of wheat (*Triticum aestivum*) variety through expert system

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Received: 8 April 2011; Revised accepted: 5 November 2011

ABSTRACT

Most of the released wheat (*Triticum aestivum* L. emend Fiori & Paol.) varieties have been documented for various characteristics that they possess. The challenge was to organize these varieties electronically so that the farmers of the country could be benefited from this information for increase in production. Researchers and students could use them for reference and include them in their future research programmes. An expert system on wheat crop management has been developed for this purpose. The system has an exclusive variety selection module with a scientific knowledge base in the background. The module suggests a variety of farmer's/user's choice based on location and desired characteristics like sowing condition, yield, protein content, response to diseases and insects. The system carries detailed information about 300 varieties that have been stored in its knowledge base.

Key Words: Expert System, Forward chaining, Inference engine, Knowledge base, Variety, Wheat

India achieved remarkable progress in wheat (*Triticum aestivum* L. emend Fiori & Paol.) production during the last four decades and is the second largest wheat producer in the world (Yadav *et al.* 2011). For maximizing yield, various factors that play important role include the selection of variety for its disease resistance, fertilizer responsiveness, lodging and shattering resistance and the desired maturity under irrigated conditions. Under rainfed conditions, the ability to withstand soil and atmospheric drought is the need and choice of the farmer. In the absence of a right variety, the production technology cannot be applied effectively. Farmers need specific variety of wheat which can be grown in a particular state, zone or district. Varieties have also been characterized based on various traits such as appearance, sowing time, quality content etc.

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Efforts were made earlier to develop expert systems on various crops. NEPER wheat expert system was one of the expert systems developed at Central Laboratory of Agricultural Expert System (CLAES) in Egypt (Edrees *et al.* 2003). This system has six components, each of which represents an individual expert system, capable of running alone or integrated with the other components. These components are variety selection, land preparation, planting, irrigation, fertilization and harvest sub-systems.

WHEATWIZ, an expert system developed in 1987 as an effective tool to assist Kansas farmers, extension workers and agri-business personnel in variety selection for hard red winter wheat (Zhang 1992). Efforts were made by Ravisankar *et al.* (2010) to develop the expert system for identification and management of abiotic stresses in tobacco (*Nicotiana tabacum* L.). They developed the system using stages and factors in a hierarchical manner for the identification of abiotic stresses. This standalone system may have the problem of knowledge updation as it was a PC- based system.

An expert system on wheat crop management (EXOWHEM) has been developed by the Division of Computer Application, IASRI, New Delhi in collaboration with IARI, New Delhi; DWR, Karnal and NCIPM, New Delhi during 2003–07. The system carries detailed information about 300 varieties that have been stored in its knowledge base. The characteristics of wheat have been classified in eight different categories. Each category has various significant characteristics. This classification led to a road

map and methodology for developing the knowledge base of the system.

MATERIALS AND METHODS

Expert System on wheat crop management has been developed using Active Server Pages (ASP) technology. ASP is a powerful tool making dynamic and interactive web pages, provided by Internet Information Server, an integrated component of Windows operating system like Windows XP and Windows Server 2000 series. Two scripting languages VBScript® and JScript™. have been applied to develop the inference engine, applying production rules and binding it with the knowledge base. ASP technology was found to be simple as a template language to create flexible, easy-to-maintain web pages. The main components of Expert Systems include knowledge base, inference engine and user's interface. The architecture and the explanation about the system is mentioned in Fig 1.

The system has been developed in client/server application model. Pages share information and can communicate with each other, or with the application objects. These have been made possible by selected information across a user session. The system has an exclusive variety selection module with a scientific knowledge base in the background. The module suggests a variety of farmer's/user's choice based on location and desired characteristics like sowing condition, yield, protein content, response to disease and insects. All these criteria were developed during a requirement analysis workshop organized at IASRI, New Delhi involving knowledge engineers and subject matter specialists.

Expert systems derive the power from the extensive knowledge bases which works as its core. The steps for developing knowledge base for 'Expert system for diagnosis of disease in rice plant' were identification of the input problem, knowledge acquisition and representation of knowledge into knowledge base. Its knowledge acquisition process was carried out through a series of interacting sub-modules integrated with the co-ordinating module for creating

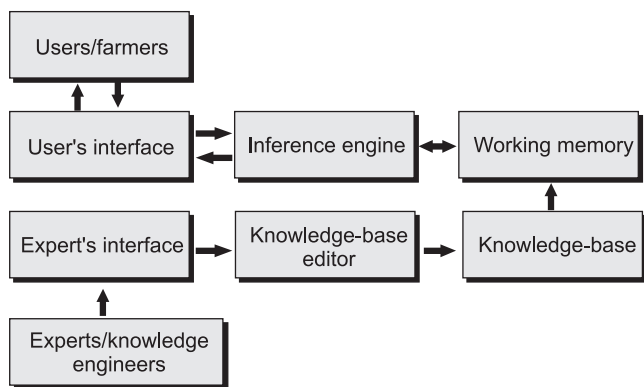


Fig 1 Expert system architecture

the knowledge database until the best conclusion was obtained (Sarma *et al.* 2008). A typical knowledge base has been developed using Microsoft Access that has stored information and knowledge in the form of rules and fact about domain. These rules contain the cognitive knowledge derived from human experience and scientific knowledge derived from research. The method used to construct the system and acquire knowledge was knowledge engineering that helped to extract relevant set of rules and data from wheat breeder through extensive questioning and some published literature. The degree of solving problem is based on the quality of data and rules obtained from the experts. This was handled by continuous evaluation and filtering the information at various levels. A number of consultations were made with the wheat breeders and experts to formulate rules for identification of a variety based on desired condition/characteristics. This material was then organized in a format suitable for representation in the system's knowledge base in the form of rules. The rules are in the form of "IF... then ELSE". The "IF" part mainly contains the conditions like location, sowing condition, seed rate, sowing time, disease resistance, protein content, type of utilization, grain characteristics, yield level etc.

Knowledge on varieties and their area of adoption, sowing condition, sowing time (Table 1), climatic condition and other characteristics were acquired from publications made by DWR, Karnal and other related institutions. The knowledge base can be updated without disturbing the whole structure of the expert system. The degree of solving farmer's problem is based on the quality of data and rules obtained from the expert.

The system interacts with the users with two interfaces, ie experts interface and user interface. Expert Interface has been designed for updating knowledge in the knowledge base and the user interface is for the farmers and other users who interact with the system to solve their problem. The front end of the system has been developed by standard web technologies can be accessed by any browser like Internet Explorer, Mozilla, Chrome etc.

The inference engine is guided by the logical reasoning and inference mechanism and a working memory where information is temporarily transferred at the time of decision making. One of the advantages of rule-based expert systems is that inference engine and knowledge base are separate. Knowledge base is a repository of information and is external to inference engine and can easily be modified without changing inference engine which implement backward and forward reasoning mechanism (Rajendra 2007). After receiving the query through the user interface, the inference engine looks for the best possible solution of the problem and gives it back to the same interface.

Knowledge representation formalizes and organizes the knowledge (Sprangler 1989) represented knowledge in form of rules to develop rule-based system. The piece of knowledge

represented by the production rule is relevant to the line of reasoning being developed. If the “IF” part of the rule is satisfied; consequently, the THEN part can be concluded, or its problem-solving action taken. Knowledge representation is the last phase of the knowledge base development. In the representation of knowledge into knowledge base, the knowledge acquired from knowledge acquisition process is represented into structured form. There are many approaches for representing knowledge into the knowledge base (Sarma *et al.* 2008). For developing this system we have chosen the knowledge representation with simple IF and THEN rules. These rules are normally in the form given below:

IF <antecedent> THEN <consequent>

For example:

IF state is Haryana THEN variety is PBW 550

Varieties are based on climatic condition, sowing condition (SC) and sowing time (ST) rules may appear like this:

IF State is “Haryana” and Sowing Time is “Timely Sown” and condition is “Irrigated” then Variety is PBW 502

The rules can be formulated as given in Fig 2.

State can be any of the 28 wheat growing states of India and can be represented as S1, S2..... Sn where n varies from 1 to 28

Wheat zone in the country has been divided in six zones based on agroclimatic conditions named northern hills zone (NHZ), north-western plains zone (NWPZ), north-eastern plains zone (NEPZ), central zone (CZ), peninsular zone (PZ) and southern hills zone (SHZ). Similarly zones can be represented as Z1, Z2,....., Zn here n varies from 1 to 6

Sowing Condition may vary from irrigated, rainfed, limited irrigation etc and are depicted as variables SC₁, SC₂, , SC_n

Sowing condition may vary from early sown, timely sown, late sown etc. and are depicted as variables ST₁, ST₂, , ST_n

IF State is S_n and sowing condition is SC_n and sowing time is ST_n then variety VAR_n should be grown.

Certain facts and rules based on them can be represented as below. The rules are fired by the inference engine that has been designed using standard programming script.

Facts

- F1: V_n is a wheat variety
- F2: V_n can be grown in Irrigated condition
- F3: V_n should be sown timely
- F4: V_n can be grown in sandy soil
- F5: Rajasthan has sandy soil

Rules

- R1: If crop is wheat and state is Rajasthan then variety V_n should be grown
- R2: If crop is wheat state is Rajasthan and sowing time is timely then Variety V_n should be grown
- R2: If soil is sandy, crop is wheat and water is adequate

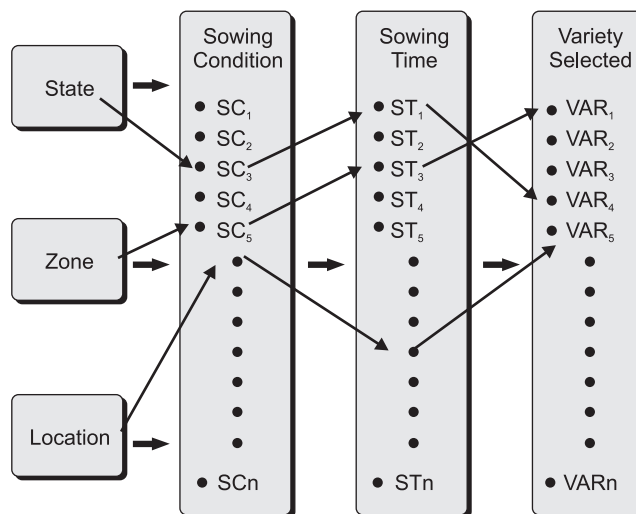


Fig 2 Rules formulation

variety V_n should be grown.

Rn-1: If crop is wheat and state is Haryana then variety is V_n

Rn: If crop is wheat and state is Haryana and not adequate water then variety is V_n

In this way n number of Rules can be formulated through different permutations and combinations. These facts and rules have been stored in the database in various Tables. Tables for state, schedules and characteristics have also been stored in the database Tables.

In addition, six major categories have been taken into consideration. Each category has been further classified on the basis of different characteristics. A user can select a variety on the basis of those characteristics or based on a combination of one or more characteristics. The system gives flexibility to the user to select a variety on the basis of state, zone or district or he can make any combination of characteristics with state or Zone. A list of these characteristics are provided in Table 2.

Knowledge on varieties with relevant area of its adoption, sowing condition, sowing time, climatic condition and other characteristics were acquired from publications made by National Agricultural Research System (NARS). A number of consultations were made with the wheat breeders and experts to formulate rules for identification of a variety

Table 1 Tabular representation of varietal rules

State	Sowing condition	Sowing time	Sowing
Haryana	Irrigated	Timely sown	DBW 17
Haryana	Irrigated	Timely sown	HD 2687
Madhya Pradesh	Salty soil and limited irrigation	Timely sown	Raj 3077
Himachal Pradesh	Rainfed	Timely sown	HS 295
Punjab	Irrigated	Timely sown	PBW 550

Table 2 Representation of characteristics

Characteristics/ representation in knowledge base	Significance
Vital characteristics–represented with letter ‘A’	These characteristics are central as far as farmer’s interest is concerned. Sowing time ,irrigation condition, yield, days to maturity, plant height, resistance to disease, susceptibility to disease, soil condition, purpose, protein, content, tolerance
General characteristics – represented with letter ‘G’	These characteristics are of academic interest and species name, parents name, year of release, releasing agency, developing agency, area of adoption
Plant characteristics – represented with letter ‘P’	Early growth habit, coleoptile colour , foliage colour, days to heading, peduncle length, peduncle attitude, pith, auricle pigmentation, auricle pubescence, flag leaf attitude, flag, leaf length, leaf width
Ear characteristics – represented with letter ‘E’	Ear colour, ear shape, ear density, spike length, no. of spikelets/ear, no. of seeds/spike, awn length, awn colour awn attitude
Quality characteristics – represented with letter ‘Q’	1 000-grain wt , phenol reaction, hardness index, hect litre, wt., sedimentation value, potential yield
Grain characteristics – represented with letter ‘S’	Grain colour, grain texture, grain shape, grain size, brush, hair length, germ width, grain crease

based on farmers’ needs. Typical rules were formulated to identify a variety.

The knowledge base can be updated directly by the experts using expert interface. Expert interface has been provided for breeding, plant protection and other experts concerned with wheat production.

RESULTS AND DISCUSSIONS

Variety selection module is an important module of the developed system that enables the farmer to select the variety of his choice. The module suggests a variety of farmer’s choice on any characteristics he wants. He can have a variety according to his state, zone, sowing condition, yield, protein content etc. As farmers, research workers, scientists and consumers select a variety based on different characteristics, the module carries two broad categories; one exclusively for farmers and the other for all other users. The vital characteristics have been identified specifically for the wheat-growing farmers. The system gives a customized search facility for all the other categories of users that includes scientists, researchers, and policy-makers. The customized category includes general, plant, grain and response characteristics as sub-categories. In this manner, expert system’s variety selection module caters to the need, not only of farmers but also other users who have their interest in wheat cultivation, research or extension of technology.

The variety selection module has been divided in six broader categories. The six broader categories have been divided in different characteristics, viz vital characteristics, general characteristics, plant characteristics, ear characteristics, quality characteristics and grain characteristics.

The expert system derives its answers by running the knowledge base through an Inference Engine, a software

programme based on ASP technology using VB Script, interacts with the user and processes generated from the rules and data in the knowledge base. The problem-solving model, or paradigm, organizes and controls the steps taken to solve the problem. The chaining mechanism used in this system is forward chaining. The expert system gets all facts from the user and chains forward to reach a conclusion. Programme modules are built by using IF-THEN rules, which is part of the inference engines or inference procedures that manipulate and use knowledge in the knowledge base to form a line of reasoning.

Forward reasoning is the process of working from a set of ‘facts’ toward a conclusion that can be drawn from this data. Thus, in the forward reasoning, the expert system produces the conclusion. In the forward reasoning, each potentially applicable rule is examined to see if the premises contained within the rule are true or not.

Research findings and development of new technologies are a continuous process. Keeping this in view, the system carries a facility to update the existing information and knowledge through an expert interface. This interface is for exclusive class of users and experts. By using the authorization code they can update the system with latest information and knowledge. Efforts were made by Ravisankar *et al.* (2010) to develop the expert system for identification and management of abiotic stresses in tobacco (*Nicotiana tabacum*). They developed the system using stages and factors in a hierarchical manner for the identification of abiotic stresses which is a standalone PC-based system (Ravisankar *et al.* 2010). EXOWHEM is a web-based system with a knowledge base editor that helps an expert or a knowledge engineer to easily update and check the knowledge base. Its user friendliness empowers the expert to update and add new information. It is evident from the architecture that the information and

knowledge can be directly entered to the system using expert interface while users get information through the user's interface.

The system is available on the IASRI web site and can also be accessible with URL <http://www.iasri.res.in/expert1>. The system provides facility to the user to select varieties on the basis of various criteria in combination with state and zone of his choice. This module takes a varied approach in providing the name of the variety to the user under his conditions and available resources. It queries from the user whether he is interested in a variety for his state, zone or location map. Gonzalez *et al.* (2006) developed an expert system for seedling weed identification in cereals. He validated the results that indicated that non-expert users were able to make identification using the expert system. The variety selection module of the expert system helps the stakeholders in identifying suitable wheat varieties. This module provides varieties for a state or a zone based on various wheat plant characteristics. All the 28 states of the country had been covered except Kerala where production of wheat is negligible. The user can get a variety for all the six wheat growing zones of India, namely: NWZP, NEPZ, NHZ, CZ, PZ and SZ. A farmer can also have a variety by clicking on the state or zonal map of India. In map-based selection of variety a user can search variety for a particular district also. The user may also select a variety of a state, a zone or a district through State Map, Zone Map or District Map respectively.

A farmer can narrow down his needs and may look for a variety that fulfils his requirement. It can be done by his selection based on various characteristics. For example, a farmer may look for a variety to grow in Haryana that should give him 4.6–5.0 tonnes/ha of yield, the grains of the variety should be amber in colour. The system gives him nine varieties based on his query. A user can get an expert advice on these varieties and the system suggests the most appropriate variety of his choice after doing a comparative study.

The user can have all the details about the variety that the system suggests him to grow. Actually he can acquire prior knowledge and all the necessary details about the variety.

Thus, the system is a repository of information of all the important wheat varieties that have been developed and released for the farmers during the last 50 years. The system carries information about 300 wheat varieties with all their

vital details and various characteristics. The system can be used by wheat-growing farmers all over the country for necessary advice and recommendations. The system can also be used by the students and researchers for planning their research programmes. The expert system will help in bridging the gap between farmers and researchers and to easily know the latest developments and the varieties released and the suitability of the same for them. The system can be of great help for farmers, researchers, breeders and students as per their requirement apart from exhaustive details on relevant agronomic practices, production technology, plant protection and management.

ACKNOWLEDGEMENTS

We are thankful to the participants of the Requirement Analysis Workshop who presented their valuable suggestions during the discussion.

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